European Position Paper on Rhinosinusitis and Nasal Polyps 2007

Wytske Fokkens, Valerie Lund, Joaquim Mullol, on behalf of the European Position Paper on Rhinosinusitis and Nasal Polyps group.
Rhinosinusitis is a significant and increasing health problem which results in a large financial burden on society. This evidence based position paper describes what is known about rhinosinusitis and nasal polyps, offers evidence based recommendations on diagnosis and treatment, and considers how we can make progress with research in this area.

Rhinitis and sinusitis usually coexist and are concurrent in most individuals; thus, the correct terminology is now rhinosinusitis. Rhinosinusitis (including nasal polyps) is defined as inflammation of the nose and the paranasal sinuses characterised by two or more symptoms, one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip), ± facial pain/pressure, ± reduction or loss of smell; and either endoscopic signs of polyps and/or mucopurulent discharge primarily from middle meatus and/or; oedema/mucosal obstruction primarily in middle meatus, and/or CT changes showing mucosal changes within the ostiomeatal complex and/or sinuses.

The paper gives different definitions for epidemiology, first line and second line treatment and for research. Furthermore the paper describes the anatomy and (patho)physiology, epidemiology and predisposing factors, inflammatory mechanisms, evidence based diagnosis, medical and surgical treatment in acute and chronic rhinosinusitis and nasal polyposis in adults and children. Evidence based schemes for diagnosis and treatment are given for the first and second line clinicians. Moreover attention is given to complications and socio-economic cost of chronic rhinosinusitis and nasal polyps. Last but not least the relation to the lower airways is discussed.
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# European Position Paper on Rhinosinusitis and Nasal Polyps 2007

## CONTENTS

1. **Introduction** 5

2. **Definition of rhinosinusitis and nasal polyps** 6
   2-1. Introduction 6
   2-2. Clinical definition 6
   2-3. Definition for use in epidemiology studies / General Practice 6
   2-4. Definition for research 7

3. **Chronic rhinosinusitis with or without nasal polyps** 8
   3-1. Anatomy and (patho)physiology 8
   3-2. Rhinosinusitis 8
   3-3. Chronic rhinosinusitis with or without nasal polyps 8

4. **Epidemiology and predisposing factors** 10
   4-1. Introduction 10
   4-2. Acute bacterial rhinosinusitis 10
   4-3. Factors associated with acute rhinosinusitis 10
   4-4. Chronic rhinosinusitis (CRS) without nasal polyps 12
   4-5. Factors associated with chronic rhinosinusitis (CRS) without nasal polyps 12
   4-6. Chronic rhinosinusitis with nasal polyps 15
   4-7. Factors associated with Chronic rhinosinusitis with nasal polyps 19
   4-8. Epidemiology and predisposing factors for rhinosinusitis in children 18
   4-9. Conclusion 18

5. **Inflammatory mechanisms in acute and chronic rhinosinusitis with or without nasal polyposis** 19
   5-1. Introduction 19
   5-2. Acute rhinosinusitis 19
   5-3. Chronic rhinosinusitis without nasal polyps 20
   5-4. Chronic rhinosinusitis with nasal polyps 26
   5-5. Aspirin sensitivity – Inflammatory mechanisms in acute and chronic rhinosinusitis 32
   5-6. Conclusion 34

6. **Diagnosis** 35
   6-1. Assessment of rhinosinusitis symptoms 35
   6-2. Examination 37
   6-3. Quality of Life 40

7. **Management** 43
   7-1. Treatment of rhinosinusitis with corticosteroids 43
   7-2. Treatment of rhinosinusitis with antibiotics 51
   7-3. Other medical management for rhinosinusitis 56
   7-4. Evidence based surgery for rhinosinusitis 64
   7-5. Influence of age concomitant diseases on sinus surgery outcome 71
   7-6. Complications of surgical treatment 76

8. **Complications of rhinosinusitis and nasal polyps** 80
   8-1. Introduction 80
   8-2. Epidemiology of complications 80
   8-3. Orbital complications 80
   8-4. Endocranial complications 81
   8-5. Cavernous sinus thrombosis 82
   8-6. Osseous complications 82
   8-7. Unusual complications of rhinosinusitis 83

9. **Special considerations: Rhinosinusitis in children** 84
   9-1. Introduction 84
   9-2. Anatomy 84
   9-3. Epidemiology and pathophysiology 84
   9-4. Symptoms and signs 85
   9-5. Clinical examination 85
   9-6. Investigations 85
   9-7. Management 87

10. **Chronic rhinosinusitis with or without nasal polyps in relation to the lower airways** 90
    10-1. Introduction 90
    10-2. Asthma and Chronic Rhinosinusitis without NP 90
    10-3. Asthma and Chronic Rhinosinusitis with NP 91
    10-4. COPD and rhinosinusitis 91

11. **Socio-economic cost of chronic rhinosinusitis and nasal polyps** 92
    11-1. Direct Costs 92
    11-2. Indirect Costs 92

12. **Outcomes measurements in research** 94

13. **Evidence based schemes for diagnostic and treatment** 95
    13-1. Introduction 95
    13-2. Introduction 97
    13-3. Evidence based management scheme for adults with acute rhinosinusitis 98
    13-4. Evidence based management scheme for adults with chronic rhinosinusitis without nasal polyps 100
    13-5. Evidence based schemes for therapy in children 103

14. **Research needs and priorities** 105
    14-1. Epidemiology: Identifying the risk factors for development of CRS an NP 105
    14-2. Beyond infection: New roles for bacteria 105
    14-3. Host response 105
    14-4. Genetics 105
    14-5. Clinical trials 105

15. **GLOSARY TERMS** 107

16. **Information on QOL instruments:** 108
    16-1. General health status instruments: 108
    16-2. Disease specific health status instruments: 108

17. **Survey of published olfactory tests** 109

18. **References** 111
Rhinosinusitis is a significant health problem which seems to mirror the increasing frequency of allergic rhinitis and which results in a large financial burden on society. Data on (chronic) rhinosinusitis are limited and the disease entity is badly defined. Therefore, the available data are difficult to interpret and extrapolate.

The last decade has seen the development of a number of guidelines, consensus documents and position papers on the epidemiology, diagnosis and treatment of rhinosinusitis and nasal polyposis. In 2005 the first European Position Paper on Rhinosinusitis and Nasal Polyps (EP3OS) was published. This first evidence based position paper was initiated by the European Academy of Allergology and Clinical Immunology (EAACI) to consider what was known about rhinosinusitis and nasal polyps, to offer evidence-based recommendations on diagnosis and treatment, and to consider how we can make progress with research in this area. The paper has been approved by the European Rhinologic Society.

Evidence-based medicine is an important method of preparing guidelines. Moreover, the implementation of guidelines is equally important.

Table 1-1. Category of evidence

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>Ia</td>
<td>evidence from meta-analysis of randomised controlled trials</td>
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<tr>
<td>Ib</td>
<td>evidence from at least one randomised controlled trial</td>
</tr>
<tr>
<td>IIa</td>
<td>evidence from at least one controlled study without randomisation</td>
</tr>
<tr>
<td>IIb</td>
<td>evidence from at least one other type of quasi-experimental study</td>
</tr>
<tr>
<td>III</td>
<td>evidence from non-experimental descriptive studies, such as comparative studies, correlation studies, and case-control studies</td>
</tr>
<tr>
<td>IV</td>
<td>evidence from expert committee reports or opinions or clinical experience of respected authorities, or both</td>
</tr>
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Table 1-2. Strength of recommendation

<table>
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<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>directly based on category I evidence</td>
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<tr>
<td>B</td>
<td>directly based on category II evidence or extrapolated recommendation from category I evidence</td>
</tr>
<tr>
<td>C</td>
<td>directly based on category III evidence or extrapolated recommendation from category I or II evidence</td>
</tr>
<tr>
<td>D</td>
<td>directly based on category IV evidence or extrapolated recommendation from category I, II or III evidence</td>
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Since the preparation of the first EP3OS document an increasing amount of evidence on the pathophysiology, diagnosis and treatment has been published (figure 1).

Figure 1. Randomized controlled trials in chronic rhinosinusitis with or without nasal polyps. The number of trials in the last 5-6 years equals the number ever published before.

In this revision new data have led to considerable increase in amount of available evidence and therefore to considerable changes in the schemes for diagnosis and treatment. Moreover the whole document has been made more consistent, some chapters are significantly extended and others are added. Last but not least contributions from many other part of the world have attributed to our knowledge and understanding.
2. Definition of rhinosinusitis and nasal polyps

2-1 Introduction

Rhinitis and sinusitis usually coexist and are concurrent in most individuals; thus, the correct terminology is now rhinosinusitis. The diagnosis of rhinosinusitis is made by a wide variety of practitioners, including allergologists, otolaryngologists, pulmonologists, primary care physicians and many others. Therefore, an accurate, efficient, and accessible definition of rhinosinusitis is required. A number of groups have published reports on rhinosinusitis and its definition. In most of these reports definitions are based on symptomatology and duration of disease and a single definition is aimed at all practitioners (4, 5, 12, 13). Due to the large differences in technical possibilities to diagnose and treat rhinosinusitis/nasal polyps by various disciplines, the need to differentiate between subgroups varies. On one hand the epidemiologist wants a workable definition that does not impose too many restrictions to study larger populations. On the other hand researchers in a clinical setting are in need of a set of clearly defined items that describes their patient population accurately and avoids the comparison of ‘apples and oranges’ in studies that relate to diagnosis and treatment. The taskforce tried to accommodate these different needs by offering definitions that can be applied in different circumstances. In this way the taskforce hopes to improve the comparability of studies, thereby enhancing the evidence based diagnosis and treatment of patients with rhinosinusitis and nasal polyps.

2-2 Clinical definition

2-2-1 Clinical definition of rhinosinusitis/nasal polyps

2-2-1-1 Bacteria

Rhinosinusitis (including nasal polyps) is defined as:
- inflammation of the nose and the paranasal sinuses characterised by two or more symptoms, one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):
  - ± facial pain/pressure,
  - ± reduction or loss of smell;
and either
- endoscopic signs of:
  - polyps and/or;
  - mucopurulent discharge primarily from middle meatus and/or; oedema/mucosal obstruction primarily in middle meatus,
and/or
- CT changes:
  - mucosal changes within the ostiomeatal complex and/or sinuses.

2-2-2 Severity of the disease

The disease can be divided into MILD, MODERATE and SEVERE based on total severity visual analogue scale (VAS) score (0 10 cm):
- MILD = VAS 0-3
- MODERATE = VAS >3-7
- SEVERE = VAS >7-10

To evaluate the total severity, the patient is asked to indicate on a VAS the answer to the question:

![VAS Scale](image)

A VAS > 5 affects patient QOL (14).

2-2-3 Duration of the disease

Acute
- < 12 weeks complete resolution of symptoms.
- Chronic
  - >12 weeks symptoms without complete resolution of symptoms.

Chronic rhinosinusitis may also be subject to exacerbations

2-3 Definition for use in epidemiology studies/General Practice

For epidemiological studies the definition is based on symptomatology without ENT examination or radiology.

Acute rhinosinusitis (ARS) is defined as: sudden onset of two or more symptoms, one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):
- ± facial pain/pressure,
- ± reduction or loss of smell;
for <12 weeks; with symptom free intervals if the problem is recurrent; with validation by telephone or interview.

Questions on allergic symptoms i.e. sneezing, watery rhinorrhea, nasal itching and itchy watery eyes should be included.

Acute rhinosinusitis can occur once or more than once in a defined time period. This is usually expressed as episodes/year but there must be complete resolution of symptoms between episodes for it to constitute genuine recurrent acute rhinosinusitis.
Common cold/ acute viral rhinosinusitis is defined as:
duration of symptoms for less than 10 days.

Acute non-viral rhinosinusitis is defined as:
increase of symptoms after 5 days or persistent symptoms after
10 days with less than 12 weeks duration.

Chronic rhinosinusitis with or without nasal polyps is defined as:
presence of two or more symptoms one of which should be
either nasal blockage/obstruction/congestion or nasal dis-
charge (anterior/posterior nasal drip):
± facial pain/pressure;
± reduction or loss of smell;
for >12 weeks;
with validation by telephone or interview.

Questions on allergic symptoms i.e. sneezing, watery rhinor-
rhea, nasal itching and itchy watery eyes should be included.

2-4 Definition for research

For research purposes acute rhinosinusitis is defined as above.
Bacteriology (antral tap, middle meatal tap) and/or radiology
(X-ray, CT) are advised, but not obligatory.

For research purposes chronic rhinosinusitis (CRS) is defined
as above. CRS is the major finding and nasal polyposis (NP) is
considered a subgroup of this entitiy. For the purpose of a
study, the differentiation between CRS and NP must be based
on out-patient endoscopy. The research definition is based on
the presence of polyps and prior surgery.

2-4-1 Definition of chronic rhinosinusitis when no earlier sinus
surgery has been performed

Chronic rhinosinusitis with nasal polyposis:
polyps bilateral, endoscopically visualised in middle meatus
Chronic rhinosinusitis without nasal polyps:
no visible polyps in middle meatus, if necessary following
decongestant

This definition accepts that there is a spectrum of disease in
CRS which includes polypoid change in the sinuses and/or
middle meatus but excludes those with polypoid disease pre-
senting in the nasal cavity to avoid overlap.

2-4-2 Definition of chronic rhinosinusitis when sinus surgery has
been performed

Once surgery has altered the anatomy of the lateral wall, the
presence of polyps is defined as bilateral pedunculated lesions
as opposed to cobblestoned mucosa > 6 months after surgery
on endoscopic examination. Any mucosal disease without
over polyps should be regarded as CRS.

2-4-3 Conditions for sub-analysis

The following conditions should be considered for sub-analy-
sis:
1. aspirin sensitivity based on positive oral, bronchial or nasal
   provocation or an obvious history;
2. asthma(bronchial hyper-reactivity /COPD/ bronchiectasies
   based on symptoms, respiratory function tests;
3. allergy based on specific serum IgE or SPT’s.

2-4-4 Exclusion from general studies

Patients with the following diseases should be excluded from
general studies, but may be the subject of a specific study on
chronic rhinosinusitis and/or nasal polyposis:
1. cystic fibrosis based on positive sweat test or DNA alleles;
2. gross immunodeficiency (congenital or acquired);
3. congenital mucociliary problems eg primary ciliary dyskine-
sia (PCD);
4. non-invasive fungal balls and invasive fungal disease;
5. systemic vasculitis and granulomatous diseases;
6. cocaine abuse;
7. neoplasia.
3. Chronic rhinosinusitis with or without nasal polyps

3-1 Anatomy and (patho)physiology

The nose and paranasal sinuses constitute a collection of air-filled spaces within the anterior skull. The paranasal sinuses communicate with the nasal cavity through small apertures. The nasal cavity and its adjacent paranasal sinuses are lined by pseudostratified columnar ciliated epithelium. This contains goblet cells and nasal glands, producers of nasal secretions that keep the nose moist and form a “tapis roulant” of mucus. Particles and bacteria can be caught in this mucus, rendered harmless by enzymes like lysozyme and lactoferrin, and be transported down towards the oesophagus. Cilia play an important role in mucus transport. All paranasal sinuses are normally cleared by this mucociliary transport, even though transport from large areas of sinuses passes through small openings towards the nasal cavity.

A fundamental role in the pathogenesis of rhinosinusitis is played by the ostiomeatal complex, a functional unit that comprises maxillary sinus ostia, anterior ethmoid cells and their ostia, ethmoid infundibulum, hiatus semilunaris and middle meatus. The key element is the maintenance of the ostial patency. Specifically, ostial patency significantly affects mucus composition and secretion; moreover, an open ostium allows mucociliary clearance to easily remove particulate matter and bacteria. Problems occur if the orifice is too small for the amount of mucus, if mucus production is increased, for instance during an upper respiratory tract infection (URTI), or if ciliary function is impaired. Stasis of secretions follows and bacterial export ceases, causing or exacerbating inflammation of the mucosa whilst aeration of the mucosa is decreased, causing even more ciliary dysfunction. This vicious cycle can be difficult to break, and if the condition persists, it can result as chronic rhinosinusitis. In chronic rhinosinusitis the role of ostium occlusion seems to be less pronounced than in ARS.

3-2 Rhinosinusitis

Rhinosinusitis is an inflammatory process involving the mucosa of the nose and one or more sinuses. The mucosa of the nose and sinuses form a continuum and thus more often than not the mucous membranes of the sinus are involved in diseases which are primarily caused by an inflammation of the nasal mucosa. Chronic rhinosinusitis is a multifactorial disease (22). Factors contributing can be mucociliary impairment (23, 27), (bacterial) infection (25), allergy (28), swelling of the mucosa for another reason, or rarely physical obstructions caused by morphological/anatomical variations in the nasal cavity or paranasal sinuses (26, 21). A role in the pathogenesis of rhinosinusitis is certainly played by the ostiomeatal complex, a functional unit that comprises maxillary sinus ostia, anterior ethmoid cells and their ostia, ethmoid infundibulum, hiatus semilunaris and middle meatus. The key element is the maintenance of the ostial patency. An in depth discussion on factors contributing to chronic rhinosinusitis and nasal polyps can be found in chapter 4.

3-3 Chronic rhinosinusitis with or without nasal polyps

Chronic rhinosinusitis with or without nasal polyps is often taken together as one disease entity, because it seems impossible to clearly differentiate both entities (22-24). Chronic rhinosinusitis with nasal polyps (CRS without NP) is considered a subgroup of chronic rhinosinusitis (CRS) (fig. 3-1). The question remains as to why “ballooning” of mucosa develops in polyposis patients and not in all rhinosinusitis patients. Nasal polyps have a strong tendency to recur after surgery even when aeration is improved (25). This may reflect a distinct property of the mucosa of polyt patients which has yet to be identified. Some studies have tried to divide chronic rhinosinusitis and nasal polyps based on inflammatory markers (26-30). Although these studies point to a more pronounced eosinophilia and IL-5 expression in nasal polyps than that found in patients with chronic rhinosinusitis, these studies also point to a continuum in which differences might be found at the ends of the spectrum but at the moment no clear cut division can be made.

Figure 3-1. The spectrum of chronic rhinosinusitis and nasal polyps

Nasal polyps appear as grape-like structures in the upper nasal cavity, originating from within the ostiomeatal complex. They consist of loose connective tissue, oedema, inflammatory cells and some glands and capillaries, and are covered with varying types of epithelium, mostly respiratory pseudostratified epithelium with ciliated cells and goblet cells. Eosinophils are the most common inflammatory cells in nasal polyps, but neutrophils, mast cells, plasma cells, lymphocytes and monocytes are also present, as well as fibroblasts. IL-5 is the predominant cytokine in nasal polyposis, reflecting activation and prolonged survival of eosinophils (26).
The reason why polyps develop in some patients and not in others remains unknown. There is a definite relationship in patients with "Samter triad": asthma, NSAID sensitivity and nasal polyps. However, not all patients with NSAID sensitivity have nasal polyps, and vice-versa. In the general population, the prevalence of nasal polyps is 4% (32). In patients with asthma, a prevalence of 7 to 15% has been noted whereas, in NSAID sensitivity, nasal polyps are found in 36 to 60% of patients (33, 34). It had long been assumed that allergy predisposed to nasal polyps because the symptoms of watery rhinorrhea and mucosal swelling are present in both diseases, and eosinophils are abundant. However, epidemiological data provide no evidence for this relationship: polyps are found in 0.5 to 1.5% of patients with positive skin prick tests for common allergens (34, 35).
4. Epidemiology and predisposing factors

4-1 Introduction

Rhinosinusitis in its many forms, constitutes one of the commonest conditions encountered in medicine and may present to a wide range of clinicians from primary care to accident and emergency, pulmonologists, allergists, otorhinolaryngologists and even intensivists and neurosurgeons when severe complications occur.

The incidence of acute viral rhinosinusitis (common cold) is very high. It has been estimated that adults suffer 2 to 5 colds per year, and school children may suffer 7 to 10 colds per year. The exact incidence is difficult to measure because most patients with common cold do not consult a doctor. Recently a case control study in the Dutch population concluded that an estimated 900,000 consultations take place annually for acute respiratory tract infection. Rhinovirus (24%) and Influenzae (11%) were the most common agents isolated. More reliable data are available on ARS. As mentioned earlier acute non-viral rhinosinusitis (ARS) is defined as an increase of symptoms after 5 days or persistent symptoms after 10 days after a sudden onset of two or more of the symptoms: nasal blockage/congestion, anterior discharge/postnasal drip, facial pain/pressure, and/or reduction/loss of smell. It is estimated that only 0.5% to 2% of viral URTIs are complicated by bacterial infection; however, the exact incidence is unknown given the difficulty distinguishing viral from bacterial infection without invasive sinus-puncture studies. Bacterial culture results in suspected cases of acute community-acquired sinusitis are positive in only 60% of cases. Signs and symptoms of bacterial infection may be mild and often resolve spontaneously.

In spite of the high incidence of ARS and prevalence and significant morbidity of chronic rhinosinusitis (CRS), with and without nasal polyps, there is only limited accurate data on the epidemiology of these conditions. This observation mainly relates to the lack of a uniformly accepted definition for CRS. In addition, patient selection criteria greatly differ between epidemiologic studies complicating comparison of studies. When interpreting epidemiologic data, one should be aware of a significant selection bias of the different studies presented below. The purpose of this section of the EP3OS document is to give an updated overview of the currently available epidemiologic data on ARS and CRS with and without nasal polyps, and illustrate the factors which are believed to predispose to their development.

4-2 Acute bacterial rhinosinusitis.

When describing the incidence of acute bacterial rhinosinusitis there has been a lot of debate about the actual definition of the condition. For example in the Cochrane Review on antibiotics for ARS, studies were included if sinusitis was proven by a consistent clinical history, and radiographic or aspiration evidence of ARS. However, most guidelines on the diagnosis of acute bacterial rhinosinusitis base the diagnosis on symptoms and clinical examination. However, if the diagnosis is based on clinical examination alone, the rate of false positive results is high. In patients with a clinical diagnosis of ARS, less than half have significant abnormalities at X-ray examination. Based on sinus puncture/aspiration (considered the most accurate), 49-83% of symptomatic patients had ARS. Compared with puncture/aspiration, radiography offered moderate ability to diagnose sinusitis Using sinus opacity or fluid as the criterion for sinusitis, radiography had sensitivity of 0.73 and specificity of 0.80.

An average of 8.4 % of the Dutch population reported at least one episode of ARS per year in 1999. The incidence of visits to the general practitioner for acute sinusitis in the Netherlands in 2000 was 20 per 1,000 men and 33.8 per 1,000 women. According to National Ambulatory Medical Care Survey (NAMCS) data in the USA, sinusitis is the fifth most common diagnosis for which an antibiotic is prescribed. Written in 2002, sinusitis accounted for 9% and 21% of all pediatric and adult antibiotic prescriptions respectively.

4-3 Factors associated with acute rhinosinusitis.

4.3-1 Pathogens

Superinfection by bacteria on mucosa damaged by viral infection (common cold) is the most important cause of ARS. The most common bacterial species isolated from the maxillary sinuses of patients with ARS are Streptococcus pneumoniae, Haemophilus influenzae, and Moraxella catarrhalis, the latter being more common in children. Other streptococcal species, anaerobic bacteria and Staphylococcus aureus cause a small percentage of cases. Resistance patterns of the predominant pathogens vary considerably. The prevalence and degree of antibacterial resistance in common respiratory pathogens are increasing worldwide. In France, increases in resistance have been observed during the last twenty years in the same geographical area for H influenzae and S pneumoniae. The association between inappropriate antibiotic consumption and the prevalence of resistance is widely assumed based on in vitro experience. Pathogens may also influence the severity of symptomatology.

4.3-2 Ciliary impairment

Normal mucociliary flow is a significant non-specific defence mechanism in the prevention of ARS. Viral rhinosinusitis
results in the loss of cilia and ciliated cells, reaching a maximum around one week after the infection. Three weeks after the beginning of the infection the number of cilia and ciliated cells increases to nearly normal. However, as a sign of regeneration, immature short cilia (0.7 to 2.5 μm in length) were often seen (52). The impaired mucociliary function during viral rhinosinusitis results in an increased sensitivity to bacterial infection.

Also in animal experiments it was shown that shortly after exposure to pathogenic bacteria, like Streptococcus pneumoniae, Hemophilus influenzae, Pseudomonas aeruginosa, a significant loss of ciliated cells from sinus mucosa and a corresponding disruption of normal mucociliary flow occurred (53).

4-3-3 Allergy
Review articles on sinusitis have suggested that atopy predisposes to rhinosinusitis (54). This theory is attractive given the popularity of the concept that disease in the ostiomeatal area contributes to the development of sinus disease. Mucosa in an individual with allergic rhinitis might be expected to be swollen and therefore more liable to obstruct sinus ostia, reduce ventilation, leading to mucus retention which in turn might be more prone to infection. Furthermore there has been an increase in the body of opinion that regard the mucosa of the nasal airway as being in a continuum with the paranasal sinuses reflected in the term ‘rhinosinusitis’ (55). However, the number of studies determining the occurrence of ARS in patients with and without allergy are very limited.

Savolainen studied the occurrence of allergy in 224 patients with verified ARS by means of an allergy questionnaire, skin testing, and nasal smears. Allergy was found in 25% of the patients and considered probable in another 6.5%. The corresponding percentages in the control group were 16.5 and 3, respectively. There were no differences between allergic and non-allergic patients in the number of previous ARS episodes nor of previously performed sinus irrigations. Bacteriological and radiological findings did not differ significantly between the groups (56). Alho showed that subjects with allergic IgE-mediated rhinitis had more severe paranasal sinus changes on CT scanning than non-allergic subjects during viral colds. These changes indicate impaired sinus functioning and may increase the risk of bacterial sinusitis (57). Alho studied cellular modifications during acute viral rhinitis in three different groups (allergic, recurrent sinusitis, and healthy patients). No significant difference in inflammatory cells was found in any group during acute (D0) and convalescent (D21) phases.

In a small prospective study, no difference in prevalence of purulent rhinosinusitis was found between patients with and without allergic rhinitis (58). Furthermore, allergy was found in 31.5% of patients with verified acute maxillary sinusitis and there were no differences between allergic and non-allergic patients in the number of prior ARS episodes (59). Newman et al. reported that whilst 39% of patients with CRS had asthma, raised specific IgE or an eosinophilia, only 25% had true markers to show they were atopic (60). Finally, Emanuel et al. found relatively lower percentages of allergic patients in the group of patients with the most severe sinus disease on CT scan and Iwens et al. reported that the prevalence and extent of sinus mucosa involvement on CT was not determined by the atopic state.

Radiologic studies are unhelpful in unravelling the correlation between allergy and rhinosinusitis. High percentages of sinus mucosa abnormalities are found on radiologic images of allergic patients, e.g. 60% incidence of abnormalities on CT scans among subjects with ragweed allergy during the season (61). However, one should interpret this data with caution in view of the fact that high percentages of incidental findings are found on radiologic images of the sinus mucosa in individuals without nasal complaints, ranging from 24.7 % to 49.2 % (62-64), that the normal nasal cycle induces cyclical changes in the nasal mucosa volume (65), and that radiological abnormalities do not correlate well with patient’s symptoms (66).

Holzmann reported an increased prevalence of allergic rhinitis in children with orbital complications of ARS, and these complications occurred especially during the pollen season (67). In a study involving 8723 children, Chen and colleagues found the prevalence of sinusitis to be significantly higher in children with allergic rhinitis than in children without allergies (68).

In conclusion, although an attractive hypothesis, we can repeat the statement made a decade ago that there are no published prospective reports on the incidence of infective rhinosinusitis in populations with and without clearly defined allergic rhinosinusitis (69).

4-3-4 Helicobacter pylori and laryngopharyngeal reflux
Very few articles can be found in the literature regarding the role of the laryngopharyngeal reflux (LPR) and/or Helicobacter pylori infection in the pathogenesis of ARS. More have investigated a possible role in CRS but without significant results. Wise described a correlation between LPR (detected either with pH sensor and/or with symptom scores), and post-nasal drip without the typical findings of CRS, a problem which might predispose a subject to an acute bacterial infection (70). In a case report, Dinis underlines the presence of Helicobacter in the sphenoid sinus of a patient with severe sphenoid sinusitis that was also treated with Helicobacter pylori therapy (71). Therefore, even if there is no clear correlation between reflux disease and/or Helicobacter pylori infection and ARS, this is undoubtedly a field for future investigation when one considers the increase of this gastrointestinal problem in developed countries and the fact that the acid content of reflux and the Helicobacter infection itself can cause mucociliary impairment.
4-3-5 Other risk factors: ventilation, naso-gastric tube

Nosocomial sinusitis are frequently observed in intensive care 
and have been generally linked to naso-tracheal intubation 
or presence of naso-gastric tube. The maxillary sinus is 
frequently involved. Endoscopy of the middle meatus is useful 
to determine the presence of purulence in the middle meatus 
and if the culture is possible. Bacteriology differs from com-
munity acquired cases with a more frequent isolation of anaer-
obic bacteria. Treatment may include, complementary to 
adjustment of antibiotic treatment, drainage, daily lavage and 
removal of the gastric tube.

4-4 Chronic rhinosinusitis (CRS) without nasal polyps

The paucity of accurate epidemiologic data on CRS with or 
without nasal polyps contrasts with the more abundant infor-
mation on microbiology, diagnosis and treatment options for 
these conditions. When reviewing the current literature on 
CRS, it becomes clear that giving an accurate estimate of the 
prevalence of CRS remains speculative, because of the hetero-
geney of the disorder and the diagnostic imprecision often 
used in publications. In a survey on the prevalence of chronic 
conditions, it was estimated that CRS, defined as having ‘sinus trouble’ for more than 3 months in the year before the inter-
view, affects 15.5% of the total population in the United States 
ranking this condition second in prevalence among all chronic conditions. Subsequently the high prevalence of CRS 
was confirmed by another survey suggesting that 16% of the 
adult US population has CRS. However, the prevalence of 
doctor-diagnosed CRS is much lower; a prevalence of 2% was 
found using ICD-9 codes as an identifier. Corroboration of 
the definitive diagnosis of CRS should be done with nasal 
endoscopy or CT. As the diagnosis of CRS has primarily 
been based on symptoms, often excluding dysosmia, this 
means that the diagnosis of CRS is often overestimated. The 
majority of primary care physicians do not have the training 
or equipment to perform nasal endoscopy that also leads to over-
diagnosis.

Interestingly, the prevalence rate of CRS was substantially 
higher in females with a female/male ratio of 6/4. In Canada, 
the prevalence of CRS, defined as an affirmative 
answer to the question ‘Has the patient had sinusitis diagnosed 
by a health professional lasting for more than 6 months?’ ranged from 3.4% in male to 5.7% in female subjects. The 
prevalence increased with age, with a mean of 2.7% and 6.6% in 
the age groups of 20-29 and 50-59 years, respectively. After 
the age of 60 years, prevalence levels of CRS levelled off to 
4.7%. In a nationwide survey in Korea, the overall preva-
lence of CRS, defined as the presence of at least 3 nasal symp-
toms lasting more than 3 months together with the endoscopic 
finding of nasal polyps and/or mucopurulent discharge within 
the middle meatus, was 1.01%, with no differences between 
age groups or gender. By screening a non-ENT population, 
which may be considered representative of the general popula-
tion in Belgium, Gordts et al. reported that 6% of subjects 
suffered from chronic nasal discharge. A comparative study in 
the north of Scotland and the Caribbean found that in ORL 
clinics in both populations there was a similar prevalence of 
CRS (9.6% and 9.3% respectively). Not withstanding the 
shortcomings of epidemiologic studies on CRS, it represents a 
common disorder of multifactorial origin. A list of factors will 
be discussed in the following chapter which are believed to be 
etiologically linked to CRS.

4-5 Factors associated with chronic rhinosinusitis (CRS) without 
nasal polyps

4-5-1 Ciliary impairment

As may be concluded from the section on anatomy and patho-
physiology, ciliary function plays an important role in the clear-
ance of the sinuses and the prevention of chronic inflamma-
tion. Secondary ciliary dyskinesia is found in patients with 
chronic rhinosinusitis, and is probably reversible, although 
restoration takes some time. As expected in patients with 
Kartagener’s syndrome and primary ciliary dyskinesia, CRS is a 
common problem and these patients usually have a long histo-
ry of respiratory infections. In patients with cystic fibrosis (CF), 
the inability of the cilia to transport the viscous mucus causes 
ciliary malfunction and consequently CRS. Nasal polyps are 
present in about 40% of patients with CF. These polyps are 
generally more neutrophilic than eosinophilic in nature but 
may respond to steroids nonetheless, as inhaled steroids in 
patients with CF reduce neutrophilic inflammation.

4-5-2 Allergy

Review articles on rhinosinusitis have suggested that atopy 
predisposes to its development. It is tempting to speculate 
that allergic inflammation in the nose predisposes the atopic 
individual to the development of CRS. Both conditions share 
the same trend of increasing prevalence and are frequently 
associated.

It has been postulated that swelling of the nasal mucosa in 
allergic rhinitis at the site of the sinus ostia may compromise 
ventilation and even obstruct sinus ostia, leading to mucus 
retention and infection. Futhermore, there has been an 
increase in the body of opinion that regard the mucosa of the 
nasal airway as being in a continuum with the paranasal sinus-
es and hence the term ‘rhinosinusitis’ was introduced. 
However, critical analysis of the papers linking atopy as a risk 
factor to infective rhinosinusitis (chronic or acute) reveal that 
whilst many of the studies suggest a higher prevalence of aller-
gy in patients presenting with symptoms consistent with sinus-
tis than would be expected in the general population, there 
may well have been a significant selection process, because the 
doctors involved often had an interest in allergy. A num-
ber of studies report that markers of atopy are more prevalent
in populations with CRS. Benninger reported that 54% of outpatients with CRS had positive skin prick tests (103). Among CRS patients undergoing sinus surgery, the prevalence of positive skin prick tests ranges from 50% to 84% (96, 98, 104), of which the majority (60%) have multiple sensitivities 105). As far back as 1975, Friedman reported an incidence of atopy in 94% of patients undergoing sphenoethmoidectomies 106).

However, the role of allergy in CRS is questioned by other epidemiologic studies showing no increase in the incidence of infectious rhinosinusitis during the pollen season in pollen-sensitized patients (107). Taken together, epidemiologic data show an increased prevalence of allergic rhinitis in patients with CRS, but the role of allergy in CRS remains unclear. Notwithstanding the lack of hard epidemiologic evidence for a clear causal relationship between allergy and CRS, it is clear that failure to address allergy as a contributing factor to CRS diminishes the probability of success of a surgical intervention (108). Among allergy patients undergoing immunotherapy, those who felt most helped by immunotherapy were the subjects with a history of recurrent rhinosinusitis, and about half of the patients, who had had sinus surgery before, believed that the surgery alone was not sufficient to completely resolve the recurrent episodes of infection (109).

4-5-3 Asthma
Recent evidence suggests that allergic inflammation in the upper and lower airways coexist and should be seen as a continuum of inflammation, with inflammation in one part of the airway influencing its counterpart at a distance. The arguments and consequences of this statement are summarized in the ARIA document (107). Rhinosinusitis and asthma are also frequently associated in the same patients, but their inter-relationship is poorly understood. The evidence that treatment of rhinosinusitis improves asthma symptoms and hence reduces the need for medication to control asthma, mainly results from research in children and will be discussed below (Chapter 9-7). In short, improvements in both asthma symptoms and medication have been obtained after surgery for rhinosinusitis in children with both conditions (108-110).

Studies on radiographic abnormalities of the sinuses in asthmatic patients have shown a high prevalence of abnormal sinus mucosa (111, 112). All patients with steroid-dependant asthma had abnormal mucosal changes on CT compared to 88% with mild to moderate asthma (113). Again caution should be exercised in the interpretation of these studies. Radiographically detected sinus abnormalities in sensitized patients may reflect inflammation related to the allergic state rather than to sinus infection.

4-5-4 Immunocompromised state
Among conditions associated with dysfunction of the immune system, congenital immunodeficiencies manifest themselves with symptoms early in life and will be dealt with in the paediatric CRS section (see Chapter 7-6). However, dysfunction of the immune system may occur later in life and present with CRS. In a retrospective review of refractory sinusitis patients, Chee et al. found an unexpectedly high incidence of immune dysfunction (114). Of the 60 patients with in vitro T-lymphocyte function testing, 55% showed abnormal proliferation in response to recall antigens. Low immunoglobulin G, A, and M titres were found in 18%, 17%, and 5%, respectively, of patients with refractory sinusitis. Common variable immunodeficiency was diagnosed in 10% and selective IgA deficiency in 6% of patients. Therefore, immunological testing should be an integral part of the diagnostic pathway of patients with CRS. In a cross-sectional study to assess the overall prevalence of otolaryngologic diseases in patients with HIV infection, Porter et al. (115) reported that sinusitis was present in more than half of the HIV-positive population, ranking this condition one of the most prevalent diseases in HIV-positive individuals. However, the relevance of these data is questioned as there was no difference in sinonasal symptom severity between HIV-positive and AIDS patients nor was there a correlation between CD4+ cell counts and symptom severity. In a more detailed study, Garcia-Rodrigues et al. (116) reported a lower incidence of rhinosinusitis (34%), but with a good correlation between low CD4+ cell count and the probability of rhinosinusitis. It should also be mentioned here that atypical organisms like Aspergillus spp, Pseudomonas aeruginosa and microsporidia are often isolated from affected sinuses and that neoplasms such as non-Hodgkin lymphoma and Kaposi’s sarcoma, may account for sinonasal problems in patients with AIDS (117).

4-5-5 Genetic factors
Although chronic sinus disease has been observed in family members, no genetic abnormality has been identified linked to CRS. However, the role of genetic factors in CRS has been implicated in patients with cystic fibrosis (CF) and primary ciliary dyskinesia (Kartagener’s syndrome). CF is one of the most frequent autosomal recessive disorders of the Caucasian population, caused by mutations of the CFTR gene on chromosome 7 (118). The most common mutation, F508, is found in 70 to 80% of all CFTR genes in Northern Europe (119, 120). Upper airway manifestations of CF patients include chronic rhinosinusitis and nasal polyps, which are found in 25 to 40% of CF patients above the age of 5 (121-124). Interestingly, Jorissen et al. (125) reported that F508 homozygosity represents a risk factor for paranasal sinus disease in CF and Wang reported that mutations in the gene responsible for CF may be associated with the development of CRS in the general population (126).

4-5-6 Pregnancy and endocrine state
During pregnancy, nasal congestion occurs in approximately one-fifth of women (127). The pathogenesis of this disorder remains unexplained, but there have been a number of proposed theories. Besides direct hormonal effects of oestrogen, progesterone and placental growth hormone on the nasal
mucosa, indirect hormonal effects like vascular changes may be involved. Whether pregnancy rhinitis predisposes to the development of sinusitis, is not clear. In a small prospective study, Sobol et al. report that 61% of pregnant women had nasal congestion during the first trimester, whereas only 3% had sinusitis. In this study, a similar percentage of non-pregnant women in the control group developed sinusitis during the period of the study. Also in an earlier report, the incidence of sinusitis in pregnancy was shown to be quite low, i.e., 1.5% (129). In addition, thyroid dysfunction has been implicated in CRS, but there is only limited data on the prevalence of CRS in patients with hypothyroidism.

4.5-7 Local host factors

Certain anatomic variations such as concha bullosa, nasal septal deviation and a displaced uncinate process have been suggested as potential risk factors for developing CRS (130). However, some studies that have made this assertion have equated mucosal thickening on CT with CRS (131) when it has been shown that incidental mucosal thickening occurs in approximately a third of an asymptomatic population (20). However, Bolger et al. found no correlation between CRS and bony anatomic variations in the nose. Holbrook et al. also found no correlation between sinus opacification, anatomical variations and symptom scores (132). However, one should mention here that no study has so far investigated whether a particular anatomic variation can impair drainage of the ostiomeatal complex per se. Whilst some authors have postulated that anatomical variations of the paranasal sinuses can contribute to ostial obstruction (134), there are several studies that show the prevalence of anatomical variations is no more common in patients with rhinosinusitis or polyposis than in a control population (20, 21, 135). One area where conjecture remains is the effect of a deviated septum. There are a number of studies that show no correlation between septal deviation and the prevalence of CRS (136, 137). Whilst there is no recognized method of objectively defining the extent of a deviated septum, some studies have found a deviation of more than 3 mm from the midline to be more prevalent in rhinosinusitis (138, 139) whilst others have not (20, 137, 140). Taken together, there is no evidence for a causal correlation between nasal anatomic variations in general and the incidence of CRS. In spite of the observation that sinonasal complaints often resolve after surgery, this does not necessarily imply that anatomic variation is etiologically involved.

CRS of dental origin should not be overlooked when considering the etiology of CRS. Obtaining accurate epidemiologic data on the incidence of CRS of dental origin is not possible as the literature is limited to anecdotal reports.

4.5-8 Micro-organisms

4.5-8.1 Bacteria

Although it is often hypothesized that CRS evolves from ARS, this has never been proven. Furthermore, the role of bacteria in CRS is far from clear. A number of authors have described the microbiology of the middle meatus and sinuses. However, if and which of these pathogens are contributory to the disease remains a matter of debate. Bhattacharyya (2005) found that both anaerobes and aerobic species could be recovered from both diseased and the non-diseased contralateral side of patients with chronic rhinosinusitis casting doubt on the aetiological role of bacteria in CRS (141). Anaerobes are more prevalent in infections secondary to dental problems.

Aruja isolated aerobes from 86% of the middle meatus samples of CRS patients, whereas anaerobes were isolated in 8%. The most frequent microorganisms were Staphylococcus aureus (36%), coagulate-negative Staphylococcus (20%), and Streptococcus pneumoniae (17%). Middle meatus and maxillary sinus cultures presented the same pathogens in 80% of cases. In healthy individuals, coagulate-negative Staphylococcus (56%), S. aureus (39%), and S. pneumoniae (9%) were the most frequent isolates (142). Some authors suggest that as chronicity develops, the aerobic and facultative species are gradually replaced by anaerobes (143, 144). This change may result from the selective pressure of antimicrobial agents that enable resistant organisms to survive and from the development of conditions appropriate for anaerobic growth, which include the reduction in oxygen tension and an increase in acidity within the sinus. Often polymicrobial colonisation is found; the contribution to the disease of the different pathogens remains unclear. The presence of intracellular S. aureus in epithelial cells of the nasal mucosa has been suggested to pay a significant risk factor for recurrent episodes of rhinosinusitis due to persistent bacterial clonotypes, which appear refractory to antimicrobial and surgical therapy (145).

4.5-8.2 Fungi

Fungi have been cultured from human sinuses (146). Their presence may be relatively benign, colonizing normal sinuses or forming saprophytic crusts. They may also cause a range of pathology, ranging from non-invasive fungus balls to invasive, debilitating disease (147).

There is an increasing interest in the concept that the most common form of sinus disease induced by fungus may be caused by the inflammation stimulated by airborne fungal antigens. In 1999 it was proposed that most patients with CRS exhibit eosinophilic infiltration and the presence of fungi by histology or culture (148). This assertion was based on finding positive fungal culture by using a new culture technique in 202 of 210 (96%) patients with CRS who prospectively were evaluated in a cohort study. No increase in type I sensitivity was found in patients as compared with controls. The term "eosinophilic
chronic rhinosinusitis” was proposed to replace previously used nomenclature (allergic chronic rhinosinusitis). Using this new culture technique, the same percentage of positive fungi cultures was also found in normal controls 148.

Pant et al. suggest that fungal-specific immunity is characterised by serum IgG3 and not IgE distinguished patients with CRS and eosinophilic mucus from healthy controls, regardless of whether fungi were found within the mucus. They found no differences between those with CRS and the eosinophilic mucus group and a group with allergic fungal rhinosinusitis. Some authors suggest that non IgE mediated mechanisms to fungal spores might be responsible for eosinophilic inflammation seen in some individuals 151. Shin et al. found that patients with CRS had an exaggerated humoral and TH1 and TH2 cellular response to common airborne fungi, particularly Alternaria. No increase in type I sensitivity was found in patients as compared with controls 152. In another study no correlation was found between fungal parameters and the clinical parameters of CRS or the presence of eosinophilia 153 and the use of quantitative PCR produced a recovery rate of fungi of 46% in a group with CRS and a control group 154.

A broad array of fungi has been identified in the sinus cavities of patients with sinusitis through varied staining and culture techniques 155,160. As with the isolation of bacteria in sinus cavities in these patients, the presence of fungi does not prove that these pathogens directly create or perpetuate disease. The use of topical or systemic antifungal agents have not consistently been shown to help patients with CRS 155,156.

4-5-9 “Osteitis”—the role of bone
Areas of increased bone density and irregular bony thickening are frequently seen on CT in areas of chronic inflammation and may be a marker of the chronic inflammatory process 157. However, the effect during the initial phases of a severe CRS frequently appears as rarefaction of the bony ethmoid partitions. Although to date bacterial organisms have not been identified in the bone in either humans or animal models of CRS, it has been suggested that that this irregular bony thickening is a sign of inflammation of the bone which in turn might maintain mucosal inflammation 158.

In rabbit studies it was demonstrated that not only the bone adjacent to the involved maxillary sinus become involved, but that the inflammation typically spreads through the Haversian canals and may result in bone changes consistent with some degree of chronic osteomyelitis at a distance from the primary infection 159,160. It is certainly possible that these changes, if further confirmed in patients, may at least in part, explain why CRS is relatively resistant to therapy.

4-5-10 Environmental factors
Cigarette smoking was associated with a higher prevalence of rhinosinusitis in Canada (85), whereas this observation was not confirmed in a nationwide survey in Korea (86). Other lifestyle-related factors are undoubtedly involved in the chronic inflammatory processes of rhinosinusitis. For instance, low income was associated with a higher prevalence of CRS (85). In spite of in vitro data on the toxicity of pollutants on respiratory epithelium, there exists no convincing evidence for the etiologic role of pollutants and toxins such as ozone in CRS.

4-5-11 Iatrogenic factors
Among risk factors of CRS, iatrogenic factors should not be forgotten as they may be responsible for the failure of sinus surgery. The increasing number of sinus mucoceles seems to correlate with the increase in endoscopic sinus surgery procedures. Among a group of 42 patients with mucoceles, 11 had prior surgery within 2 years prior to presentation 161. Another reason for failure after surgery can be the recirculation of mucus out of the natural maxillary ostium and back through a separate surgically created antrostomy resulting in an increased risk of persistent sinus infection 162.

4-5-12 Helicobacter pylori and laryngopharyngeal reflux
Helicobacter pylori DNA has been detected in between 11% (163) and 33% (164) of sinus samples from patients with CRS but not from controls. However, as in ARS this does not prove a causal relationship.

4-6 Chronic rhinosinusitis with nasal polyps
Epidemiologic studies rely on nasal endoscopy and/or questionnaires to report on the prevalence of nasal polyps (NP). Large NP can be visualized by anterior rhinoscopy, whereas nasal endoscopy is warranted for the diagnosis of smaller NP. Nasal endoscopy appears to be a prerequisite for an accurate estimate of the prevalence of NP, as not all patients that claim to have NP actually have polyps on nasal endoscopy 165. Therefore, surveys based on questionnaires asking for the presence of NP, may provide us with an overestimation of the self-reported prevalence of NP. Recently, a French expert panel of ENT specialists elaborated a diagnostic questionnaire/algorithm with 90 % sensitivity and specificity 166.

In the light of epidemiologic research, a distinction needs to be made between clinically silent NP or preclinical cases, and symptomatic NP. Asymptomatic polyps may transiently be present or persist, and hence remain undiagnosed until they are discovered by clinical examination. On the other hand, polyps that become symptomatic may remain undiagnosed, either because they are missed during anterior rhinoscopy and/or because patients do not see their doctor for this problem. Indeed, one third of patients with CRS with NP do not seek medical advice for their sinonasal symptoms 167. Compared to
patients with CRS with NP not seeking medical attention, those actively seeking medical care for CRS with NP had more extensive NP with more reduction of peak nasal inspiratory flow and greater impairment of the sense of smell (186).

In a population-based study in Skövde, Sweden, Johansson et al. (168) reported a prevalence of nasal polyps of 2.7% of the total population. In this study, NP were diagnosed by nasal endoscopy and were more frequent in men (2.2 to 1), the elderly (5% at 60 years of age and older) and asthmatics. In a nationwide survey in Korea, the overall prevalence of polyps diagnosed by nasal endoscopy was 0.5% of the total population (130). Based on a postal questionnaire survey in Finland, Hedman et al. (32) found that 4.3% of the adult population answered positively to the question as to whether polyps had been found in their nose. Using a disease-specific questionnaire, Klossek et al. (172) report a prevalence of NP of 2.1% in France.

From autopsy studies, a prevalence of 2% has been found using anterior rhinoscopy (168). After removing whole naso-ethmoidal blocks, nasal polyps were found in 5 of 19 cadavers (170), and in 42% of 31 autopsy samples combining endoscopy with endoscopic sinus surgery (171). The median age of the cases in the 3 autopsy studies by Larsen and Tos ranged from 70 to 79 years. From these cadaver studies, one may conclude that a significant number of patients with NP do not feel the need to seek medical attention or that the diagnosis of NP is often missed by doctors.

It has been stated that between 0.2% and 1% of people develop NP at some stage (172). In a prospective study on the incidence of symptomatic NP, Larsen and Tos (173) found an estimated incidence of 0.86 and 0.39 patients per thousand per year for males and females, respectively. The incidence increased with age, reaching peaks of 1.68 and 0.82 patients per thousand per year for males and females respectively in the age group of 50-59 years. When reviewing data from patient records of nearly 5,000 patients from hospitals and allergy clinics in the US in 1977, the prevalence of NP was found to be 4.2% (174), with a higher prevalence (6.7%) in the asthmatic patients.

In general, NP occur in all races and becomes more common with age (175, 176). The average age of onset is approximately 42 years, which is 7 years older than the average age of the onset of asthma (177-179). NP are uncommon under the age of 20 (180) and are more frequently found in men than in women (175, 176), except in the studies by Settipane (174) and Klossek (165).

4-7 Factors associated with chronic rhinosinusitis with nasal polyps

4-7-1 Allergy

From 0.5 to 4.5% of subjects with allergic rhinitis have NP (34, 181, 186), which compares with the normal population (172). In children the prevalence of CRS with NP has been reported to be 0.1% (34) and Kern found NP in 25.6% of patients with allergy compared to 3.9% in a control population (187). On the other hand, the prevalence of allergy in patients with NP has been reported as varying from 10% (186) to 54% (187) and 64% (188). Contrary to reports that have implicated atopy as being more prevalent in patients with NP, others have failed to show this (34, 186, 189-191). Recently, Bachert et al. (192) found an association between levels of both total and specific IgE and eosinophilic infiltration in NP. These findings were unrelated to skin prick test results. Although intradermal test to food allergens are known to be unreliable, positive intradermal tests to food allergens have been reported in 70% (193) and 81% (194) of NP patients compared to respectively 34% and 11% of controls. Based on questionnaires, food allergy was reported by 22% (195) and 31% (175) of patients with NP, which was significantly higher than in non-NP controls (193). Pang et al. found a higher prevalence of positive intradermal food tests (81%) in patients with NP compared to 11% in a small control group (196). Further research is needed to investigate a possible role for food allergy in the initiation and perpetuation of NP.

4-7-2 Asthma

Bronchial symptoms are associated with NP in a subgroup of patients (189). Wheezing and respiratory discomfort are present in 31% and 42% of patients with NP, and asthma is reported by 26% of patients with NP, compared to 6% of controls (174). Alternatively, 7% of asthmatic patients have NP (181), with a prevalence of 13% in non-atopic asthma (skin prick test and total and specific IgE negative) and 5% in atopic asthma (182). Late onset asthma is associated with the development of nasal polyps in 10-15% (14). Asthma develops first in approximately 69% of patients with both asthma and CRS with NP. NP take between 9 and 13 years to develop, only two years in aspirin induced asthma (190). Ten percent develop both polyps and asthma simultaneously and the remainder develop polyps first and asthma later (between 2 and 12 years) (176). Generally NP are twice as prevalent in men although the proportion of those with polyps and asthma is twice that in women than men. Women that have nasal polyps are 1.6 times more likely to be asthmatic and 2.7 times to have allergic rhinitis (178).

4-7-3 Aspirin sensitivity

In patients with aspirin sensitivity 36-96% have CRS with NP (182, 197-200) and up to 96% have radiographic changes affecting their paranasal sinuses (201). Patients with aspirin sensitivity, asthma and NP are usually non-atopic and the prevalence increases over the age of 40 years. The children of patients with asthma, NP, and aspirin sensitivity had NP and rhinosinusitis more often than the children of controls (201). Concerning hereditary factors, HLA A1/B8 has been reported as having a higher incidence in patients with asthma and aspirin sensitivity (202) although Klossek et al (167) found no difference between gender in 10,033 patients. Zhang found that IgE antibodies to enterotoxins can be found in the majority of patients polyps who are aspirin sensitive (206).
polyps

Although the mechanisms involved in the pathogenesis of nasal polyps (NP) remain largely unclear, there are reports suggesting an underlying genetic predisposition. This concept is supported by some clinical data and genetic studies. This chapter does not include NP in cystic fibrosis (CF), which is known to be a hereditary disease with multi-systemic involvement with genetic variations, presenting with defect in chloride transport across membranes and dehydrated secretions.

4-7-4-1 Family and twin studies

An interesting observation is that NP are frequently found to run in families, suggesting a hereditary or with shared environmental factor. In the study by Rugina et al., more than half of 224 NP patients (52%) had a positive family history of NP. The presence of NP was considered when NP had been diagnosed by an ENT practitioner or the patients had undergone sinus surgery for NP. A lower percentage (14%) of familial occurrence of NP was reported earlier by Greisner et al. in smaller group (n = 50) of adult patients with NP. Thus, these results strongly suggest the existence of a hereditary factor in the pathogenesis of NP.

However, studies of monozygotic twins have not shown that both siblings always develop polyps, indicating that environmental factors are likely to influence the occurrence of NP. NPs have been described in identical twins, but given the prevalence of nasal polyps it might be expected that there would be more than a rare report of this finding.

4-7-4-2 Linkage analysis and association studies

In the literature, some studies were able to show linkage of certain phenotypes of NP to candidate gene polymorphisms. Karjalainen et al. reported that subjects with a single G-to-T polymorphism in exon 5 at +4845 of the gene encoding IL-1alpha (IL-1A) were found to have less risk of developing NP as compared to subjects with common G/G genotype. In another study, polymorphism of IL-4 (IL-4/-590 C-T), a potential determinant of IgE mediated allergic disease, was found to be associated with a protective mechanism against NPs in the Korean populations.

A number of genetic association studies found a significant correlation between certain HLA (human leukocyte antigen) alleles and NP. HLA is the general name of a group of genes in the human major histocompatibility complex (MHC) region on the human chromosome 6 that encodes the cell-surface antigen-presenting proteins. Luxenberger et al. reported an association between HLA-A74 and NPs, whereas Molnar-Gabor et al. reported that subjects carrying HLA-DR7-DQA1*0201 and HLA-DR7-DQB1*0202 haplotype had a 2 to 3 times odds ratio of developing NP. The risk of developing NP can be as high as 5.53 times in subjects with HLA-DQA1*0201-DQB1*0201 haplotype. Although several HLA alleles were found to be associated with NP, such susceptibility can be influenced by ethnicity. In the Mexican Mestizo population, increased frequency of the HLA-DRB1*03 allele and of the HLA-DRB1*04 allele were found in patients with NP as compared to healthy controls.

4-7-4-3 Multiple gene expressions in nasal polyps

The development and persistence of mucosal inflammation in NPs have been reported to be associated with numerous genes and potential single nucleotide polymorphisms (SNPs). The products of these genes determine various disease processes, such as immune modulation or immuno-pathogenesis, inflammatory cells (e.g., lymphocytes, eosinophils, neutrophils) development, activation, migration and life span, adhesion molecule expression, cytokine synthesis, cell-surface receptor display, and processes governing fibrosis and epithelial remodelling.

In the literature, gene expression profiles in nasal polyp have been performed by many studies, including the major repertoire of disease-related susceptibility genes or genotypic markers (Table 4-1). With the advance of microassay technique, expression profiles of over 10,000 of known and novel genes can be detected. A recent study showed that in NP tissues, 192 genes were upregulated by at least 2-fold, and 156 genes were downregulated by at least 50% in NP tissues as compared to sphenoid sinuses mucosa. In another study, microarray analysis was used to investigate the expression profile of 491 immune-associated genes in nasal polyps. The results showed that 87 genes were differentially expressed in the immune-associated gene profile of nasal polyps, and 15 genes showed differential expression in both NP and controls (turbinate). These seemingly conflicting results are likely due to the heterogeneity of inflammatory cells within nasal polyps and the differences in study designs and analytic approaches. In addition, in most of the published studies, the functional significance of aberrant gene expression with respective to the pathogenesis of NP is yet to be determined.

The expression of gene products is regulated at multiple levels, such as during transcription, mRNA processing, translation, phosphorylation and degradation. Although some studies were able to show certain NP associated polymorphisms and genotypes, the present data is still fragmented. Same as for many common human diseases, inherited genetic variation appears to be critical but yet still largely unexplained. Future studies are needed to identify the key genes underlying the development or formation of NP and to investigate the interactions between genetic and environmental factors that influence the complex traits of this disease. Identifying the causal genes and variants in NP is important in the path towards improved prevention, diagnosis and treatment of NPs.

4-7-5 Environmental factors
The role of environmental factors in the development of CRS with NP is unclear. No difference in the prevalence of CRS with NP has been found related to the patient’s habitat or pollution at work (287). One study found that a significantly smaller proportion of the population with polyps were smokers compared to an unselected population (15% vs. 35%) (277), whereas this was not confirmed by others (217). One study reports on the association between the use of a woodstove as a primary source of heating and the development of NP (219).

4-8 Epidemiology and predisposing factors for rhinosinusitis in children

4-8-1 Epidemiology

Few prospective population studies exist (see Table 4.1). The first longitudinal study was performed by Maresh and Washburn (219) who followed 100 healthy children from birth to maturity, looking at history, physical examination and routine postero-anterior radiograph of the paranasal sinuses 4 times a year. Postero-anterior standard X-ray of the sinuses in a child gives only information about the maxillary sinuses. There existed a relatively constant percentage (30%) of “pathologic” antra in the films taken between 1 and 6 years of age. From 6 to 12 years, this percentage dropped steadily to approximately 15%. Variations in size of the sinuses occurred frequently, without any relation to infections. When there was an upper respiratory tract infection (“URTI”) in the previous 2 weeks, less than 50% showed clear sinuses. Tonsillectomy had no demonstrable effect on the radiographic appearance of the sinuses. Since the introduction of CT scanning, it has become clear that a runny nose in a child is not only due to limited rhinitis or adenoid hypertrophy, but that in the majority of the cases the sinuses are involved as well – 64% in a CT scan study of children with a history of chronic purulent rhinorrhea and nasal obstruction (220). In an MRI study of a non-ENT paediatric population (217), it was shown that the overall prevalence of sinusitis signs in children was 45%. This prevalence increased in the presence of a history of nasal obstruction to 50%, to 80% when bilateral mucosal swelling was present on rhinoscopy, to 81% after a recent upper respiratory tract infection (URI), and to 100% in the presence of purulent secretions. Kristo et al found a similar overall percentage (50%) of abnormalities on MRI in 24 school children (221). At follow-up after 6 to 7 months about half of the abnormal sinuses on MRI findings had resolved or improved without any intervention.

Therefore, in younger children with CRS, there exists a spontaneous tendency towards recovery after the age of 6 to 8 years. A decrease in prevalence of rhinosinusitis in older children was also confirmed by other authors in patient populations (223).

4-8-2 Predisposing factors

These include day care (224, 225), nasal obstruction and passive smoking (226, 227). No protective effect of breast-feeding has been demonstrated (228, 229). Urban atmospheric pollution in Sao Paulo was associated with a higher prevalence of rhinitis, sinusitis and URTIs in 1000 schoolchildren aged 7-14 years than that seen in 1000 rural children (221). Children with tonsillitis or otitis media are more likely to suffer from sinusitis than those without suggesting that immunological deficiencies are involved (222). CRS is more common in children with mucociliary dysfunction due to CF (often plus NP) or primary ciliary dyskinesia and in those with humoral immune deficiencies (225). Heterozygotes for CF genes occur more commonly than expected in the CRS population suggesting that this may be a predisposing factor (224). Anatomical variations of the lateral nasal wall are common in children but bear no relationship to sinusitis (223).

4-9 Conclusion

The overview of the currently available literature illustrates the paucity of accurate information on the epidemiology of ARS, and CRS with and without NP, especially in European countries, and highlights the need for large-scale epidemiologic research exploring their prevalence and incidence. Only by the use of well standardized definitions for ARS, CRS and NP, and well-defined inclusion criteria for epidemiologic research, will it be possible to obtain accurate epidemiologic data on the natural evolution of CRS and NP, the influence of ethnic background and genetic factors on CRS and NP, and the factors associated with the disease manifestation. Such studies need to be performed in order to make significant progress in the development of diagnostic and therapeutic strategies for affected patients.

Table 4-1. Results of epidemiologic studies in rhinosinusitis is children.

<table>
<thead>
<tr>
<th>author/year</th>
<th>included group</th>
<th>examination method</th>
<th>result</th>
<th>conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maresh, Washburn</td>
<td>100 healthy children from birth to maturity</td>
<td>ENT-examination and pa-Xray of sinuses</td>
<td>30% “pathologic antra” overall &gt;50% “pathologic antra” with previous upper airway infection (URTI) in the last two weeks</td>
<td>high rate of pathology, can be under or over estimated because of the examination technique</td>
</tr>
<tr>
<td>(219)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bagatsch 1980</td>
<td>24,000 children in the area of Rostock followed up for 1 year</td>
<td>one or more URTI in the year: 0-2 years: 84% 4-6 years: 74% &gt;7 years: 89%</td>
<td>increased between November and February</td>
<td></td>
</tr>
</tbody>
</table>
5. Inflammatory mechanisms in acute and chronic rhinosinusitis with or without nasal polyposis

5-1 Introduction

Rhinosinusitis is a heterogeneous group of diseases, with different underlying aetiologies and pathomechanisms, and may indeed represent an umbrella, covering different disease entities. It is currently not understood whether acute recurrent rhinosinusitis necessarily develops into chronic rhinosinusitis, which then possibly gives rise to polyp growth, or whether these entities develop independently from each other. All of these items may be referred to as “rhinosinusitis”, meaning “inflammation of the nose and sinuses”; however, for didactic reasons and for future clinical and research purposes, a differentiation of these entities is preferred. For this purpose, we differentiate between acute rhinosinusitis (ARS), chronic rhinosinusitis (CRS) without polypos and chronic rhinosinusitis with nasal polyposis (NP), and omit an ill-defined group of “hypoplastic chronic rhinosinusitis”, which might be included in CRS, or represent an overlap between CRS and NP.

5-2 Acute rhinosinusitis

The pathophysiology of ARS remains underexplored because of the difficulty of obtaining mucosal samples during the course of the disease. Few experimental models have been dedicated to bacterial infections though experimental models of viral rhinosinusitis in animals and man exist. The common cold is commonly presumed to be implicated in opportunistic bacterial infections due to impairment of mechanical, humoral and cellular defences and epithelial damage. Usually two phases of reaction are described: a non-specific phase where the mucus and its contents (eg: lysozyme, defensin) play a major role and a second including the immune response and inflammatory reaction. Common cold symptoms are usually short-lived with a peak of severity at 48 hours; the course of the disease. Few experimental models have been dedicated to bacterial infections though experimental models of viral rhinosinusitis in animals and man exist. The common cold is commonly presumed to be implicated in opportunistic bacterial infections due to impairment of mechanical, humoral and cellular defences and epithelial damage. Usually two phases of reaction are described: a non-specific phase

5-2-1 Histopathology: inflammatory cells and mediators

From single case reports or a single study including 10 patients with complications, neutrophils are mainly found in the mucosa and the sinus fluid. Epithelial cells are the first barrier in contact with virus or bacteria. These release and express several mediators and receptors to initiate different viral elimination mechanisms. Recently evidence of biofilms has been suggested in experimentally-induced bacterial (pseudomonas) sinusitis in rabbits.

5-2-1-1 Epithelial cells

No specific studies are available concerning the role of epithelial cells in ARS. In cases of experimental induced viral rhinosinusitis, epithelial damage is observed. In vitro release of IL-6 after rhinovirus inoculation has been found. Epithelial cells in contact with human rhinovirus express intracellular adhesion molecule 1 (ICAM-1) which belongs to the immunoglobulin supergene family. Membranous (m-ICAM) and circulating (s-ICAM) forms are detected during common colds and expressed in vitro by epithelial cells.

5-2-1-2 Granulocytes

Neutrophils are responsible for proteolytic degradation due to the action of protease. In vitro leucocytes produce lactic acid during S. pneumoniae induced rhinosinusitis. Neutrophils are a likely source of IL-8 and TNF-α.

5-2-1-3 T lymphocytes

These are stimulated during ARS by pro-inflammatory cytokines such as IL-1β, IL-6 and TNF-α. Experimentally, antigen stimulated TH2 seems active in the augmented response to bacterial with S. pneumoniae in allergic mice.

5-2-1-4 Cytokines

Mucosal tissue sampled from the maxillary sinus in ARS (n=10), demonstrated significantly elevated IL-8 concentrations compared to 7 controls. IL-8 belongs to the CXC-chemokine group and is a potent neutrophil chemotactic protein, which is constantly synthesized in the nasal mucosa. Similar results, though not reaching significance, were obtained for IL-1β and IL-6, whereas other cytokines such as GM-CSF, IL-5 and IL-4 were not upregulated. Another study confirm that some specific cytokines were more implicated in ARS (IL-12, IL-4, IL-10, IL-13). Recently, IL-8, TNF-alpha and total protein content were increased in nasal lavage from subjects with ARS compared to controls and allergic rhinitis subjects. The cytokine pattern found in ARS resembles that in lavage from naturally acquired viral rhinitis.
5-2-1-5 Adhesion molecules
Human rhinoviruses use intercellular adhesion molecule-1 (ICAM-1) as their cellular receptor. Expression of cell adhesion molecules is induced by pro-inflammatory cytokines.

5-2-1-6 Neuromediators
The role of the nervous system in ARS is not documented but probably needs further investigation. Human axon responses are considered as an immediate protective mucosal defense mechanism but no specific investigation has been performed during ARS.

5-3 Chronic rhinosinusitis without nasal polyps

5-3-1 Histopathology and inflammatory cells
In the sinus fluid of patients with chronic rhinosinusitis undergoing surgery, the inflammatory cells are predominantly neutrophils, as observed in ARS, but a small number of eosinophils, mast cells and basophils may also be found. The mucosal lining in chronic rhinosinusitis is characterized by basement membrane thickening, goblet cell hyperplasia, subepithelial oedema, and mononuclear cell infiltration. In a recent study evaluating the percentage of eosinophils (out of 1000 inflammatory cells counted per vision field), 31 patients with untreated chronic rhinosinusitis without nasal polyps all had less than 10% eosinophils (overall mean 2%), whereas in 123 untreated nasal polyp specimen, 108 samples showed more than 10% eosinophils (overall mean 50%). These observations suggest that tissue eosinophilia is not a hallmark of chronic rhinosinusitis without polyp formation, and that there are major differences in the pathophysiology of these sinus diseases.

5-3-1-1 Lymphocytes
T cells, in particular CD4+ T helper cells, participate in the CRS pathophysiology by being predominant at the initiation and regulation of inflammation. Epithelial cells from CRS express functional B7 co-stimulatory molecules (B7-H1, B7-H2, B7-H3, and B7-DC) and may contribute in the regulation of lymphocytic activity at mucosal surfaces.

5-3-1-2 Eosinophils
Tissue eosinophilia in CRS has been widely reported as a marker of inflammation, and also shows some relationship to severity and prognosis. CRS is also accompanied by 3-nitrotyrosine formation, largely restricted to the eosinophils while Br-Tyr, a molecular footprint predominantly formed by eosinophil peroxidase-catalyzed tissue damage, may serve as an objective index of sinus disease activity when compared to healthy mucosa.

The association between eosinophil inflammation and the presence of fungi in CRS has recently been a matter of considerable interest and investigation. Eosinophil infiltration on mucus cytology is correlated with the clinical diagnosis, the presence of fungal elements on cytology, and serum IgE. No significant correlations between the fungal culture, middle meatal eosinophilia and clinical parameters of CRS were found. In addition, a chronic eosinophilic inflammatory response to Aspergillus fumigatus is also evoked in a murine model of CRS, mimicking the human eosinophilic disease.

CRS has lower levels of eosinophilic markers compared with nasal polyps, while round cell infiltration, eosinophils and plasma cells also differ in CRS and nasal polyp patients. All

| Table 5-1. Inflammatory cells and mediators in acute rhinosinusitis |
|-------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| author/year       | tissue/patients | cells           | mediators       | technique       | conclusions     |
| Rudack 1998 (248) | sinus mucosa acute RS surgical cases | no | IL-8, IL-1β, IL-6, IL-5 | ELISA | increase IL-8, IL-1β, IL-6 during ARS |
| Ramadan 2002 (250) | virus-induced ARS reovirus | B cells T cells | no | histology | B and T cells interactions are still present after D14 and D21 confirming delayed immune response |
| Passariello 2002 (251) | cell culture epithelial pneumocyst | IL-6, IL-8, ICAM-1 | ELISA | HRV promotes internalisation of S. aureus due to the action of cytokines and ICAM-1 |
| Yu 2004 (252) | mice: S.Pneumoniae-induced ARS and allergic sensitisation | eosinophils, polymorphonuclear cells | IL-12, IL-4, IL-10, IL-13 | IHC | differential profile between ARS and CRS: IL-12, IL-4, IL-10, IL-13 |
| Riechelman 2005 (253) | nasal secretion human ARS | infection with pseudomonas | IL-12, IL-4, IL-10, IL-13 | IHC | differential profile between ARS and CRS: IL-12, IL-4, IL-10, IL-13 |
| Perloff 2005 (254) | maxillary mucosa rabbits | no | IL-6, IL-8, IL-10, IL-13 | IHC | differential profile between ARS and CRS: IL-12, IL-4, IL-10, IL-13 |
| Khoury 2006 (255) | sinusonasal mucosa mice S.pneumoniae mice | T lymphocyte eosinophil | IL-6, IL-8, IL-10, IL-13 | IHC | differential profile between ARS and CRS: IL-12, IL-4, IL-10, IL-13 |
these findings suggest that CRS without and with nasal polyps might be two different disease entities, although they may also be interpreted as different degrees of inflammation.

5-3-1-3 Macrophages (CD68+ cells)
There is an increase in the number of macrophages in CRS and nasal polyps with different phenotypes of macrophages present in the diseases. The macrophage mannose receptor (MMR), capable of phagocytosis of invaders and signal transduction for pro-inflammatory mechanisms, might be of importance in CRS immune interactions since MMR shows a higher expression in CRS than in nasal polyps and controls.

5-3-1-4 Mast Cells
Both mast cells (tryptase) and eosinophils (ECP) are involved in non-allergic and allergic forms of chronic nasal inflammation including CRS. Mast cell, eosinophil, and IgE+ cell numbers are raised in patients with CRS when compared with controls.

5-3-1-5 Neutrophils
In one study, tissue infiltration in CRS was dominated by lymphocytes and neutrophils. In another study, eosinophils dominated in the middle meatal lavages of asthma patients while neutrophils dominate in the nasal cytology of patients with small airway disease. Their correlation with lung function suggests an involvement of the lower airways in CRS.

5-3-2 Pathomechanisms and inflammatory mediators
A range of mediators and cytokines, namely IL-1, IL-6, IL-8, TNF-α, IL-3, GM-CSF, ICAM-1, MPO and ECP, have been described as increased in CRS versus control tissue, mostly from inferior turbinates. Interestingly, VCAM-1, an adhesion molecule involved in selective eosinophil recruitment, and IL-5, a key cytokine for eosinophil survival and activity, were not increased. This cytokine and mediator profile resembles the profile found in viral rhinitis or ARS, with the exception of a small though significant increase of ECP. This profile is different from the pattern in nasal polyps.

<table>
<thead>
<tr>
<th>author/year</th>
<th>tissue/patients</th>
<th>cell type</th>
<th>technique</th>
<th>conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernardes 2004</td>
<td>sinonasal mucosa (CRS) healthy nasal mucosa</td>
<td>eosinophils</td>
<td>IHC</td>
<td>CRS: increase of eosinophil activation</td>
</tr>
<tr>
<td>Claeys, 2004</td>
<td>sinonasal mucosa (CRS without NP and wNP)</td>
<td>macrophages</td>
<td>RT-PCR</td>
<td>CRS without NP: MMR mRNA expression is higher than in NP and controls</td>
</tr>
<tr>
<td>Chan, 2004</td>
<td>sinonasal mucosa (CRS children &amp; adults)</td>
<td>eosinophils lymphocytes</td>
<td>histology</td>
<td>CRS in children: eosinophil inflammation lower than in adult CRS</td>
</tr>
<tr>
<td>Kramer, 2004</td>
<td>nasal secretions (CRS patients)</td>
<td>mast cells</td>
<td>uniCAP system</td>
<td>mast cells are involved in CRS inflammation</td>
</tr>
<tr>
<td>Muluk, 2004</td>
<td>sinonasal mucosa (CRS) healthy turbinet</td>
<td>T lymphocytes</td>
<td>IHC</td>
<td>CRS: increase in T lymphocytes numbers</td>
</tr>
<tr>
<td>Rudack 2004</td>
<td>sinonasal mucosa (CRS)</td>
<td>neutrophils</td>
<td>IHC</td>
<td>neutrophils dominate in CRS inflammation</td>
</tr>
<tr>
<td>Kim, 2005</td>
<td>sinonasal mucosa</td>
<td>nasalepithelial primary cells</td>
<td>IHC</td>
<td>expression of functional B7 costimulatory molecules</td>
</tr>
<tr>
<td>Polzehl, 2005</td>
<td>sinonasal mucosa (CRS without NP and wNP)</td>
<td>eosinophils, mast cells, macrophages, B cells, T cells</td>
<td>IHC</td>
<td>differential infiltration of inflammatory cells in both patient’s groups</td>
</tr>
<tr>
<td>Ragab, 2005</td>
<td>nasal middle meatal lavage (CRS)</td>
<td>neutrophils</td>
<td>nasal cytology</td>
<td>neutrophils dominate in nasal mucosa of patients with small airway disease</td>
</tr>
<tr>
<td>Seibering, 2005</td>
<td>sinonasal mucosa (CRS without NP and wNP)</td>
<td>eosinophils</td>
<td>histology, ELISA</td>
<td>CRS without NP: lower eosinophil inflammation than CRS with NP</td>
</tr>
<tr>
<td>Carney, 2006</td>
<td>infundibular nasosinusal mucosa (CRS)</td>
<td>mast cells</td>
<td>IHC</td>
<td>CRS: increase of mast cell numbers compared to controls</td>
</tr>
<tr>
<td>Citardi, 2006</td>
<td>sinonasal mucosa (CRS normal ethmoid mucosa)</td>
<td>eosinophils</td>
<td>mass spectrometry</td>
<td>CRS: increase of eosinophil activation</td>
</tr>
<tr>
<td>Hafidh, 2006</td>
<td>nasal mucosa (CRS patients &amp; healthy subjects)</td>
<td>fungal spores (mucus) eosinophils (cytology)</td>
<td>histology</td>
<td>CRS: correlation between nasal eosinophilia and fungal presence</td>
</tr>
<tr>
<td>Lindsay, 2006</td>
<td>mice sensitised to Aspergillus fumigatus</td>
<td>eosinophils</td>
<td>histology</td>
<td>murine CRS model: eosinophil inflammation mimicks human CRS</td>
</tr>
<tr>
<td>Ragab, 2006</td>
<td>nasal lavages (CRS patients) during FESS</td>
<td>eosinophils</td>
<td>histology (H&amp;E, GMS)</td>
<td>CRS: No correlation of fungal culture with eosinophilia, and clinical parameters</td>
</tr>
<tr>
<td>Van Zele, 2006</td>
<td>sinonasal mucosa (CRS without NP and wNP)</td>
<td>eosinophils, T cells</td>
<td>IHC</td>
<td>CRS without NP: increased T cells and decreased eosinophils, compared to NP</td>
</tr>
</tbody>
</table>

IHC: immunohistochemistry; RT-PCR: reverse-transcriptase protein chain reaction; ELISA: enzyme-linked immunosorbent assay; CRS without NP: chronic rhinosinusitis without nasal polyps; CRS with NP: chronic rhinosinusitis with nasal polyps; H&E: hematoxilin & eosin; GMS: Giemsa
5-3-2-1 Cytokines

IL-8, a highly potent chemoattractant for neutrophils, has been demonstrated in chronic rhinosinusitis tissue (280) and IL-8 protein concentrations in nasal discharge from chronic rhinosinusitis patients were significantly higher than in allergic rhinitis patients in a study also involving immunohistochemistry and in situ hybridization (281). In a study measuring cytokine protein concentrations including IL-3, IL-4, IL-5, IL-8 and GM-CSF in tissue homogenates, IL-8 was found to be significantly increased in ARS, and IL-3 in chronic rhinosinusitis mucosa compared to inferior turbinate samples (277). IL-3 might be involved in the local defense and repair of chronically inflamed sinus mucosa by supporting various cell populations and indirectly contributing to fibrosis and thickening of the mucosa (282).

In patients with CRS, IL-5, IL-6, and IL-8, and expression in nasal mucosa is elevated in comparison with healthy subjects (283). Reports of different types and quantities of inflammatory mediators also support the hypothesis that CRS and nasal polyps may constitute two different disease entities. Albumin and IL-5 levels, but not IL-8, are lower in patient with CRS without than with nasal polyps (284). CRS without nasal polyps is characterized by a Th1 polarization with high levels of IFN-γ and TGF-β, while CRS with nasal polyps shows a Th2 polarization with increased IL-5 and IgE concentrations (286).

By assessing biomarker profiles of disease, lower levels of IgE and IL-5 were found in CRS than in nasal polyps (284). While no differences were found in IL-6, IL-8, and IL-11, TGF-β was found to be 3 times greater in patients with nasal polyps, as well as responding more to IL-4, than in patients with CRS alone (285). Levels of IL-5 and ECP were lower in CRS than in nasal polyps, and correlated directly with peptide-LTs and inversely with PGE2 (286).

Patients with CRS show exaggerated humoral and cellular responses, both of Th1 and Th2 (IL-5, IL-13) types, to common airborne fungi, particularly Alternaria (287). Using the YAMIK sinus catheter, both saline or betamethasone decreased IL-1?α and IL-8 levels after the 2nd and 3rd weeks of therapy in CRS patients while TNF-α and IL-8 levels after the 2nd and 3rd weeks of therapy in CRS inversely with PGE2 (288). Other chemokines such as growth-related oncogene-alpha (GRO-alpha) and granulocyte chemotactic protein-2 (GCP-2), mainly produced by gland and epithelial cells, contribute to neutrophil chemotaxis in CRS, whereas IL-8 and ENA-78 appear to be of secondary importance (289).

In addition, CCL-20 expression was localized to the epithelial and submucosal glandular and increased in CRS patients (285).

In CRS patients without NP, COX-2 mRNA and PGE2 were found to be higher than CRS with nasal polyps while 15-Lipoxygenase and lipoxin A? were increased in all CRS groups compared with healthy mucosa. LTC4 synthase, 5-lipoxygenase mRNA, and peptide-LT levels were increased in proportion to disease severity (285). CysLT1 receptor expression is decreased in CRS compared to nasal polyps whereas CysLT2 is enhanced in both groups compared to healthy controls. Both receptor levels were correlated to eosinophil numbers, soluble IL-5Rα, ECP, and peptide-LTs. PGE2 protein concentrations and prostanoid receptors (EP1 and EP3) are up-regulated in CRS compared to nasal polyps, whereas EP2 and EP4 expression is enhanced in both diseased groups compared to controls (286).

5-3-2-2 Chemokines

In patients with CRS, chemokines have a different expression in atopic (increased CCR4+ and EG2+ cells) and non-atopic (decreased CCR5+ cells), suggesting a potential association of eosinophil and Th2 cell infiltration in atopic rhinosinusitis (286). Other chemokines such as growth-related oncogene-alpha (GRO-alpha) and granulocyte chemotactic protein-2 (GCP-2), mainly produced by gland and epithelial cells, contribute to neutrophil chemotaxis in CRS, whereas IL-8 and ENA-78 appear to be of secondary importance (289).

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5-3-2-3 Adhesion molecules

In patients with maxillary CRS, eosinophilia and vessels expressing endothelial L-selectin ligands increased during chronic rhinosinusitis compared with uninflamed control tissue, correlating with the severity of the inflammation (290).

5-3-2-4 Eicosanoids

In CRS patients without NP, COX-2 mRNA and PGE2 were found to be higher than CRS with nasal polyps while 15-Lipoxygenase and lipoxin A? were increased in all CRS groups compared with healthy mucosa. LTC4 synthase, 5-lipoxygenase mRNA, and peptide-LT levels were increased in proportion to disease severity (285). CysLT1 receptor expression is decreased in CRS compared to nasal polyps whereas CysLT2 is enhanced in both groups compared to healthy controls. Both receptor levels were correlated to eosinophil numbers, soluble IL-5Rα, ECP, and peptide-LTs. PGE2 protein concentrations and prostanoid receptors (EP1 and EP3) are up-regulated in CRS compared to nasal polyps, whereas EP2 and EP4 expression is enhanced in both diseased groups compared to controls (286).

5-3-2-5 Metalloproteinases and TGF-β

The expression of transforming growth factor beta 1 (TGF-β1) at protein and RNA level is significantly higher in CRS without NP versus CRS with NP and linked to a fibrotic cross anatomy (286). In CRS, MMP-9 and TIMP-1, a natural antagonist, but not MMP-7 are increased (290), probably resulting in a low MMP-9 activity.

In patients with CRS, MMP-9 concentrations in nasal fluid are paralleled by MMP-9 in extracellular matrix (ECM) and independently predicted by the number of neutrophils and macrophages in the tissue, but not related to fibrosis, number of myofibroblasts, or TGF-β1 expression (286).

Several findings also suggest different histopathological characters between CRS and nasal polyps. CRS is histologically characterized by fibrosis and reflected by an increased expression of TGF-β1 compared with nasal polyps, suggesting a potential differentiation between these two entities (280). In CRS and nasal polyp tissues, the expression of TGF-β1, MMP-7, MMP-9, and TIMP-1 was increased compared with controls while TGF-β1 and TIMP-1 were higher in CRS and MMP-7 in nasal polyps (282). After sinus surgery, MMP-9 and TGF-β1 were initially increased and healing quality correlated to preoperative MMP-
9 levels in nasal secretions. MMP-9 was also lower in patients with good healing compared to those with poor healing, suggesting MMP-9 as a potential factor to predict and monitor healing quality after sinus surgery. Clarithromycin therapy also reduces cellular expression of TGF-β and NFκB in biopsies from CRS patients. Immune globulin IgE+ cell numbers are raised in patients with allergic, fungal, and eosinophilic CRS when compared with controls. In a clinical trial, preoperative total IgE levels showed a significant correlation with the extent of disease on sinus CT, without any change one year after sinus surgery. IgG antibodies to

Table 5-3. Inflammatory mediators (cytokines, chemokines, toll-like receptors, adhesion molecules, eicosanoids, and matrix metalloproteinases) in chronic rhinosinusitis without nasal polyps

<table>
<thead>
<tr>
<th>author, year</th>
<th>tissue, patient</th>
<th>marker</th>
<th>technique</th>
<th>conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruback, 2004</td>
<td>sinonasal mucosa (biopsies)</td>
<td>IL-5, IL-8</td>
<td>ELISA</td>
<td>CRS without NP: lower levels of IL-5 but not IL-8 than in NP</td>
</tr>
<tr>
<td>Shin, 2004</td>
<td>PBMC from CRS (in vitro)</td>
<td>IFN-γ, IL-5, IL-13</td>
<td>ELISA</td>
<td>exposition to Alternaria increase cytokine levels</td>
</tr>
<tr>
<td>Van der Meer, 2004</td>
<td>sinonasal mucosa</td>
<td>toll-like receptors (TLR)</td>
<td>RT-PCR</td>
<td>TLR are expressed in CRS</td>
</tr>
<tr>
<td>Wallwork, 2004</td>
<td>CRS nasal mucosa (in vivo &amp; in vitro)</td>
<td>TGF-β1, NFκB</td>
<td>IHC</td>
<td>clarithromycin inhibits TGF-β1 and NFκB only in vitro</td>
</tr>
<tr>
<td>Watelet, 2004</td>
<td>sinonasal mucosa (FESS)</td>
<td>TGF-β1</td>
<td>IHC</td>
<td>CRS without NP: increased expression of TGF-β1 compared to NP</td>
</tr>
<tr>
<td>Watelet, 2004</td>
<td>sinonasal mucosa (FESS)</td>
<td>MMP-9, TGF-β1</td>
<td>IHC</td>
<td>correlation with the tissue healing quality</td>
</tr>
<tr>
<td>Bradley, 2005</td>
<td>sinonasal mucosa (FESS)</td>
<td>TGF-β</td>
<td>RT-PCR</td>
<td>CRS without NP: lower expression of TGF-β than in NP</td>
</tr>
<tr>
<td>Elhini, 2005</td>
<td>ethmoidal sinus mucosa</td>
<td>CCR4++, CCR5+</td>
<td>IHC</td>
<td>Real Time PCR</td>
</tr>
<tr>
<td>Furukido, 2005</td>
<td>sinus lavage (with YAMIK catheter)</td>
<td>IL-1β, IL-8, TNF-α</td>
<td>ELISA</td>
<td>betamethasone and Saline decrease cytokine levels</td>
</tr>
<tr>
<td>Pérez-Novo, 2005</td>
<td>sinonasal mucosa</td>
<td>IL-5</td>
<td>ELISA</td>
<td>CRS without NP: lower levels of IL-5 and ECP than in NP</td>
</tr>
<tr>
<td>Riechelman, 2005</td>
<td>nasal secretions</td>
<td>15 cytokines (IL-5)</td>
<td>ELISA</td>
<td>CRS without NP: lower levels of IL-5 than in NP</td>
</tr>
<tr>
<td>Toppila-Salmi, 2005</td>
<td>maxillary sinus mucosa (surgery)</td>
<td>L-selectin ligands</td>
<td>IHC</td>
<td>increased expression in CRS endothelial cells</td>
</tr>
<tr>
<td>Damm, 2006</td>
<td>CRS primary epithelial cells (cultures)</td>
<td>IL-6</td>
<td>ELISA</td>
<td>SA enterotoxin B increases IL-6 in CRS</td>
</tr>
<tr>
<td>Lane, 2006</td>
<td>ethmoidal mucosa (surgery)</td>
<td>TLR2, RANTES, GM-CSF</td>
<td>real time PCR</td>
<td>increase in CRS compared to healthy controls</td>
</tr>
<tr>
<td>Lee, 2006</td>
<td>sinonasal mucosa</td>
<td>CCL 20</td>
<td>IHC</td>
<td>Real Time PCR</td>
</tr>
<tr>
<td>Lin, 2006</td>
<td>sinonasal mucosa (FESS)</td>
<td>IL-4, IL-5</td>
<td>ELISA</td>
<td>sinus surgery increases cytokine levels</td>
</tr>
<tr>
<td>Rudack, 2006</td>
<td>sinonasal mucosa</td>
<td>GRO-α, GCP-2, IL-8, ENA-78</td>
<td>HPLC + bioassay</td>
<td>expression of GRO-α and GCP-2 in CRS</td>
</tr>
<tr>
<td>Pérez-Novo, 2005</td>
<td>sinonasal mucosa</td>
<td>COX-2, PGE2</td>
<td>real time PCR</td>
<td>ELISA</td>
</tr>
<tr>
<td>Pérez-Novo, 2006</td>
<td>nasal mucosa</td>
<td>CysLT receptors</td>
<td>real time PCR</td>
<td>ELISA</td>
</tr>
<tr>
<td>Watelet, 2006</td>
<td>sinonasal mucosa (FESS)</td>
<td>MMP-9</td>
<td>IHC</td>
<td>there exists a correlation between MMP-9 expression and tissue healing quality</td>
</tr>
<tr>
<td>Lu, 2005</td>
<td>sinonasal mucosa (surgery)</td>
<td>MMP-7, MMP-9, TIMP-1, TGF-β1</td>
<td>ELISA</td>
<td>there exists a different profile expression in CRSwo NP, nasal polyps, and healthy mucosa</td>
</tr>
<tr>
<td>Van Zele, 2006</td>
<td>sinonasal mucosa</td>
<td>INF-γ, TGF-β</td>
<td>ELISA</td>
<td>UniCAP system</td>
</tr>
<tr>
<td>Xu, 2006</td>
<td>sinonasal mucosa</td>
<td>IL-5, IL-6, IL-8, NFκB</td>
<td>ELISA</td>
<td>RT-PCR</td>
</tr>
</tbody>
</table>

Alternaria and Cladosporium are clearly increased in patients with CRS compared with normal individuals while less than 30% of CRS patients have specific IgE antibodies to Alternaria or Cladosporium. Fungal-specific IgG (IgG3) and IgA levels (to Alternaria alternata and Aspergillus fumigatus), but not IgE, are higher in CRS with eosinophilic mucus compared with healthy volunteers, challenging the presumption of a unique pathogenic role of fungal allergy in “allergic fungal sinusitis”.

5-3-2-7 Nitric Oxide (NO)
CRS epithelial cells show a stronger expression of TLR-4 and iNOS than controls, iNOS being upregulated in nasal epithelium and correlated with TLR-4. In a prospective randomized trial in patients with CRS who had failed initial medical therapy with nasal corticosteroids, the rise in nNO seen on both medical and surgical treatments correlated with symptom score, saccharin clearance time, endoscopic changes, and polyp size, suggesting that nNO provides a non-invasive objective measure of the response of CRS to therapy on an individual basis. However, some contradictory results on the role of nNO on nasal inflammation have been recently assessed.

5-3-2-8 Neuropeptides
Neurogenic inflammation may play a potential role on the manifestation of chronic rhinosinusitis. In addition, CGRP (trigeminal sensory) and VIP (parasympathetic) levels in saliva were significantly elevated between attacks in patients with the diagnosis of allergic CRS and migraine compared to controls, returning to baseline after pseudoephedrine therapy but only in CRS patients.

5-3-2-9 Mucins
Airway mucus is overproduced in CRS. Mucins are the major components of mucus and the macromolecules that impart rheologic properties to airway mucus. MUC5AC and MUC5B are

<table>
<thead>
<tr>
<th>author, year</th>
<th>tissue, patient</th>
<th>marker</th>
<th>technique</th>
<th>conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kim, 2004</td>
<td>maxillary sinonasal mucosa</td>
<td>MUC5AC, MUC5B</td>
<td>RT-PCR</td>
<td>increased in CRS compared to healthy controls</td>
</tr>
<tr>
<td>Lee, 2004</td>
<td>maxillary sinonasal mucosa</td>
<td>MUC8</td>
<td>RT-PCR</td>
<td>MUC8 is upregulated in CRS compared to controls</td>
</tr>
<tr>
<td>Maniscalco, 2004</td>
<td>allergic rhinitis patients</td>
<td>nasal NO</td>
<td>chemi-luminescence</td>
<td>nNO during humming is a reliable marker of sinus patency</td>
</tr>
<tr>
<td>Shin, 2004</td>
<td>PBMC from CRS (in vitro)</td>
<td>fungal IgG</td>
<td>UniCAP system</td>
<td>IgG is increased in CRS compared to healthy controls</td>
</tr>
<tr>
<td>Wang, 2004</td>
<td>sinonasal mucosa</td>
<td>TLR4, iNOS</td>
<td>in-situ hybridization</td>
<td>TLR4 and iNOS are increased in CRS compared to healthy controls</td>
</tr>
<tr>
<td>Ali, 2005</td>
<td>CRS patients (sinusal mucus)</td>
<td>MUC5AC, MUC2</td>
<td>ELISA</td>
<td>increase of MUC5AC and decrease of MUC2 in CRS</td>
</tr>
<tr>
<td>Pant, 2005</td>
<td>CRS patients (serum)</td>
<td>fungal IgG, IgA</td>
<td>ELISA</td>
<td>IgG and IgA are increased in CRS</td>
</tr>
<tr>
<td>Sun, 2005</td>
<td>CRS patients (sinus effusions, nasal secretions, serum)</td>
<td>VEGF</td>
<td>ELISA</td>
<td>VEGF expression is higher in the sinus mucosa than in nasal mucosa and serum</td>
</tr>
<tr>
<td>Bellamy, 2006</td>
<td>allergic CRS (saliva)</td>
<td>VIP, CGRP</td>
<td>radioimmunoassay</td>
<td>Neuropeptides are increased in acute attacks</td>
</tr>
<tr>
<td>Carney, 2006</td>
<td>infundibular sinonasal mucosa</td>
<td>IgE+ cells</td>
<td>immunohistochemistry</td>
<td>IgE+ cells are increased in CRS compared to healthy controls</td>
</tr>
<tr>
<td>Lal, 2006</td>
<td>CRS patients (serum)</td>
<td>total IgE</td>
<td>ELISA</td>
<td>correlation of IgE levels with the CRS extent</td>
</tr>
<tr>
<td>Martinez, 2006</td>
<td>sinonasal mucosa (FESS)</td>
<td>MUC1, MUC2, MUC4, MUC5AC, MUC5B</td>
<td>IHC</td>
<td>In situ hybridization</td>
</tr>
<tr>
<td>Pena, 2006</td>
<td>children with CRS (sinonasal mucosa)</td>
<td>MUC5AC</td>
<td>IHC</td>
<td>MUC5AC is expressed in the epithelium but not in submucosal glands</td>
</tr>
<tr>
<td>Ragab SM, 2006</td>
<td>CRS patients</td>
<td>nasal NO</td>
<td>chemi-luminescence</td>
<td>Medial and surgical treatments increase nNO, with correlation with nasal symptoms</td>
</tr>
<tr>
<td>Viswanathan, 2006</td>
<td>CRS patients (nasal mucus)</td>
<td>MUC5AC, MUC5B</td>
<td>ELISA</td>
<td>Increased in CRS compared to healthy controls</td>
</tr>
<tr>
<td>Hu, 2007</td>
<td>children with CRS (sinonasal mucosa)</td>
<td>VEGF</td>
<td>IHC</td>
<td>CRS without NP: lower expression of VGEF compared to NP</td>
</tr>
<tr>
<td>Lee, 2006</td>
<td>sinonasal mucosa (FESS)</td>
<td>surfactant protein-A</td>
<td>RT-PCR</td>
<td>increased expression of SP-A in CRS compared to healthy controls</td>
</tr>
</tbody>
</table>

FESS: functional endoscopic sinus surgery; IHC: immunohistochemistry; CRS without NP: chronic rhinosinusitis without nasal polyps; CRS with NP: chronic rhinosinusitis with nasal polyps; RT-PCR: reverse-transcriptase protein chain reaction; ELISA: enzyme-linked immunosorbent assay.
ent pattern from CRS with nasal polyps and antrochoanal polyps (decreased MUC2) also expressed a different pattern of VEGF production by nasal fibroblasts and TNF-α and decreased MUC2 and vice versa. In CRS, upregulation of MUC5AC was associated with downregulation of MUC2 and vice versa. MUC5AC and MUC5B represent the major mucin component in sinus while cystic fibrosis CRS (increased MUC5B) and paranasal sinuses and nasal mucosa and it has been found to increased in CRS compared with healthy sinus mucosa. MUC5AC and MUC5B are expressed in the maxillary sinus mucosa while cystic fibrosis CRS (increased MUC5B) and paranasal sinuses and nasal mucosa and it has been found to increased in CRS compared with healthy sinus mucosa. MUC5AC and MUC5B represent the major mucin component in sinus while cystic fibrosis CRS (increased MUC5B) and paranasal sinuses and nasal mucosa and it has been found to increased in CRS compared with healthy sinus mucosa. MUC5AC and MUC5B represent the major mucin component in sinus while cystic fibrosis CRS (increased MUC5B) and paranasal sinuses and nasal mucosa and it has been found to increased in CRS compared with healthy sinus mucosa.

Table 5-5. Biofilms in chronic rhinosinusitis

<table>
<thead>
<tr>
<th>Author/year</th>
<th>Population</th>
<th>Evidence for biofilms in CRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryer 2004 (328)</td>
<td>Adults with CRS (n=16) Biopsies of mucosa</td>
<td>Morphological evidence of EPS seen on four of the specimens and of bacteria in one on SEM</td>
</tr>
<tr>
<td>Perloff 2004 (328)</td>
<td>Frontal recess stents from post FESS adults (n=6)</td>
<td>All six had biofilm morphology on SEM and five had cultures with S. aureus</td>
</tr>
<tr>
<td>Ferguson 2005 (314, 407)</td>
<td>Adults with CRS (n=4) TEM of Biopsies of mucosa</td>
<td>Morphologic evidence of biofilm in two of the samples on TEM</td>
</tr>
<tr>
<td>Palmer 2005 (322)</td>
<td>Rabbit model of P. aeruginosa (type IV pili mutants) maxillary sinusitis (n=4) SEM of mucosa</td>
<td>Biofilm not seen in sinusitis model with bacteria defective with type IV pili (impaired attachment). Increased CBF seen in response.</td>
</tr>
<tr>
<td>Perloff (326)</td>
<td>Rabbit model of P. aeruginosa maxillary sinusitis (n=22)</td>
<td>All clinically had sinusitis. 21 cultured P. aeruginosa. Morphological evidence of biofilm seen in all on SEM. No biofilm seen in the 22 contralateral controls</td>
</tr>
<tr>
<td>Ramadan (330)</td>
<td>Adults with CRS (n=5) SEM of Mucosal biopsies</td>
<td>All 5 had morphological evidence of biofilms based on SEM</td>
</tr>
<tr>
<td>Sanclement (334)</td>
<td>Adults with CRS (n=30) controls (n=4) SEM/TEM of mucosal biopsies</td>
<td>Morphological evidence of biofilms seen in 24 patients. No controls positive.</td>
</tr>
<tr>
<td>Bendouah 2006 (332)</td>
<td>Adults with CRS (n=19) Semi quantitative in vitro culture assessment</td>
<td>22 of 31 isolates of S. aureus, Coagulase negative Staphylococcal Species, P. aeruginosa demonstrated biofilm forming capacity in vitro</td>
</tr>
<tr>
<td>Bendouah 2006 (336)</td>
<td>Adults with CRS (n=19) Semi quantitative in vitro culture assessment</td>
<td>Correlates above data with a dichotomous outcome of 'poor or favourable' based on symptoms and endoscopic signs. Poor outcome overrepresented in patients with biofilm forming isolates</td>
</tr>
<tr>
<td>Sanderson (337)</td>
<td>Adults with CRS (n = 18) controls (n=5) FISH visualised with confocal microscopy of mucosal biopsies</td>
<td>FISH for S. pneumoniae, S. aureus, H. influenza and P. aeruginosa and standard cultures 14 of 18 had evidence of biofilm and 2 of 5 controls. Cultures did not correlate.</td>
</tr>
<tr>
<td>Zuliani (338)</td>
<td>Children with CRS and OSA (n =16 ) Adenoid samples</td>
<td>All 8 CRS patients had biofilms in the adenoids. No control demonstrated significant biofilm coverage.</td>
</tr>
</tbody>
</table>


Increased VEGF expression was shown to be lower within CRS mucosa than in nasal polyps (322). Surfactant protein A (SP-A), a protein that appears to play an important role in mammalian first-line host defense, was found to be increased in sinus mucosa of CRS patients compared with healthy sinus mucosa (325).

5-3-2-11 Other Biofilms

The conversion of free-floating planktonic bacterial forms into complex sessile communities has been extensively investigated. Biofilms are structured, specialised communities of adherent micro-organisms encased in a complex extra-cellular polymeric substance (EPS) (325). There is no one common biofilm structure with bacteria responding to environment and intrinsic genetic programming. These influences and cell-cell signalling that exists between bacteria in close proximity (quorum sensing) facilitates the development of the biofilm phenotype (326). Although the bacteria per se may be susceptible to antibiotics, the adoption of a biofilm strategy is protective resulting in chronic and recalcitrant infectious processes. Biofilms have been found in otitis media, cholesteatoma and tonsillitis (327). There are presently 11 papers in the literature showing evidence for biofilm formation in CRS (328).
5-4 Chronic rhinosinusitis with nasal polyps

5-4-1 Histopathology and inflammatory cells

Histomorphological characterisation of polyp tissue reveals frequent epithelial damage, a thickened basement membrane, and oedematous to sometimes fibrotic stromal tissue, with a reduced number of vessels and glands, but virtually no neural structure (323-324). The stroma of mature polyps is mainly characterised by its oedematous nature and consists of supporting fibroblasts and infiltrating inflammatory cells, localized around “empty” pseudocyst formations. Among the inflammatory cells, EG2 (activated) eosinophils are a prominent and characteristic feature in about 80% of European polyps (342), whereas lymphocytes and neutrophils are the predominant cells in cystic fibrosis and in CRS without NP. Eosinophils are localised around the vessels, glands, and directly beneath the mucosal epithelium (346). However, neutrophils are also a constant finding in nasal polyps, and their number is increased compared to controls (348). Furthermore, increased numbers of activated T-cells and plasma cells characterize the typical cell composition.

In small polyps, not larger than 5 mm, growing on normal looking mucosa of the middle turbinate in patients with bilateral polyposis, the early processes of polyp growth have been studied (340). Numerous subepithelial EG2+ eosinophils were present in the luminal compartment of the early stage polyp, forming a cap over the central pseudocystic area. In contrast, mast cells were scarce in the polyp tissue, but were normally distributed in the pedicle and the adjacent mucosa, which had a normal appearance. This contrasts to mature polyps, where degranulated mast cells and eosinophils are often diffusely distributed in the polyp tissue. Fibronectin deposition was noticed around the eosinophils in the luminal compartment of the early stage polyp, was accumulated subepithelially, and formed a network-like structure in the polyp centre and within the pseudocysts. The presence of myofibroblasts was limited to the central pseudocystic area. Interestingly, albumin and probably other plasma proteins were deposited within the pseudocysts, adjacent to the eosinophil infiltration. These observations suggest a central deposition of plasma proteins, regulated by the subepithelial eosinophilic inflammation, as a patho-genetic principle of polyp formation and growth.

5-4-1-1 Lymphocytes

Nasal polyps show a significantly increased number of T-lymphocytes (CD3) and activated T-lymphocytes (CD25) compared to control patients (380). In non-allergic CRS with nasal polyps a tendency to fewer CD4+ cells in the epithelium and more CD8+ cells in the lamina propria was found (344). An inverse median ratio of CD4+/CD8+ T cells as compared to the middle turbinates of control subjects was found in one recent study (345). Functional studies on T-cells, especially T regulatory cells, are lacking so far. Interestingly, there were almost no naïve B-lymphocytes (CD20) present in the tissue, although a significantly higher number of plasma cells (CD138) was present in NP versus controls and CRS without polyps (346, 348). This fact is reflected by a significant increase in immunoglobulin A, G and E synthesis (van Zele, unpublished).

S. aureus superantigens (SAgs) bind the V beta-region of the T-cell receptor (TCR) outside the peptide-binding site. Approximately 50 distinct V beta-domains exist in the human repertoire, and distinct SAgs will bind only particular domains, generating a pattern of V beta-enrichment in lymphocytes dependent on the binding characteristics of a given toxin. Flow cytometry was used to analyze the V beta-repertoire of poly-derived CD4+ and CD8+ lymphocytes in the light of the known skewing associated with SAg exposure. Seven of 20 subjects exhibited skewing in V beta-domains with strong associations to S. aureus SAgs. This study establishes evidence of S. aureus SAg-T-cell interactions in polyp lymphocytes of 35% of CRS with NP patients (347).

5-4-1-2 Eosinophils

An increased number of eosinophils, demonstrated by HE staining or EG2 IHC, is a hallmark of Caucasian NPs. Eosinophil numbers are significantly higher in NP tissue compared to CRS (348) and other sinus disease and control mucosa, and are further increased in patients with co-morbid asthma and/or aspirin sensitivity, but independent from atopy (342, 348). In a study evaluating the percentage of eosinophils (out of 1000 inflammatory cells counted per vision field), 31 patients with untreated chronic sinusitis without nasal polyps all had less than 10% eosinophils (overall mean 2%), whereas in 123 untreated nasal polyp specimens, 108 samples showed more than 10% eosinophils (overall mean 50%) (350). Generally, the differences in ECP measurement between diseases are more pronounced than the cell numbers, indicating a more intense activation of eosinophils in polyps. However, the eosinophilic inflammation in nasal polyp tissue from China, as measured by ECP and cytokine/chemokine levels (IL-5, eotaxin), was not significantly different from control tissue, and was significantly lower compared to Caucasian polyps. The semi-quantitative scores for EG2+ eosinophils were 0.45+1.15 for the Chinese polyp patients and 1.95 ± 2.85 for the Caucasian polyp patients, being significantly different (344). Furthermore, eosinophil numbers are not different from controls and cystic fibrosis polyps (269).

5-4-1-3 Macrophages and dendritic cells

Macrophage numbers seem to be slightly increased in nasal polyps, and these cells express increased amounts of macrophage mannospecific receptors (MMR), an innate pattern recognizing receptor, capable of phagocytosis of invaders and signal transduction for proinflammatory mechanisms (279). There also is a higher number of macrophages in patients with CF than in patients with CRS or in controls (341). Our knowledge on dendritic cells is very limited; they are present in nasal polyps, and express the high affinity IgE receptor (342, 342).
<table>
<thead>
<tr>
<th>author/year</th>
<th>tissue, patients</th>
<th>cell type</th>
<th>technique</th>
<th>conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fokkens, 1990</td>
<td>nasal polyps healthy nasal mucosa allergic rhinitis nasal mucosa</td>
<td>T lymphocytes B lymphocytes eosinophils neutrophils dendritic cells Ig+ cells</td>
<td>IHC</td>
<td>CRS with NP: more than 10% eosinophils compared to CRS without NP</td>
</tr>
<tr>
<td>Jankowski, 1996</td>
<td>nasal polyps sinonasal mucosa (CRS)</td>
<td>eosinophils</td>
<td>IHC</td>
<td>greater mast cell degranulation in CRS with NP compared to healthy inferior turbinate</td>
</tr>
<tr>
<td>Drake-Lee, 1997</td>
<td>nasal polyps inferior turbinate</td>
<td>mast cells</td>
<td>IHC</td>
<td>CRS with NP: more than 10% eosinophils compared to CRS without NP</td>
</tr>
<tr>
<td>Haas, 1997</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>dendritic cell</td>
<td>IHC</td>
<td>dendritic cells are present in NP</td>
</tr>
<tr>
<td>Jahnson, 1997</td>
<td>nasal polyps</td>
<td>endothelial cells</td>
<td>flow cytometry RT-PCR</td>
<td>CRS with NP: more than 10% eosinophils compared to CRS without NP</td>
</tr>
<tr>
<td>Loesel, 2001</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>mast cells</td>
<td>fluorescence microscopy</td>
<td>number of mast cells is not different between controls and CRS with NP</td>
</tr>
<tr>
<td>Seong, 2002</td>
<td>nasal polyps</td>
<td>epithelial cells</td>
<td>ELISA RT-PCR</td>
<td>In CRS with NP: inflammatory mediators may over-express MUC8 mRNA in NP and downregulate MUC5AC</td>
</tr>
<tr>
<td>Sobol, 2002</td>
<td>nasal polyp from cystic fibrosis (CF) NP from non-CF</td>
<td>neutrophils</td>
<td>IHC</td>
<td>there is a neutrophil massive activation in CF-NP compared to non CF-NP</td>
</tr>
<tr>
<td>Wittekindt, 2002</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>endothelial cells</td>
<td>IHC</td>
<td>VPF/VEGF expression was higher in NP than in healthy nasal mucosa</td>
</tr>
<tr>
<td>Shin, 2003</td>
<td>eosinophils from healthy volunteers incubated with CRS with NP polyp epithelial cell</td>
<td>epithelial cells</td>
<td>ELISA</td>
<td>eosinophils in nasal secretions are activated by GM-CSF, which is produced by nasal epithelial cells</td>
</tr>
<tr>
<td>Chen, 2004</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>epithelial cells</td>
<td>IHC RT-PCR</td>
<td>CRS with NP epithelial cells express increased amounts of IL-37, an antimicrobial peptide</td>
</tr>
<tr>
<td>Claeyys, 2004</td>
<td>nasal polyps sinonasal mucosa (CRS) healthy nasal mucosa</td>
<td>macrophages</td>
<td>real-time RT-PCR</td>
<td>CRS with NP: MMR has a higher expression than in CRS without NP and controls</td>
</tr>
<tr>
<td>Watanabe, 2004</td>
<td>nasal polyps</td>
<td>epithelial cells</td>
<td>IHC</td>
<td>clinical efficacy of glucocorticoids on NP epithelial GM-CSF production, which prolongs eosinophil survival</td>
</tr>
<tr>
<td>Gosepath, 2005</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>endothelial cells</td>
<td>ELISA</td>
<td>VPF/VEGF are increased in NP compared to healthy nasal mucosa</td>
</tr>
<tr>
<td>Kowalski, 2005</td>
<td>nasal polyps</td>
<td>epithelial cells, stem cell factor (SCF)</td>
<td>ELISA RT-PCR</td>
<td>epithelial cells release stem cell factor (SCF)</td>
</tr>
<tr>
<td>Conley, 2006</td>
<td>nasal polyps antrochoanal polyp</td>
<td>S. aureus superantigens of the T-cell receptor</td>
<td>flow cytometry</td>
<td>S. aureus SAg-T-cell interactions in 35% of CRS with NP lymphocytes</td>
</tr>
<tr>
<td>Hao, 2006</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>T lymphocytes</td>
<td>IHC</td>
<td>inverse median ratio of CD4+/CD8+ T cells as compared to the middle turbinate</td>
</tr>
<tr>
<td>Schaefer, 2006</td>
<td>nasal polyps sinonasal mucosa (CRS) healthy nasal mucosa</td>
<td>epithelial cells</td>
<td>IHC ELISA</td>
<td>NP endothelial and epithelial cells are the main source of CC chemokine eotaxin-2</td>
</tr>
<tr>
<td>Van Zele, 2006</td>
<td>nasal polyps sinonasal mucosa (CRS) healthy nasal mucosa</td>
<td>T lymphocytes plasma cells eosinophils neutrophils</td>
<td>IHC</td>
<td>CRS with NP: increase in T lymphocytes numbers and activated T-lymphocytes, CD4+/CD8+ T cells, and eosinophils than CRS without NP and controls. CRS with NP: increased number of neutrophils and more MPO compared to healthy controls but not to CRS without NP</td>
</tr>
<tr>
<td>Ramanathan, 2007</td>
<td>nasal polyps healthy nasal mucosa</td>
<td>epithelial cells</td>
<td>flow cytometry RT-PCR</td>
<td>TLR9 is down-regulated in NP epithelial cells and involved in innate immunity functions</td>
</tr>
</tbody>
</table>
5-4-1-4 Mast Cells
The number of mast cells is not different between controls and nasal polyps, these cells are however more often IgE-positive, especially in asthmatics, independent of atopy (355). There was greater mast cell degranulation in the nasal polyp compared to inferior turbinate (355). The density of mast cells in the epithelial and stromal layers of nasal polyps correlated with the expression of SCF mRNA and protein in the supernatants of NP epithelial cells (355).

5-4-1-5 Neutrophils
There is an increased number of neutrophils and higher concentrations of MPO protein in nasal polyps vs. controls, but not compared to CRS without polyps, and both parameters are even higher in CF NPs (358, 359) indicating a massive activation in CF-NPs compared to non-CF-NPs. The role of neutrophils currently is not understood in NPs.

5-4-1-6 Epithelial cells
Human nasal epithelial cells contain and secrete IL-8, GM-CSF, eotaxin, eotaxin-2 and RANTES, and thus may provide enough growth factors to attract eosinophils (356, 357), with GM-CSF being important for the survival of those cells (358). Epithelial cells also release stem cell factor (SCF), a cytokine with chemotactic and survival activity for mast cells, with the expression of SCF mRNA correlating to SCF protein, and with the density of mast cells in epithelial and stromal layers of nasal polyps (358).
Inflammatory mediators may lead to over-expression of MUC8 mRNA in nasal polyps and downregulation of MUC5AC mRNA expression, and influence the composition of mucus in polyp disease (358). Nasal polyp epithelial cells also express increased amounts of IL-37, an antimicrobial peptide (358), but down-regulate the level of TLR9 expression (357), and are thus directly involved in innate immunity functions.

5-4-1-7 Endothelial cells (See also adhesion molecules)
Endothelial cells express VCAM-1, induced by IL-4 and IL-13, which plays an important role for the preferential recruitment of eosinophils and T lymphocytes (360). However, a key phenomenon in nasal polyps is the remarkable oedema, which awaits explanation. Vascular permeability/vascular endothelial growth factor (VPF/VEGF) plays an important role in inducing angiogenesis and modulating capillary permeability. In fact, the expression of VPF/VEGF in specimens of nasal polyps was significantly stronger than in specimens of healthy nasal mucosa of controls (362). VPF/VEGF in polypous tissue was mainly localized in vascular endothelial cells, in basal membranes and perivascular spaces, and in epithelial cells. The markedly increased expression in nasal polyps as opposed to healthy nasal mucosa suggests that VPF/VEGF may play a significant role in both the formation of nasal polyps and in the induction of heavy tissue oedema (363).

5-4-2 Pathomechanisms and Inflammatory Mediators
5-4-2-1 Cytokines
A large body of studies has focused on eosinophilic mediators in nasal polyp tissue, and demonstrated that different cell types generate these mediators. Early studies by Denburg et al (367) demonstrated that conditioned medium, derived from cultured nasal polyp epithelial cells, contained potent eosinophil colony-stimulating activities, as well as an interleukin-3-like activity. The authors suggested that accumulation of eosinophils in polyps may partly be a result of differentiation of progenitor cells stimulated by soluble haemopoietic factors derived from mucosal cell populations. An increased synthesis of GM-CSF by epithelial cells, fibroblasts, monocytes, and eosinophils was suggested later (99, 368-370). According to Hamilos et al (30), polyp tissue samples from patients with or without allergy contained different cytokine profiles. Other studies involving protein measurements in tissue homogenates could not support these findings (31, 378).
In contrast, IL-5 was found to be significantly increased in nasal polyps, compared to healthy controls, and the concentration of IL-5 was independent of the atopic status of the patient. Indeed, the highest concentrations of IL-5 were found in subjects with non-allergic asthma and aspirin sensitivity. Furthermore, eosinophils were positively stained for IL-5, suggesting a possible autocrine role for this cytokine in the activation of eosinophils, and a strong correlation between concentrations of IL-5 protein and eosinophil cationic protein (ECP) was demonstrated later (371). The key role of IL-5 was supported by the finding that treatment of eosinophil-infiltrated polyp tissue with neutralizing anti-IL-5 monoclonal antibody (mAB), but not anti-IL-3 or anti-GM-CSF mAbs in vitro, resulted in eosinophil apoptosis and decreased tissue eosinophilia (372).
Collectively, these studies suggest that increased production of IL-5 is likely to influence the predominance and activation of eosinophils in nasal polyps independent of atopy. The lack of difference in the amounts of cytokines detected in polyps from allergic or non-allergic patients was meanwhile supported by several other studies (372, 373). Furthermore, Wagenmann et al (374) demonstrated that both Th1 and Th2 type cytokines were upregulated in eosinophilic NP, irrespective of allergen skin test results.
Recently, the regulation of the IL-5 receptor, which exists in the soluble and transmembrane isoform, has been investigated (375). Whereas the probably antagonistic soluble isoform is upregulated, the signal transducing transmembrane isoform is down-regulated in nasal polyps, especially if associated with asthma.

5-4-2-2 Chemokines
Recent studies have also shown that nasal polyps also express high levels of RANTES and eotaxin, the predominant recognised eosinophil chemoattractants. Bartels and colleagues (376) demonstrated that expression of eotaxin- and RANTES
mRNA, but not MCP-3 mRNA, was elevated in non-atopic and atopic nasal polyps, when compared to normal nasal mucosa. Similarly, several publications demonstrated an increased mRNA expression for eotaxin, eotaxin-2, eotaxin-3, and MCP-4 (397–399). The expression of eotaxin-2, a CCR3-specific chemokine, was found to be the most prominent of the three chemokines investigated. According to other data (31, 36, 243), it appears that eotaxin, rather than RANTES, in cooperation with IL-5, plays a key role in chemo-attraction and activation of eosinophils in NP tissue. This is in accordance with the findings of a recent extensive study of about 950 non-allergic and allergic polyp patients, which has also suggested that nasal polyp eosinophilic infiltration and activation may correlate mainly with increased eotaxin gene expression, rather than with RANTES expression (386). The excessive production of eotaxin in nasal polyps was recently confirmed in comparison to controls and CRS patients (261).

5-4-2-3 Adhesion molecules
Studies of cell adhesion molecules are relatively few. Early studies by Symon and colleagues (391) demonstrated that ICAM-1, E-selectin and P-selectin were well expressed by nasal polyp endothelium, whereas VCAM-1 expression was weak or absent. An elegant study by Jahnsen et al. (392), employing three-colour immunofluorescence staining, has however demonstrated that both the number of eosinophils and the proportion of vessels positive for VCAM-1 were significantly increased in nasal polyps compared with the turbinate mucosa of the same patients. Moreover, treatment with topical glucocorticosteroids decreases the density of eosinophils and the expression of VCAM-1 in polyps (385). The interaction between VLA-4 on eosinophils and VCAM-1 on endothelial cells may not only be of particular importance for transendothelial migration of eosinophils, but may also modify their activation and effector functions (386).

5-4-2-4 Eicosanoids
Levels of leukotrienes and their receptors have been shown to be up-regulated in nasal polyp tissue (395, 396), more pronounced in patients with intolerance to aspirin (398, 397, 188). A recent study suggested that high levels of LTC4 synthase are directly linked to the manifestation of aspirin intolerance (398), and polymorphisms linked to this enzyme have been suggested to cause the syndrome (260). However, up-regulation of cysteinyl-leucotrienes (CysLTS) does occur in chronic rhinosinusitis even in the absence of clinical aspirin sensitivity and appears to be closely related to the severity of eosinophilic inflammation (IL-5 and ECP), a hallmark of nasal polyp disease (399). Increased expression of the CysLT1 and CysLT2 receptors have been demonstrated on inflammatory cells in nasal polyp tissue (397, 396, 392), but also inflammatory cells in nasal lavage from patients with allergic rhinitis (398). Thus, the regulation of CysLTS does not seem to be a pathognomonic feature of aspirin intolerance. The regulation of the cyclo-oxygenases and their products, the prostaglandins, in nasal polyps is characterized by a deficit in the production of PGE2 compared to CysLT levels (297, 390–398). This phenomenon was also observed in nasal polyp tissue and peripheral blood from aspirin-intolerant subjects (399), and cyclooxygenase (COX)-2 mRNA expression and NF-kB activity were markedly lower in nasal polyp tissue from aspirin intolerant subjects compared to tolerant patients (397, 398). However, our recent data indicate that levels of PGE2 inversely correlate with the degree of eosinophilic inflammation in nasal tissue from aspirin intolerant, but also tolerant patients. These findings support previous studies, (395, 398) and suggest that this down-regulation may again represent a bystander phenomenon linked to the severity of the inflammatory process. Of interest, research on prostanooid E (EP) receptor regulation has recently been performed, with controversial results. A down-regulation of EP1 and EP3 and an up-regulation of EP2 and EP4 receptors in nasal polyp tissue compared to normal nasal mucosa was shown (297). It is known that EP2 and EP4 are highly expressed on eosinophils and a deficiency of PGE2 production may up-regulate the expression of these receptors. However, the expression of EP2 and EP4 receptors did not correlate with eosinophil numbers or eosinophil activation markers, indicating that the regulation of these receptors may involve other cellular sources. This was recently confirmed by Ying et al. who showed the expression of EP receptors in a variety of inflammatory cells in the nasal mucosa (400). These authors found a down-regulation of the EP2 receptor in aspirin intolerant patients and speculated on the effects on the production of inflammatory mediators. However, PGD2 may also mediate eosinophil chemotaxis and activation and the production of cytokines such as interleukins IL-4, IL-5, and IL-13 by human Th2 inflammatory cells via different receptors, e.g. via the CRTH2 receptor (401, 402). The relative contributions of EP and other PG receptors is far from being unravelled, and so far, little points to a specific change in PG regulation in aspirin-intolerant subjects.

Finally, lipoxins are generally associated with anti-inflammatory effects and have been reported to reduce leukocyte infiltration (403). However, certain di-hydroxyeicosatetraenoic acids (HETEs), which are precursors of these molecules, may have also pro-inflammatory effects, specifically neutrophilic and eosinophilic chemotaxis (404). Nasal polyp tissue has been shown to have a high capacity to produce LXA4 after incubation with exogenous LTA4 in the presence of polymorphonuclear granulocytes (405). In addition, severity of asthma has been associated with increased expression and activation of the 15-LO (lipoygenase) enzyme, collagen deposition and eosinophil accumulation (406). Interestingly, the capacity to produce lipoxins is decreased in epithelial cells from patients with aspirin intolerance (407). These results are in line with those showing that basal levels of this enzyme are increased in nasal polyp tissue of aspirin-tolerant, but down-regulated in aspirin intolerant subjects. 15-LO and LXA4 levels were increased in all chronic sinus disease groups, but significantly down-regulated in
patients with aspirin intolerance, suggesting a specific regulation in this subgroup (209).

Summarizing, eicosanoid changes in paranasal sinus diseases are generally characterized by an up-regulation of CysLTs, LXA4 and PGD2 and a down-regulation of COX-2 and PGE2. Eosinophilic markers such as ECP and IL-5 correlate directly with LTC4/D4/E4 and inversely with PGE2 concentrations, demonstrating the close relationship to severity of inflammation. In the sinus mucosa of aspirin intolerant subjects, these changes might be extreme, as the degree of inflammation is maximal, and the clinically apparent aspirin intolerance triad may be dependent on severe inflammation in the airways. In contrast, specific changes such as a relative down-regulation of lipoxin LXA4 in those patients is less obvious, as they possibly only unfold under the pre-condition of severe inflammation.

5-4-2-5 Metalloproteinases and TGF-β
The expression of TGF-β1 and TGF-β2, predominantly by eosinophils, and their putative effects on fibroblast activity and pathogenesis of nasal polyps have been suggested in several studies (225-228). These studies compared protein levels in tissue homogenates from patients with nasal polyps who were either untreated or treated with oral corticosteroids, and control subjects. Patients with untreated polyp samples and controls showed significantly higher concentrations of IL-5, eotaxin, ECP and albumin, and significantly lower concentrations of TGF-β1. In contrast, corticosteroid treatment significantly reduced IL-5, ECP and albumin concentrations, whereas TGF-β1 was increased (209).

These observations suggest that IL-5 and TGF-β1 represent cytokines with counteracting activities, with a low TGF-β1 protein concentration in IL-5 driven nasal polyps. Furthermore, they support the deposition of albumin and other plasma proteins as a possible pathogenic principle of polyp formation, caused by the lack of upregulation/production of TGF-β1. The lack of TGFβ also may prevent the upregulation of TIMPs, thus failing to prevent ECM breakdown by metalloproteinases. The relative down-regulation of ECM is especially apparent in comparison to CRS, demonstrating a significantly increased TGF versus controls (209).

TGF-β1 is a potent fibrogenic cytokine that stimulates extracellular matrix formation, acts as a chemoattractant for fibroblasts, but inhibits the synthesis of IL-5 and abrogates the survival-prolonging effect of haematopoietins (IL-5 and GM-CSF) on eosinophils (209). Staphylococcal enterotoxins may induce a further down-regulation of TGF in specific populations of patients (209). Oedema and pseudocyst formation characterize NP, with a few areas of fibrosis. An imbalance of metalloproteinases with an upregulation of MMP-7 and MMP-9, but not TIMP-1, in nasal polyps has been recently demonstrated (209). This results in the enhancement of MMP-9 in NP, which may account for oedema formation with albumin retention. The therapeutic effect of macrolide antibiotics may partially be related to the suppression of MMPs in the airways (209).

5-4-2-6 Nitric Oxide (NO)
Inducible nitric oxide synthase (iNOS) expression is upregulated in nasal polyp epithelium, especially in patients with asthma and aspirin-exacerbated respiratory disease (410). The role of NO in nasal polyp formation and the possible diagnostic use are currently evaluated.

5-4-3 Impact of Staphylococcus aureus enterotoxins (SAEs)
Early studies have shown that tissue IgE concentrations and the number of IgE positive cells may be raised in nasal polyps, suggesting the possibility of local IgE production (401). The local production of IgE is a characteristic feature of nasal polyposis, with a more than tenfold increase of IgE producing plasma cells in NP versus controls. Analysis of specific IgE revealed a multiclonal IgE response in nasal polyp tissue and IgE antibodies to Staphylococcus aureus enterotoxins (SAEs) in about 30-50% of the patients and in about 60-80% of nasal polyp subjects with asthma (50, 141, 144, 412-414). A recent prospective study revealed that colonization of the middle meatus with Staphylococcus aureus is significantly more frequent in NP (63.6%) compared to CRS (27.3%, p< 0.05), and is related to the prevalence of IgE antibodies to classical enterotoxins (27.8 vs 5.9%) (401). If aspirin sensitivity, including asthma, accompanied nasal polyp disease, the S. aureus colonization rate was as high as 87.5%, and IgE antibodies to enterotoxins were found in 80% of cases. Total and specific IgE as well as ECP in polyp homogenates are only partially reflected in the serum of the patients, however, the likelihood is clearly increased in patients with nasal polyps and asthma. Staining of NP tissue revealed follicular structures characterised by B- and T-cells, and lymphoid agglomerates with diffuse plasma cell infiltration, demonstrating the organization of secondary lymphoid tissue with consecutive local IgE production in NP (415).

The classical SAEs, especially TSST-1 and Staphylococcus protein A (SPA), are excellent candidates to induce multiclonal IgE synthesis by increasing the release of IL-4 as well as the expression of CD40 ligand on T-cells and B7.2 on B-cells cells (416). SPA furthermore interacts with the VH3-family of immunoglobulin heavy chain variable gene products and thus preferentially selects plasma cells presenting such immunoglobulins on their surface, which leads to a VH3 bias (416). Inducible nitric oxide synthase (iNOS) expression is upregulated in nasal polyp epithelium, especially in patients with asthma and aspirin-exacerbated respiratory disease (410). The role of NO in nasal polyp formation and the possible diagnostic use are currently evaluated.
<table>
<thead>
<tr>
<th>author, year</th>
<th>tissue, patient</th>
<th>marker</th>
<th>technique</th>
<th>conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camilos, 1993</td>
<td>nasal polyps, sinonasal mucosa (biopsies)</td>
<td>GM-CSF, IL-3</td>
<td>IHC</td>
<td>cellular sources of GM-CSF and IL-3 in NP remain to be determined</td>
</tr>
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<td>Xaubet, 1994</td>
<td>nasal polyps</td>
<td>GM-CSF</td>
<td>IHC</td>
<td>eosinophil infiltration into the respiratory mucosa (allergic reaction, CRS with nasal polyps) is modulated by epithelial cell GM-CSF</td>
</tr>
<tr>
<td>Mullol, 1995</td>
<td>nasal polyps</td>
<td>IL-8, GM-CSF, IL-1β, IL-6, IL-8, TNF-α</td>
<td>ELISA RT-PCR</td>
<td>nasal polyps may represent a more active inflammatory tissue (more cytokines) than healthy nasal mucosa</td>
</tr>
<tr>
<td>Bartels, 1997</td>
<td>nasal polyps</td>
<td>CC-chemokines (eotaxin, RANTES and MCP-3)</td>
<td>ELISA</td>
<td>expression of eotaxin and RANTES but no MCP-3 is elevated in atopic and non-atopic NP compared to normal mucosa</td>
</tr>
<tr>
<td>Bachert, 1997</td>
<td>nasal polyps</td>
<td>IL-1β, IL-3, IL-4, IL-5, IL-10, TNF-α, GM-CSF, IL-1RA, RANTES, GRO-α</td>
<td>ELISA</td>
<td>IL-5 plays a key role in eosinophil pathophysiology of nasal polyps and may be produced by eosinophils.</td>
</tr>
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<td>Ming, 1997</td>
<td>nasal polyps</td>
<td>IL-4, IL-5, IFN-γ mRNA</td>
<td>RT-PCR Southern blot</td>
<td>NP and allergic rhinitis may differ in the mechanism by which IL-4 and IL-5 are increased</td>
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<td>Simon, 1997</td>
<td>nasal polyps</td>
<td>IL-5</td>
<td>ELISA RT-PCR</td>
<td>IL-5 is an important cytokine that may delay the death process in NP eosinophils</td>
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<td>Bachert, 1998</td>
<td>nasal polyps</td>
<td>Th1, Th2 cytokines</td>
<td>Elispot</td>
<td>Th1 and Th2 type cytokines are upregulated in NP, irrespective of allergen skin test results.</td>
</tr>
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<td>Bachert, 2001</td>
<td>nasal polyps</td>
<td>IL-5, IL-4, eotaxin, LTC4/D4/E4, sCD23, ImmunoCAP</td>
<td>ELISA</td>
<td>association between increased levels of total IgE, specific IgE, and eosinophilic inflammation in NP</td>
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<td>Gevaert, 2003</td>
<td>nasal polyps</td>
<td>Soluble IL-5Rα</td>
<td>RT-PCR</td>
<td>antagonistic soluble isoform is upregulated, the signal transducing transmembrane isoform is down-regulated in nasal polyps, mainly in asthma.</td>
</tr>
<tr>
<td>Wallwork, 2004</td>
<td>CRS nasal mucosa (in vivo &amp; in vitro)</td>
<td>TGF-β1, NFkB</td>
<td>IHC</td>
<td>clarithromycin inhibits TGF-β1 and NFkB only in vitro</td>
</tr>
<tr>
<td>Watelet, 2004a</td>
<td>sinonasal mucosa (FESS)</td>
<td>MMP-9, TGF-β1</td>
<td>IHC ELISA</td>
<td>correlation with the tissue healing quality</td>
</tr>
<tr>
<td>Watelet, 2004b</td>
<td>sinonasal mucosa (FESS)</td>
<td>TGF-β1</td>
<td>IHC ELISA</td>
<td>CRS without NP: increased expression of TGF-β1 compared to NP</td>
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<tr>
<td>Elhini, 2005</td>
<td>ethmoidal sinus mucosa</td>
<td>CCR4+, CCR5+</td>
<td>IHC real time PCR</td>
<td>CRS patients: increase of CCR4+ in atopics and decrease of CCR5+ in non-atopics</td>
</tr>
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<td>Lu, 2005</td>
<td>sinonasal mucosa (surgery)</td>
<td>MMP-7, MMP-9, TIMP-1, TGF-β1</td>
<td>ELISA</td>
<td>different profile expression in CRS, NP, and healthy mucosa</td>
</tr>
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<td>Pérez-Novo, 2005</td>
<td>sinonasal mucosa</td>
<td>COX-2, PGE2</td>
<td>real time PCR ELISA</td>
<td>CRS: COX-2 and PGE2 are more expressed than in NP</td>
</tr>
<tr>
<td>Toppila-Salmi, 2005</td>
<td>maxillary sinus mucosa (surgery)</td>
<td>L-selectin ligands</td>
<td>IHC</td>
<td>increased expression in CRS endothelial cells</td>
</tr>
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<td>Lane, 2006</td>
<td>ethmoidal mucosa (surgery)</td>
<td>TLR2, RANTES, GM-CSF</td>
<td>real time PCR</td>
<td>CRS: increase compared to healthy controls</td>
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<td>Lee, 2006</td>
<td>sinonasal mucosa</td>
<td>CCL-20</td>
<td>IHC real time PCR</td>
<td>increased expression of CCL 20 in CR</td>
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<td>Olze, 2006</td>
<td>nasal polyps</td>
<td>eotaxin, CCL-20, and -3</td>
<td>ELISA</td>
<td>eotaxin is expressed in CRS</td>
</tr>
<tr>
<td>Pérez-Novo, 2006</td>
<td>nasal mucosa</td>
<td>CysLT receptors</td>
<td>real time PCR</td>
<td>CRS: CysLT and EP receptors are more expressed than in NP</td>
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<td>Rudack, 2006</td>
<td>sinonasal mucosa</td>
<td>GRO-α, CCF-2, IL-8, ENA-78</td>
<td>HPLC + bioassay</td>
<td>expression of GRO-α and GCP-2 in CRS</td>
</tr>
<tr>
<td>Watelet, 2006</td>
<td>sinonasal mucosa (FESS)</td>
<td>MMP-9</td>
<td>IHC</td>
<td>correlation between MMP-9 expression and tissue healing quality</td>
</tr>
</tbody>
</table>
lower airways, when applied in either of those locations (427). In fact, when comparing SAE-IgE positive nasal polyps to SAE-IgE negative, the number of IgE positive cells and eosinophils is significantly increased. The more severe inflammation is also reflected by significantly increased levels of IL-5, ECP and total IgE. Furthermore, a possible link to aspirin sensitivity has been proposed, with SAEs creating a severe inflammation possibly serving as a basis for the specific changes seen in aspirin sensitivity (412, 414). A review on the current knowledge on the impact of SAEs on nasal polyposis and lower airway disease was recently published (296). IgE antibody formation to SAE can be seen in nasal polyp tissue, but rarely in CRS without polyps.

In conclusion, SAEs are able to induce a more severe eosinophilic inflammation as well as the synthesis of a multiclonal IgE response with high total IgE concentrations in the tissue, which would suggest that SAEs are at least modifiers of disease in CRS with nasal polyps (294, 430). Interestingly, similar findings have recently been reported in asthma, which is known to be associated with NP (349), and in COPD (423), thus providing a link between upper and lower airways.

5-4-4 Nasal polyps in cystic fibrosis

NPs and CF-NPs share the remodelling pattern, i.e. they can be discriminated from CRS without polyps and controls by the oedema formation. Different to NPs, CF-NP display a very prominent neutrophilic inflammation, with abnormally increased concentrations of IL-1ß, IL-8 and MPO (269) and an increased activity of NFkB (424), whereas macrophages, but not eosinophils, are significantly increased over control mucosa. Furthermore, there seems to be a reactive imbalance in innate immunity markers, with mRNA expression of HBD 2 and of TLR 2 being significantly higher in CF-NP compared to non-CF-NP (425). The calcium-activated chloride channel hCLCA1 is thought to regulate the expression of soluble gel-forming mucins, and is upregulated by IL-9. Increased expression of IL-9 and IL-9R, as well as upregulation of hCLCA1, in mucus-overproducing epithelium of patients with cystic fibrosis supports the hypothesis that IL-9 contributes to mucus overproduction in cystic fibrosis (430).

5-4-5 CRS with or without nasal polyps

When searching through the literature, it is apparent that definitions do matter; especially in older literature, the term CRS was confused by “hyperplastic CRS” or “hyperplastic CRS with polyp formation”, which would probably be equivalent to NPs rather than CRS. However, because of a lack of clinical data provided in those papers, the distinction between these diseases can often not be made, and the interpretation from those studies has to be done with caution. For the purpose of this chapter, we have used clearly defined patient populations. Whereas NPs are characterized by oedema formation, with an increased VPF/VEGF, an upregulation of MMPs, but not TIMP, and a low level or decrease in TGF-β1, CRS shows a fibrotic remodelling pattern with a balanced MMP system and a significantly increased TGF-β protein content (298). This fundamental difference has been linked to the predominant type of inflammation: eosinophilic or neutrophilic; however, this notion has to be challenged in the light of 1) the fact that NPs and NPs in CF both show oedema formation, but are characterized by either abundant eosinophils or neutrophils and their products; and 2) the fact that NPs from different parts of the world do not show the same degree of eosinophilic inflammatory pattern (Zhang 2006). It is important to note that also in NPs, the number of neutrophils is increased versus controls, and the frequent impression of a predominantly “eosinophilic” inflammation neglects those cells.

Both chronic sinus diseases, CRS and NPs, show increased numbers and activation of T-cells, while only NPs display a significant increase in plasma cells and consecutive immunoglobulin synthesis (290). The role of this observation is unclear, and may reflect a constant microbial trigger.

NP have significantly higher levels of eosinophilic markers (eosinophils, eotaxin and ECP) compared to CRS and controls in Caucasians, in whom CRS is characterized by proinflammatory cytokines (IL-1β and TNF-α), a Th1 polarisation with high levels of IFN-γ, and a significant increase in profibrotic TGF-β, while NPs show a Th2 polarisation with high IL-5 and IgE concentrations and a decrease in TGF-β (206). Further studies will have to investigate TH1 and TH2-specific transduction signals, as well as the role of T regulatory cells, to fully understand the stability of these patterns; studies in non-caucasian populations may further be helpful to differentiate primary from secondary phenomena.

5-5 Aspirin sensitivity – Inflammatory mechanisms in acute and chronic rhinosinusitis

5-5-1 Introduction

The presence of aspirin-intolerance in a patient with rhinosinusitis with or without nasal polyposis is associated with a particularly persistent and treatment-resistant form of disease, coexisting usually with severe asthma and referred to as the “aspirin triad” (435). The prevalence of nasal polyposis in aspirin-sensitive asthmatics may be as high as 60-70%, as compared to less than 10% in the population of aspirin-tolerant asthmatics (25). The unusual severity of the upper airway disease in these patients is reflected by high recurrence of nasal polyps, and frequent need for endoscopic sinus surgery (25, 431, 432). Rhinosinusitis in aspirin hypersensitive patients with nasal polyposis is characterized by involvement of all sinuses and nasal passages and higher thickness of hypertrophic mucosa as has been documented with computer tomography (432).

5-5-2 Mechanisms of acute ASA-induced reactions

In ASA-sensitive patients acute nasal symptoms (sneezing, rhinorrhea and congestion) may be induced by challenge with
oral or intranasal aspirin but also with other cross-reacting nonsteroidal anti-inflammatory drugs (NSAIDs). The mechanism of these acute adverse reactions has been attributed to inhibition by NSAIDs of an enzyme cyclooxygenase-1, with subsequent inflammatory cell activation and release of both lipid and non-lipid mediators. The ASA-induced nasal reaction is accompanied by an increase in both glandular (lactoferrin, lysozyme) and plasma (albumin) proteins in nasal secretions indicating a mixed response, involving both glandular and vascular sources. Concomitant release of both mast cell (tryptase, histamine) and eosinophil (ECP) specific mediators into nasal washes clearly indicate activation of both types of cells. Increased concentration of cysteinyl leukotrienes in nasal secretion was also observed within minutes after ASA challenge although the cellular source of leukotrienes has not been determined. In parallel with inflammatory mediator release an influx of leucocytes into nasal secretions occurred with significant enrichment in eosinophils.

5-5-3 Chronic rhinosinusitis with nasal polyps
Although the pathogenesis of chronic eosinophilic inflammation of the airway mucosa and nasal polyps in ASA-sensitive patients, does not seem to be related to intake of aspirin or other NSAIDs it has been speculated that the pathomechanism underlying rhinosinusitis with nasal polyps in aspirin-sensitive patients may be different from that in aspirin tolerant patients.

5-5-3-1 Cells and cytokine profile
A high degree of marked tissue eosinophilia is a prominent feature of rhinosinusitis with nasal polyps in ASA-hypersensitive patients, and accordingly significantly more ECP was released from non-stimulated or stimulated nasal polyp dispersed cells from ASA-sensitive patients. An increased number of eosinophils in the tissue has been linked to a distinctive profile of cytokine expression with upregulation of several cytokines related to eosinophil activation and survival (e.g., IL-5, GMC-SF, RANTES, eotaxin). It has been suggested that overproduction of IL-5 might be a major factor responsible for an increased survival of eosinophils in the nasal polyps resulting in increased intensity of the eosinophilic inflammation particularly in aspirin-sensitive patients. In fact decreased apoptosis was documented in polyps from aspirin-sensitive patients, and increased infiltration with eosinophils was associated with prominent expression of CD45RO+ activated/memory cells and this cellular pattern was related to clinical features of rhinosinusitis. Bachert at al demonstrated that IgE antibodies to Staphylococcal enterotoxins (SAEs) were present in nasal polyp tissue and their concentration correlated with both glandular and vascular sources. The ASA-induced nasal reaction is accompanied by an increase in both glandular (lactoferrin, lysozyme) and plasma (albumin) proteins in nasal secretions indicating a mixed response, involving both glandular and vascular sources.

5-5-3-2 Arachidonic acid metabolites
Since Szczeklik et al reported an increased susceptibility of nasal polyps cells from ASA-sensitive patients to the inhibitory action of aspirin, arachidonic acid metabolism abnormalities have been considered a distinctive feature of nasal polyps in this subpopulation of patients. A significantly lower generation of PGE2 by nasal polyps and, nasal polyp epithelial cells as well as a decreased expression of COX-2 in nasal polyps of these patients were reported. Low expression of COX-2 mRNA in nasal polyps from ASA-sensitive patients was in turn linked to a downregulation of NF-κB activity and to abnormal regulation of COX-2 expression mechanisms at the transcriptional level. Since PGE2 has significant anti-inflammatory activity, including inhibitory effect on eosinophil chemotaxis and activation, it has been speculated that an intrinsic defect in local generation of PGE2 could contribute to development of more severe eosinophilic inflammation in aspirin-sensitive patients. Although a significant deficit of PGE2 was demonstrated in polyp tissue of ASA-sensitive as compared to ASA-tolerant patients, decreased expression of COX-2 mRNA and PGE production seem to be a feature of CRS with nasal polyps also in patients without ASA-sensitivity representing more general mechanism involved in the growth of nasal polyps. On the other hand the percentages of neutrophils, mast cells, eosinophils, and T cells expressing prostaglandin EP2, but not EP1, EP3, or inflammation in ASA-sensitive patients and some studies demonstrated an increased production of cysteinyl leukotrienes in nasal polyps of ASA-sensitive asthmatics as compared to aspirin tolerant patients in vitro but these observations could not be reproduced in vivo when nasal washes were analysed. Similarly when nasal polyp dispersed cells were cultured basal and stimulated release of LTC4 was found to be similar in nasal polyp cells from ASA-sensitive and ASA-tolerant patients. Whole blood cells from aspirin sensitive and tolerant patients did not differ in their ability to generate cyclooxygenase and lipooxygenase
products \cite{457}. More recently an increased expression of enzymes involved in production of leukotrienes (5-LOX and LTC4 synthase) and an increased generation of LTC4/D4/E4 in nasal polyp tissue from ASA-sensitive patients were found \cite{288, 439, 454}. Cysteinyl leukotriene production correlated with tissue ECP concentration both in ASA-sensitive and ASA-tolerant polyps suggesting that these mediators may be linked to tissue eosinophilia rather than to aspirin-sensitivity. On the other hand an increased expression of leukotriene LT1 receptors was found in the nasal mucosa of ASA-sensitive patients, suggesting local hyper-responsiveness to leukotrienes in this subpopulation of patients \cite{389, 392}. More recently other arachidonic acid metabolites generated on 15-LOX pathway have been associated with CRS with nasal polyps in ASA-sensitive patients. In nasal polyp epithelial cells from ASA-sensitive but not ASA-tolerant patients aspirin triggers 15-HETE generation, suggesting the presence of a specific abnormality of 15-LO pathway in these patients \cite{448}. Upregulation of 15-lipoxygenase and decreased production of the anti-inflammatory 15-LO metabolite lipoxin A4 found in nasal polyp tissue from ASA-sensitive patients further points to a distinctive but not yet understood role for 15-LO metabolites in nasal polyps \cite{288}.

5-6 Conclusion

Although far from being completely understood, pathomechanisms in ARS, CRS and NP are better understood today and begin to allow us to differentiate these diseases via their cytokine profile, their pattern of inflammation as well as remodeling processes.
6. Diagnoses

6-1 Assessment of rhinosinusitis symptoms

6-1-1 Symptoms of rhinosinusitis
Subjective assessment of rhinosinusitis is based on symptoms.

• nasal blockage, congestion or stuffiness;
• nasal discharge or postnasal drip, often mucopurulent;
• facial pain or pressure, headache, and
• reduction/loss of smell.

Besides these local symptoms, there are distant and general symptoms. Distant symptoms are pharyngeal, laryngeal and tracheal irritation causing sore throat, dysphonia and cough, whereas general symptoms include drowsiness, malaise and fever. Individual variations of these general symptom patterns are many. It is interesting to note that only a small proportion of patients with purulent rhinosinusitis, without coexisting chest disease, complain of cough.

The symptoms are principally the same in acute and chronic rhinosinusitis as well as in CRS with nasal polyps, but the symptom pattern and intensity may vary. Acute forms of infections, both acute and acute exacerbations of chronic rhinosinusitis, have usually more distinct and often more severe symptoms.

Simple nasal polyps may cause constant non-periodic nasal blockage, which can have a valve-like sensation allowing better airflow in only one direction. Nasal polyps may cause nasal congestion, which can be a feeling of pressure and fullness in the nose and paranasal cavities. This is typical for ethmoidal polyposis, which in severe cases can cause widening of the nasal and paranasal cavities demonstrated radiologically and in extreme cases, hypertelorism. Disorders of smell are more prevalent in patients with nasal polyps than in other chronic rhinosinusitis patients.

6-1-2 Subjective assessment of the symptoms
Subjective assessment of the symptoms should consider the strength or degree of the symptoms, the duration of the symptom. During the last decade more attention has been paid not only to symptoms but also to their effect on the patient’s quality of life (QoL).

The assessment of subjective symptoms is done using questionnaires or in clinical studies recorded in logbooks. Evaluation frequency depends on the aims of the study, usually once or twice daily. Continuous recording devices are also available.

The degree or strength of the symptoms can be estimated using many different grading tools.

• recorded as such: severe, moderate, slight and no symptom;
• recorded as numbers: from 0 to 4 or as many degrees as needed;
• recorded as VAS score on a line giving a measurable continuum (0 – 10 cm).

Terms such as mild, moderate or severe may include both symptom severity estimation, but also an estimate of duration i.e. “moderate symptom severity” can mean an intense symptom but only for a short time in the recorded period or less severe symptom but lasting for most of the recording period.

A recent study has considered the relationship between subjective assessment instruments in chronic rhinosinusitis and has shown that ‘mild’ equates to a visual analogue score of 3 or less, ‘moderate’ to >3-7 and ‘severe’ to >7-10. (Lim et al Rhinology in press).

The duration of the symptoms is evaluated as symptomatic or symptom-free moments in given time periods, i.e. as hours during the recording period or as day per week.

“No symptom” can be regarded as a consistent finding in most studies. It provides the possibility to record time periods (eg. days) without symptoms, which can be reliably compared between testees (inter-patient) and from study to study.

These criteria are inconsistent and not always comparable when considering rhinosinusitis, where the symptoms may fluctuate from time to time. Nevertheless in many randomised, controlled and prospective rhinosinusitis intervention studies, both allergic and infective, these methods of recording symptoms have given statistically significant results.

In a study correlating nasosinal symptoms with topographic distribution of chronic rhinosinusitis as demonstrated by CT scanning, the symptoms of nasal obstruction, anterior and posterior nasal discharge, sneezing and facial congestion failed to discriminate site of disease. By contrast loss of smell and taste were correlated with what the authors refer to as ‘diffuse rhinosinusitis’ i.e. mainly CRS with nasal polyps, whereas cacosmia and facial pain correlated with ‘localised or anterior sinusitis’ i.e. mainly sinusitis of dental or foreign body origin.

6-1-3 Validation of subjective symptoms assessment
Validation of the rhinosinusitis symptoms to show the relevance in distinguishing disease modalities and repeatability between ratings of the same patient (intrapatient, longitudinal validity) and between different patients (interpatient, cross-sectional validity) have been done. Lately, more specific and validated subjective symptom scoring tools have become available.
with the development of quality of life (QoL) evaluations. These are either assess general health evaluating (463, 464) or are disease specific (465).

6-1-3-1 Nasal obstruction
Validation of subjective assessment of nasal obstruction or stuffiness has been done by studying the relationship between subjective and objective evaluation methods for functional nasal obstruction. However, the patient's interpretation of nasal blockage varies from true mechanical obstruction of airflow to the sensation of fullness in the midface.

Generally the subjective sensation of nasal obstruction and rhinomanometric or nasal peak flow evaluations show a good intra-individual correlation in a number of studies considering normal controls, patients with structural abnormalities, hyperreactivity or infective rhinitis (466-470). However, there are also some studies where this correlation is not seen (471) or the correlation was poor (472, 473).

The interpatient variation in subjective scoring suggests that every nose is "individually calibrated", which makes interpatient comparisons less reliable but still significant (460, 462).

Subjective nasal obstruction correlates better with objective functional measurements of nasal airflow resistance (rhinomanometry, peak flow) than with measurements of nasal cavity width, such as acoustic rhinometry (473, 474). Nasal obstruction can also be assessed objectively by tests using personal nasal peak flow instruments, inspiratory or expiratory, which patients can take home or to their work place and do measurements at any desired time intervals. Subjective assessment of nasal obstruction is a well validated criterion.

6-1-3-2 Nasal discharge
Techniques for objective assessment of nasal discharge are not as good as for nasal obstruction: Counting the nose blowings in a diary card or using a new handkerchief from a counted reservoir for each blow and possibly collecting the used handkerchiefs in plastic bags for weighing have been used in acute infective rhinitis (475) and in "autonomic (previously termed vasomotor) rhinitis" (476).

Validating correlation studies between "objective" discharge measures (collecting and measuring amount or weight of nasal secretion as drops, by suction, or using hygroscopic paper strips etc) and subjective scoring of nasal discharge or post-nasal drip has not been done.

6-1-3-3 Smell abnormalities
Fluctuations in the sense of smell are associated with chronic rhinosinusitis. This may be due to mucosal obstruction of the olfactory niche (conductive loss) and/or degenerative alterations in the olfactory mucosa due to the disease or its treatment eg repeated mucosal due to the disease or its treatment eg repeated nasal surgery.

Subjective scoring of olfaction is a commonly used assessment method. In validating clinical settings, subjective scores have been found to correlate significantly to objective olfactory threshold and qualitative tests in normal population, rhinosinusitis and other disease conditions (477-480) as well as numerous clinical studies concerning other diseases than rhinosinusitis (Evidence level Ib).

6-1-3-4 Facial pain and pressure
Facial or dental pain, especially unilateral, have been found to be predictors of acute maxillary sinusitis with fluid retention in patients with a suspicion of infection, when validated by maxillary antral aspiration (477) or paranasal sinus radiographs (481). The importance of facial pain as a cardinal sign of chronic rhinosinusitis has also been called into question (482) where the symptoms are more diffuse and fluctuate rendering the clinical correlation of facial pain and pressure scorings against objective assessments unconvincing. Poor correlation between facial pain localisation and the affected paranasal sinus CT pathology in patients with supposed infection, both acute and chronic, has been reported (483). However, rhinosinusitis disease specific quality of life studies also include facial pain-related parameters, which have been validated (485).

6-1-3-5 Overall rating of rhinosinusitis severity
Overall rating of rhinosinusitis severity can be obtained as such or by total symptoms scores, which are summed scores of the individual symptoms scores. These are both commonly used, but according to an old validation study for measuring the severity of rhinitis, scores indicating the course of individual symptoms should not be combined into a summed score, rather the patient's overall rating of the condition should be used (484). QoL methods have produced validated questionnaires which measure the impact of overall rhinosinusitis symptoms on everyday life (486).

6-1-3-6 Chronic Sinusitis Survey (CSS)
This is a 6 item duration based monitor of sinusitis specific outcomes which has both systemic and medication-based sections (486). In common with other questionnaires, it is rather better at determining the relative impact of chronic rhinosinusitis compared to other diseases than as a measure of improvement following therapeutic intervention but can be a useful tool (487). (Evidence Level Ib). Mean scores one year after endoscopic frontal sinus surgery showed a significant improvement in symptoms of pain, congestion, and drainage and medication use was also significantly reduced (487).

6-1-3-7 The Chronic Rhinosinusitis Type Specific Questionnaire
This test contains three forms. Form 1 collects data on nasal and sinus symptoms prior to treatment, Form 2 collects data
Examination

6-2-1 Anterior rhinoscopy
Anterior rhinoscopy alone is inadequate, but remains the first step in examining a patient with these diseases.

6-2-2 Endoscopy
This may be performed without and with decongestion and semi-quantitative scores (457) for polyps, oedema, discharge, crusting and scarring (post-operatively) can be obtained (Table 6.1) at baseline and at regular intervals following therapeutic interventions eg at 3, 6, 9 and 12 months. This has a high inter-rater concordance (489). A number of staging systems for polyps have been proposed (486-489). Johansson showed good correlation between a 0 3 scoring system and their own system in which they estimated the percentage projection of polyps from the lateral wall and the percentage of the nasal cavity volume occupied by polyps. However, they did not find a correlation between size of polyps and symptoms. (Level III).

6-2-3 Nasal cytology, biopsy and bacteriology
Generally cytology has not proved a useful tool in diagnosis of rhinosinusitis although a biopsy may be indicated to exclude more sinister and severe conditions such as neoplasia and the vasculitides.

Several microbiology studies (494-498) [Evidence Level IIb] have shown a reasonable correlation between specimens taken from the middle meatus under endoscopic control and proof puncture leading to the possibility of microbiological confirmation of both the pathogen and its response to therapy (Table 6-2). A meta-analysis showed an accuracy of 87% with a lower end confidence level of 81.3% for the endoscopically directed middle meatal culture when compared with maxillary sinus taps in acute maxillary sinus infection (499).

6-2-4 Imaging
Plain sinus x-rays are insensitive and of limited usefulness for the diagnosis of rhinosinusitis due to the number of false positive and negative results (501-503). Nevertheless it can be usefull to prove ARS in studies.

Transillumination was advocated in the 1970 as an inexpensive and efficacious screening modality for sinus pathology (504). The insensitivity and unspecificity makes it unreliable for the diagnosis of rhinosinusitis (505).

Sinus ultrasound is also insensitive and of limited usefulness for the diagnosis of rhinosinusitis due to the number of false positive and negative results. However, the results in well trained hands are comparable to X-ray in the diagnostics of ARS (41, 506, 507).

<table>
<thead>
<tr>
<th>author</th>
<th>no of samples</th>
<th>type of rhinosinusitis</th>
<th>technique</th>
<th>concordance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold &amp; Tami, 1997 (495)</td>
<td>21</td>
<td>chronic</td>
<td>endoscopic tap (MM) v maxillary aspiration during ESS</td>
<td>85.7%</td>
</tr>
<tr>
<td>Klossek et al, 1998 (494)</td>
<td>65</td>
<td>chronic</td>
<td>endoscopic swab (MM) v maxillary aspiration during ESS</td>
<td>73.8%</td>
</tr>
<tr>
<td>Vogan et al, 2000 (496)</td>
<td>16</td>
<td>acute</td>
<td>endoscopic swab (MM) v maxillary sinus tap</td>
<td>93%</td>
</tr>
<tr>
<td>Casiano et al, 2001 (497)</td>
<td>29</td>
<td>acute (intensive care)</td>
<td>endoscopic tissue culture (MM) v maxillary sinus tap</td>
<td>60%</td>
</tr>
<tr>
<td>Talbot et al, 2001 (498)</td>
<td>46</td>
<td>acute</td>
<td>endoscopic swab (MM) v maxillary sinus tap</td>
<td>90.6%</td>
</tr>
<tr>
<td>Joniau et al 2005 (499)</td>
<td>26</td>
<td>acute</td>
<td>endoscopic swab (MM) v maxillary sinus tap</td>
<td>88.5%</td>
</tr>
</tbody>
</table>

MM: middle meatus; ESS: endoscopic sinus surgery
CT scanning is the imaging modality of choice confirming the extent of pathology and the anatomy. However, it should not be regarded as the primary step in the diagnosis of the condition, except where there are unilateral signs and symptoms or other sinister signs, but rather corroborates history and endoscopic examination after failure of medical therapy. The demonstration of the complex sinonasal anatomy has been regarded as at least as important as confirmation of inflammatory change[519-523]. Considerable ethnic as well as individual differences may be encountered [511]. Many protocols have been described and interest has recently centred on improving definition whilst reducing radiation dose [512].

MRI is not the primary imaging modality in chronic rhinosinusitis and is usually reserved in combination with CT for the investigation of more serious conditions such as neoplasia.

A range of staging systems based on CT scanning have been described using stages 0-4 and of varying complexity [513,517]. The Lund-Mackay system relies on a score of 0-2 dependent upon the absence, partial or complete opacification of each sinus system and of the ostiomeatal complex, deriving a maximum score of 12 per side (Table 3) [490].

Table 6-3. CT scoring system [490]

<table>
<thead>
<tr>
<th>sinus system</th>
<th>left</th>
<th>right</th>
</tr>
</thead>
<tbody>
<tr>
<td>maxillary (0,1,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>anterior ethmoids (0,1,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>posterior ethmoids (0,1,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sphenoid (0,1,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>frontal (0,1,2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ostiomeatal complex (0 or 2 only)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total points</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0-no abnormalities; 1-partial opacification; 2-total opacification.
*0-not occluded; 2-occluded

This has been validated in several studies [518] [Evidence Level IIb] and was adopted by the Rhinosinusitis Task Force Committee of the American Academy of Otolaryngology Head and Neck Surgery in 1996 (5). CT and endoscopic scores correlate well [520] but the correlation between CT findings and symptom scores has generally been shown to be poor and is not a good indicator of outcome [513,519,521] [Evidence Level IIb]. However, Wabnitz and colleagues did find a correlation between VAS and CT score though not between CT score and QoL as measured with the Chronic Sinusitis Score [522]. Bhattacharyya compared three staging systems with the Rhinosinusitis Symptom Inventory [521] and found the Lund score to correlate best with nasal scores but the degree of correlation remained low.

It should be noted that incidental abnormalities are found on scanning in up to a fifth of the ‘normal’ population [64]. A mean LM score of 4.26 in adults [520] and 2.81 in children aged 1-18 years [520] have been reported. In addition for ethical reasons a CT scan is generally only performed post-operatively when there are persistent problems and therefore CT staging or scoring can only be considered as an inclusion criterion for studies and not as an outcome assessment.

6-2-5.4 Nasomucociliary clearance

The use of saccharin, dye or radioactive particles to measure mucociliary transit time has been available for nearly thirty years [528-530]. It allows if altered one to recognize early alterations of rhinosinusual homeostasis Although a crude measure, it has the advantage of considering the entire mucociliary system and is useful if normal (<35 minutes). However, if it is prolonged, it does not distinguish between primary or secondary causes of ciliary dysfunction.

Nasomucociliary clearance has also been measured using a mixture of vegetable charcoal powder and 3% saccharin to demonstrate a delay in patients with CRS as compared to normals, hypertrophied inferior turbinates and septal deviation [520].

6-2-5.2 Ciliary beat frequency

Specific measurements of ciliary activity using a phase contrast microscope with photometric cell [538,531] have been used in a number of studies to evaluate therapeutic success [532,533] [Evidence Level IIb]. The normal range from the inferior turbinate is over 8 Hz but these techniques are available in only a few centres to which children suspected of primary ciliary dyskinesia (PCD) should be referred. The final gold standard of ciliary function involves culture techniques for 6 weeks [534].

6-2-5.3 Electron microscopy

This may be used to confirm the presence of specific inherited disorders of the cilia as in PCD.

6-2-5.4 Nitric oxide

This metabolite found in the upper and lower respiratory tract is a sensitive indicator of the presence of inflammation and ciliary dysfunction, being high with inflammation and low in ciliary dyskinesia. It requires little patient co-operation and is quick and easy to perform using chemiluminescence, but the availability of measuring equipment at present limits its use. The majority of nitric oxide is made in the sinuses (chest < 20 ppb, nose 400-900 ppb, sinuses 20 25 ppm) using an LR 2000 Logan Sinclair nitric oxide gas analyser (values may differ with different machines). Less than 100 ppb from the upper and <10 ppb from the lower respiratory tract would be highly suspicious of PCD. However, whilst very low levels in the nose can indicate primary ciliary dyskinesia, they may also be due to sig-
significant sinus obstruction eg severe CRS with nasal polyps. Conversely elevated levels suggest nasal inflammation but ostiomeatal patency [Evidence Level IIb]. It can potentially be used, as an outcome measure after therapy [Evidence Level IIa] [Evidence Level IIb]. However, some contradictory results on the role of nNO on nasal inflammation have been recently assessed [IIb].

6-2-6 Nasal airway assessment

6-2-6-1 Nasal inspiratory peak flow
This inexpensive, quick and easy test is a useful estimate of airflow which can be performed at home as well as in the hospital setting. However, it measures both sides together and has little direct role in the assessment of chronic rhinosinusitis. It could be used to assess gross reduction in nasal polyps and compares well with rhinomanometry [Evidence Level IIIa]. Normative data is now available in an adult Caucasian population [Evidence Level IIb]. Expiratory peak flow is less often used as mucus is expelled into the mask and the technique may be associated with eustachian dysfunction.

Furthermore in non-allergic, non-infectious perennial rhinitis versus controls, repeated PNIF resulted in a brief but statistically significant increase in nasal airway resistance in the rhinitic patients suggesting a neuronal mechanism [Evidence Level IIb].

6-2-6-2 Rhinomanometry (active anterior and posterior).
The measurement of nasal airway resistance by assessing nasal flow at a constant pressure is again of limited usefulness in chronic rhinosinusitis and with and without nasal polyps but can be useful in confirming that improvement in nasal congestion is the result of reduction in inflammation in the middle meatus rather than mechanical obstruction [Evidence Level IIb].

6-2-6-3 Acoustic rhinometry
The distortion of a sound wave by nasal topography allows quantification of area at fixed points in the nose from which volume may be derived. It can be used to demonstrate subtle changes, both as a result of medical and surgical intervention [Evidence Level IIa].

6-2-6-4 Rhinostereometry
This also measures subtle changes in mucosal swelling, largely in the inferior turbinates [Evidence Level IIb] and is therefore not directly applicable to assessment of chronic rhinosinusitis.

6-2-7 Olfaction

6-2-7-1 Threshold Testing
The estimation of olfactory thresholds by the presentation of serial dilutions of pure odourants such as pm carbinol have been used in a number of studies [Evidence Level IIb].

6-2-7-2 Other quantitative olfactory testing
Scratch and sniff test using patches impregnated with micro-encapsulated odorants are available [Evidence Level IIb] and have been utilised in studies of both chronic rhinosinusitis with and without nasal polyps [Evidence Level IIIa]. A cruder screening test, the Zurich Smell Diskette test may also be used and has the advantage of pictorial representation of the items [Evidence Level IIIa]. Also on a national footing, the Barcelona Smell Test has been developed, comprising 24 odours and has been compared with the Zurich Smell Diskette Test [Evidence Level IIb]. More complex tests exist [Evidence Level IIb] e.g. ‘Sniff ‘n’ sticks’ which limit their application to the research setting. A combined supra-threshold detection and identification test has been devised as a cross-cultural tool in the European population, the results of which are presented in the appendix [Evidence Level III].

Sources of some commercially available and validated olfactory tests are also mentioned in the appendix.

6-2-8 Aspirin and other challenges
Objective experiments to differentiate patient groups according to rhinosinusitis severity or aetiology have been done using nasal provocation with histamine or metacholine which test mucosal hyper-reactivity. The tests can differentiate sub-populations with statistical significance, but because of considerable overlap of results, these tests have not achieved the equivalent position in rhinitis severity evaluations as the corresponding bronchial tests i.e. in asthma diagnosis.

Establishing a diagnosis of aspirin hypersensitivity is important since it provides the patient with a long list of common drugs that must not be taken in view of the risk of a severe reaction. It diagnoses a particular type of asthma and sinonasal disease and allows choice of a specific therapy, i.e. aspirin desensitization.

The oral aspirin challenge test was introduced to clinical practice in the early 1970s [Evidence Level III]. Over the following years it was validated and more frequently used [Evidence Level III]. An inhalation test was introduced in 1977 by S Bianco. This challenge is safer and faster to perform than the oral one, although less sensitive [Evidence Level III]. Contrary to the oral challenge it does not produce systemic reactions. The nasal provocation test was employed in the late 1980s [Evidence Level III]. It is recommended especially for patients with predominantly nasal symptoms and those in whom oral or inhaled tests are contraindicated because of the asthma severity. A negative nasal challenge should be followed by oral challenge. Lysine aspirin, the only truly soluble form of aspirin must be used for both respiratory routes. Test procedures have recently been reviewed in detail [Evidence Level III]. The sensitivity and specificity of the tests are shown in Table 6-4.

Table 6-4. Diagnosis of aspirin sensitivity

<table>
<thead>
<tr>
<th>history ±</th>
<th>challenge sensitivity (%)</th>
<th>specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral</td>
<td>77</td>
<td>93</td>
</tr>
<tr>
<td>bronchial</td>
<td>77</td>
<td>93</td>
</tr>
<tr>
<td>nasal</td>
<td>73</td>
<td>94</td>
</tr>
</tbody>
</table>
6-2-9 Laboratory assessments – C-reactive protein (CRP)
Known since 1930, C-reactive protein is part of the acute phase response proteins. Its principal properties are short half-life (6-8 h), rapid response (within 6 hours) and high levels (x500 normal) after injury. It activates the classical complement pathway, leading to bacterial opsonization. Studies have shown that the CRP value is useful in the diagnosis of bacterial infections. However, among patients suspected of an infectious disease, CRP levels up to 100 mg/l are compatible with all types of infections (bacterial, viral, fungal, and protozoal). Sequential CRP measurements will have greater diagnostic value than a single measurement and changes of the CRP values often reflect the clinical course. When used in general practice the diagnostic value of CRP is found to be high in adults with pneumonia, sinusitis and tonsillitis. Measurement of CRP is an important diagnostic test but the analysis should not stand alone but be evaluated together with the patient’s history and clinical examination. CRP is most reliably used for exclusion of bacterial infection: two values less than 10 mg/l and 8-12 hours apart can be taken to exclude bacterial infection.

6-3 Quality of Life
During the last decade more attention has been paid to not only symptoms but also to patient’s quality of life (QoL). The QoL questionnaires can provide either general (generic) or disease specific health assessment. However, it is of interest that the severity of nasal symptoms or findings do not always correlate with QoL scales. [Evidence Level IIb]. General (generic) health status instruments

6-3-1 General (generic) health status instruments
General (generic) measurements enable the comparison of patients suffering from chronic rhinosinusitis with other patient groups. Of these the Medical Outcomes Study Short Form 36 (SF36) is by far the most widely used and well validated and this has been used both pre- and post-operatively in chronic rhinosinusitis. [Evidence Level IIa,IIb]. It includes eight domains: physical functioning, role functioning physical, bodily pain, general health, vitality, social functioning, role-functioning emotional and mental health. Many other generic measurements are also available. For example EuroQOL, Short Form-12 and Quality of Well-Being Scale have been used in sinusitis studies. The Glasgow Benefit Inventory has also been applied to chronic rhinosinusitis and its treatment as has the EuroQol and McGill pain questionnaires.

6-3-2 Disease specific health status instruments (see also appendix)
Several disease specific questionnaires for evaluation of quality of life in chronic rhinosinusitis have been published. In these questionnaires specific symptoms for rhinosinusitis are included. Such areas include headache, facial pain or pressure, nasal discharge or postnasal drip, and nasal congestion. Disease specific questionnaires are usually used to measure effects within the disease in response to interventions. They are usually more sensitive than general health status instruments.

6-3-2-1 Rhinosinusitis outcome measure (RSOM) and Sinonasal Outcome Test-20
RSOM contains 31 items classified into 7 domains and takes approximately 20 minutes to complete. RSOM has been well validated and allows measurement of symptom severity and importance to the patient. The severity and importance scales, however, make it somewhat difficult for the patient to fill the questionnaire. RSOM-31 has been used in medical studies.

6-3-2-2 Sinonasal Outcome Test 20
A modified instrument referred to as the Sinonasal Outcome Test 20 (SNOT 20) is validated and easy to use. This has been used in a number of studies both medical and surgical. [Evidence Levels Ib, IIb]. However, the lack of the SNOT-20 is that it does no contain questions on nasal obstruction and loss of smell and taste. These questions are included in the SNOT-22 questionnaire which however is not validated. This test was the primary outcome in the largest audit to date of surgery for chronic rhinosinusitis with or without nasal polyps.

6-3-2-3 Sinonasal Outcome Test 16
The Sinonasal Outcome Test 16 (SNOT 16) is also a rhinosinusitis specific quality of life health related instrument.

6-3-2-4 Rhinosinusitis Disability Index (RSDI)
In this 30 item validated questionnaire, the patient is asked to relate nasal and sinus symptoms to specific limitations on daily functioning. It is similar to the RSOM 31 in the types of questions it contains. It can be completed easily and quickly but does not allow the patient to indicate their most important symptoms. However, it does have some general questions similar to the SF-36.

6-3-2-5 Rhinoconjunctivitis quality of life questionnaire (RQLQ)
This is a well-validated questionnaire but specifically focuses on allergy and is not validated in acute and CRS with or without NP. A newer standardized version RQLQ(S) is also available and it has been used for example in a nasal lavage study in chronic rhinosinusitis.

6-3-2-6 RhinoQOL
The RhinoQol is a sinusitis specific instrument which measures symptom frequency, bothersomeness and impact. It can be used for acute and chronic sinusitis.

6-3-2-7 Rhinitis Symptom Utility Index (RSUI)
This consists of ten questions on the severity and frequency of

6-3-1 General (generic) health status instruments
General (generic) measurements enable the comparison of patients suffering from chronic rhinosinusitis with other patient groups. Of these the Medical Outcomes Study Short Form 36 (SF36) is by far the most widely used and well validated and this has been used both pre- and post-operatively in chronic rhinosinusitis. [Evidence Level IIa,IIb]. It includes eight domains: physical functioning, role functioning physical, bodily pain, general health, vitality, social functioning, role-functioning emotional and mental health. Many other generic measurements are also available. For example EuroQOL, Short Form-12 and Quality of Well-Being Scale have been used in sinusitis studies. The Glasgow Benefit Inventory has also been applied to chronic rhinosinusitis and its treatment as has the EuroQol and McGill pain questionnaires.

6-3-2 Disease specific health status instruments (see also appendix)
Several disease specific questionnaires for evaluation of quality of life in chronic rhinosinusitis have been published. In these questionnaires specific symptoms for rhinosinusitis are included. Such areas include headache, facial pain or pressure, nasal discharge or postnasal drip, and nasal congestion. Disease specific questionnaires are usually used to measure effects within the disease in response to interventions. They are usually more sensitive than general health status instruments.

6-3-2-1 Rhinosinusitis outcome measure (RSOM) and Sinonasal Outcome Test-20
RSOM contains 31 items classified into 7 domains and takes approximately 20 minutes to complete. RSOM has been well validated and allows measurement of symptom severity and importance to the patient. The severity and importance scales, however, make it somewhat difficult for the patient to fill the questionnaire. RSOM-31 has been used in medical studies.

6-3-2-2 Sinonasal Outcome Test 20
A modified instrument referred to as the Sinonasal Outcome Test 20 (SNOT 20) is validated and easy to use. This has been used in a number of studies both medical and surgical. [Evidence Levels Ib, IIb]. However, the lack of the SNOT-20 is that it does no contain questions on nasal obstruction and loss of smell and taste. These questions are included in the SNOT-22 questionnaire which however is not validated. This test was the primary outcome in the largest audit to date of surgery for chronic rhinosinusitis with or without nasal polyps.

6-3-2-3 Sinonasal Outcome Test 16
The Sinonasal Outcome Test 16 (SNOT 16) is also a rhinosinusitis specific quality of life health related instrument.

6-3-2-4 Rhinosinusitis Disability Index (RSDI)
In this 30 item validated questionnaire, the patient is asked to relate nasal and sinus symptoms to specific limitations on daily functioning. It is similar to the RSOM 31 in the types of questions it contains. It can be completed easily and quickly but does not allow the patient to indicate their most important symptoms. However, it does have some general questions similar to the SF-36.

6-3-2-5 Rhinoconjunctivitis quality of life questionnaire (RQLQ)
This is a well-validated questionnaire but specifically focuses on allergy and is not validated in acute and CRS with or without NP. A newer standardized version RQLQ(S) is also available and it has been used for example in a nasal lavage study in chronic rhinosinusitis.

6-3-2-6 RhinoQOL
The RhinoQol is a sinusitis specific instrument which measures symptom frequency, bothersomeness and impact. It can be used for acute and chronic sinusitis.

6-3-2-7 Rhinitis Symptom Utility Index (RSUI)
This consists of ten questions on the severity and frequency of
a stuffy or blocked nose, runny nose, sneezing, itching, watery eyes and itching nose or throat. The RSUI is designed for cost-effectiveness studies. The two-week reproducibility of the RSUI was weak, probably reflecting the day to day variability of rhinitis.

6-3-2-8 SN-5
SN-5 is a validated HRQoL instrument that can be used to measure child’s QoL in relation to chronic sinonasal symptoms. The SN-5 domains are sinus infection, nasal obstruction, allergy symptoms, emotional distress, and activity limitations. The information for the questionnaire is given by a child’s caregiver.

6-3-3 Results

6-3-3-1 General (generic) questionnaires
In three generic SF-36 surveys the scores of chronic rhinosinusitis patients were compared to those of a healthy population. The results showed statistically significant differences in seven of eight domains. Two studies have reported that patients with chronic rhinosinusitis have more bodily pain and worse social functioning than for example patients with chronic obstructive pulmonary disease, congestive heart failure, diabetes, or back pain. The EuroQol, SF-36 and McGill pain questionnaire were used to assess 56 patients with refractory CRS in an RCT investigating use of filgrastim. Baseline results confirmed that patient QOL was below normal and suggested an improvement (though not significant) in the actively treated group.

The effect of surgical treatment was studied with generic questionnaires preoperatively and usually 3, 6 or 12 months after the operation. Following endoscopic sinus surgery, the SF-36 questionnaire demonstrated a return to normality in all eight domains six months post-operatively which was maintained at twelve months. In a study by Gliklich and Metson after the sinus surgery significant improvements were found in reduction of the symptoms and medications needed. Significant improvements in general health status were noted in six of eight categories, and most attained near-normative levels. Oral steroid treatment also had a similar effect on HRQoL as surgery as measured by SF-36.

Radenne et al. have studied the QoL of nasal polyposis patients using a generic SF-36 questionnaire. Polyposis impaired the QoL more than for example perennial rhinitis. Treatment significantly improved the symptoms and the QoL of the polyposis patients. FESS surgery on asthmatic patients with massive nasal polyposis improved nasal breathing and QoL, and also the use of asthma medications was significantly reduced.

In a recent study evaluating the effect of radical surgery on QoL, the SF36 and McGill Pain questionnaires were used on 23 patients who underwent Denker’s procedures. Both questionnaires demonstrated improvement in most domains when post-operative results at 1 and 2 years were compared with baseline.

6-3-3-2 Disease specific questionnaires
A disease-specific questionnaire seems to be more sensitive than a general questionnaire in following patients after ethmoid sinus surgery. 76% patients reported relief of the symptoms at least in two of the domains studied after FESS surgery.

Despite similarities in objective disease measures, female patients reported significantly worse QoL scores before and after FESS surgery as measured with RSDI questionnaire.

The RSOM questionnaire was used in a study where the effect of 50 mg prednisolone or placebo daily for 14 days was compared. Significant improvement was noted in total RSOM score with both active and placebo treatments (53% vs. 21%). However, the subset of nasal-specific RSOM scores (6 parameters) showed significant improvement only in the prednisolone group.

In a recent randomised study of patients with chronic rhinosinusitis/nasal polyposis, treatment was either endoscopic sinus surgery or three months of a macrolide antibiotic such as erythromycin. Patients were followed up at 3, 6, 9 and 12 months with a variety of parameters including visual analogue scores of nasal symptoms, SNOT 20, SF-36, nitric oxide measurements of upper and lower respiratory tract expired air, acoustic rhinometry, saccharine clearance test and nasal endoscopy. Ninety patients were randomised, with 45 in each arm and at the end of one year, 38 were available for analysis in the medical arm and 40 in the surgical arm. The study showed that there had been improvement in all subjective and objective parameters but there was no difference between the medical and surgical groups except that total nasal volume as measured by acoustic rhinometry was greater in the surgical group. This study shows the usefulness of objective measurement in confirming subjective impressions.

In a prospective multicentre cohort study of 3128 adults undergoing surgery for chronic rhinosinusitis/nasal polyposis health-related quality of life was compared at 12 and 36 months after surgery using a SNOT-22 questionnaire. This is a non-validated modification of the SNOT-20 by the addition of two questions on nasal blockage and sense of taste and smell and was useful in demonstrating significant improvement following surgery which did not change between 12 and 36 months. However, it was not possible with this outcome measure to show advantage of extended sinus clearance over ‘simple’ polypectomy.
Nowadays there are many generic and disease specific HRQoL questionnaires available to rhinosinusitis studies. However, most of the questionnaires are not yet validated. QoL measurement is quite a new tool evaluating the impact of disease and the efficacy of treatment. In rhinosinusitis studies, when the effect of medical treatment or surgery has been evaluated, QoL has been considered to be an important outcome measurement as distinct from classic rhinosinusitis symptom parameters. In a number of studies, chronic rhinosinusitis has been shown to significantly impair QoL [Level Ib] (465, 572, 584, 591, 592) and this has also been shown to improve significantly with treatment [Level IIb] (479, 486, 585, 597, 593, 594).
7. Management

7-1 Treatment of rhinosinusitis with corticosteroids

The introduction of topically administered glucocorticoids has improved the treatment of upper (rhinitis, nasal polyps) and lower (asthma) airway inflammatory disease. The clinical efficacy of glucocorticoids may depend in part on their ability to reduce airway eosinophil infiltration by preventing their increased viability and activation. Both topical and systemic glucocorticoids may affect the eosinophil function by both directly reducing eosinophil viability and activation (276, 427, 595, 596) or indirectly reducing the secretion of chemotactic cytokines by nasal mucosa and poly epithelial cells (508, 597-599). The potency of these effects is lower in nasal polyps than in nasal mucosa suggesting an induced inflammatory resistance to steroid treatment in chronic rhinosinusitis / nasal polyposis (598, 987).

The biological action of glucocorticoids is mediated through activation of intracellular glucocorticoid receptors (GR) (600), expressed in many tissues and cells (601). Two human isoforms of GR have been identified, GRα and GRβ, which originate from the same gene by alternative splicing of the GR primary transcript (602). Upon hormone binding, GRα enhances anti-inflammatory or represses proinflammatory gene transcription, and exerts most of the anti-inflammatory effects of glucocorticoids through protein-protein interactions between GR and transcription factors, such as AP-1 and NF-κB. The GRβ isoform does not bind steroids but may interfere with the GR* function. There may be several mechanisms accounting for the resistance to the antiinflammatory effects of glucocorticoids, including an overexpression of GRβ or a downexpression of GRα. Increased expression of GRβ has been reported in patients with nasal polyps (602, 604) while downregulation of GRα levels after treatment with glucocorticoids (605, 606) has also been postulated to be one of the possible explanations for the secondary glucocorticoid resistance phenomenon.

The anti-inflammatory effect of corticosteroids could, theoretically, be expected as well in non-allergic (i.e. infectious) as in allergic rhinosinusitis. Tissue eosinophilia is thus also seen in CRS (239).

Indications for corticosteroids in rhinosinusitis:
- Acute rhinosinusitis;
- Prophylactic treatment of acute recurrent rhinosinusitis;
- Chronic rhinosinusitis without NP;
- Chronic rhinosinusitis with NP;
- Postoperative treatment of chronic rhinosinusitis with or without NP.

7-1-1 Acute rhinosinusitis

Most studies on corticosteroids in ARS determine the effect of topical corticosteroids as adjunct therapy to antibiotics. Very recently a study is published in which topical corticosteroid treatment as monotherapy is compared to antibiotics.

7-1-1-1 Topical corticosteroid as monotherapy in acute rhinosinusitis

Recently mometasone furoate (MF) has been used and compared to amoxicillin and placebo in ARS (607). MF 200ug twice daily was significantly superior to placebo and amoxicillin at improving symptom score. Used once daily MF was also superior to placebo but not to amoxicillin. This randomized study was done double-blind, double-dummy on 981 subjects. This is the first study to show topical steroids when used twice daily are effective in ARS as monotherapy and more effective than amoxicillin when used twice daily.

7-1-1-2 Topical corticosteroid as adjunct therapy in acute rhinosinusitis

Qvamborg et al (608) measured the clinical effect of budesonide (BUD)/placebo as a complement to erythromycin and sinus washout in a randomized, double-blind study on patients referred for sinus surgery due to chronic or recurrent acute maxillary sinusitis. Three months treatment was given to 20 subjects in 2 groups, all without NP. Treatment with BUD resulted in a significant improvement of nasal symptoms, facial pain and sensitivity. No significant improvement was seen in mucosal thickening on x-ray. The final clinical outcome did not differ between the groups. No side effects of treatment were noted. It is not possible in this study to distinguish chronic from ARS but all cases were reported to have intermittent “episodes of sinusitis for the last two years”.

In a multicentre study Meltzer et al (609) used flunisolide as adjunctive therapy to amoxicillin clavulanate potassium in patients with ARS or CRS for three weeks and an additional four weeks on only flunisolide. The overall score for global assessment of efficacy was greater in patients treated with flunisolide than placebo (p=0.007) after 3 weeks and after 4 additional weeks p=0.08. No difference was seen on x-ray but inflammatory cells were significantly reduced in flunisolide group compared to placebo.

Barlan et al (610) used BUD as adjunctive therapy to amoxicillin clavulanate potassium for three weeks in a randomized, placebo controlled study in children with ARS. Improvement in cough and nasal secretion were seen at the end of the second week of treatment in the BUD group, p<0.05 for both symptoms compared to placebo. At the end of week three there were no differences between the groups.

Melzer et al (611) gave mometasone furoate (MF) 400 ug to 200
patients and placebo to 207 patients with ARS as adjunctive therapy to amoxicillin/clavulanate potassium for 21 days. Total symptom score and individual symptom scores as congestion, facial pain, headache and rhinorrhea improved significantly, but not postnasal drip in the MF group. The effect was most obvious after 16 days treatment. Improvement on CT was seen in MF group but was not statistically significant. No side effects of treatment were seen.

In a study by Dolor et al (612) 200 ug FP daily was used as adjunctive therapy for 3 weeks (to cefuroxime for 10 days and xylometazoline for 3 days) in a double blind placebo controlled multicentre trial (n=47 in FP group and 48 in control group) in patients with ARS. Time was measured to clinical success. After two weeks, success was seen in 73.9 and 93.5% in placebo and FP group respectively (p=0.009). Time to clinical success was 9.5 and 6.0 days respectively (p=0.01)

Nayak et al (613) compared MF 200 and 400 ug to placebo in 325, 318 and 324 patients with ARS (no NP) as adjunctive therapy to amoxicillin/clavulanate potassium for 21 days treatment. Total symptom score (TSS) was improved from day 4 and at the end of the study (21 days) in both MF groups compared to placebo. Improvement compared to the situation before treatment was 50 and 51% for MF groups and 44% in placebo group, p<0,017. Individual nasal symptom scores such as nasal congestion, facial pain, rhinorrhea and postnasal drip improved in both MF-groups compared to placebo. CT was improved, but not statistically significant in MF groups compared to placebo. No side effects of treatment were seen.

All these studies were on study groups where intranasal steroids have been used as an additional treatment to antibiotics. Only the Meltzer study compares topical corticosteroid as monotherapy to antibiotics. The findings by Meltzer et al (607) are of great interest but one might argue that objective references of bacterial infection were lacking (sinus aspirates for culture) as well as CT or x-ray. There might be a high number of viral infections but the results are in favour of a more restricted attitude to antibiotics in ARS. The evidence level as monotherapy and as adjunctive therapy to systemic antibiotics is I.

7-1-1-3 Oral corticosteroid as adjunct therapy in acute rhinosinusitis Gehanno et al (614) tried 8 mg methylprednisolone three times daily for 5 days as adjunctive therapy to 10 days treatment with amoxicillin clavulanate potassium in patients with ARS (criteria: symptoms < 10 days, craniofacial pain, purulent nasal discharge with purulent drainage from the middle meatus, opacities of the sinuses in x-ray or CT scan) in a placebo controlled study. No difference was seen in therapeutic outcome at day 14 between the groups (n=417) but at day 4 there was a significant reduction of headache and facial pain in the steroid group.

In a multicentre study Klossek et al (615) assessed in a double

<table>
<thead>
<tr>
<th>study</th>
<th>drug</th>
<th>antibiotic</th>
<th>number</th>
<th>effect</th>
<th>X-ray</th>
<th>level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qvarnberg, 1992 (608)</td>
<td>budesonide</td>
<td>erythromycin</td>
<td>20</td>
<td>significant effect on nasal symptoms, facial pain and sensitivity; final clinical outcome did not differ</td>
<td>mucosal thickening = no effect</td>
<td>Ib</td>
</tr>
<tr>
<td>Meltzer, 1993 (695)</td>
<td>flunisolide</td>
<td>amox/clav</td>
<td>180</td>
<td>significant effect: overall score for global assessment of efficacy was greater in the group with flunisolide</td>
<td>no effect on x-ray</td>
<td>Ib</td>
</tr>
<tr>
<td>Barlan, 1997 (638)</td>
<td>budesonide</td>
<td>amox/clav</td>
<td>89 (children)</td>
<td>improvement in cough and nasal secretion seen at the end of the second week of treatment</td>
<td>not done</td>
<td>Ib</td>
</tr>
<tr>
<td>Meltzer, 2000 (610)</td>
<td>mometasone furoate</td>
<td>amox/clav</td>
<td>407</td>
<td>significant effect in congestion, facial pain, headache and rhinorrhea. No significant effect in postnasal drip</td>
<td>no statistical difference in CT outcome</td>
<td>Ib</td>
</tr>
<tr>
<td>Dolor, 2001 (622)</td>
<td>fluticasone propionate</td>
<td>cefuroxime axetil</td>
<td>95</td>
<td>significant effect. Effect measured as clinical success depending on patients self-judgment of symptomatic improvement</td>
<td>not done</td>
<td>Ib</td>
</tr>
<tr>
<td>Nayak, 2002 (622)</td>
<td>mometasone furoate</td>
<td>amox/clav</td>
<td>967</td>
<td>total symptom score (TSS) was improved (nasal congestion, facial pain, rhinorrhea and postnasal drip)</td>
<td>no statistical difference in CT outcome</td>
<td>Ib</td>
</tr>
<tr>
<td>Meltzer, 2005 (617)</td>
<td>mometasone furoate</td>
<td></td>
<td>981</td>
<td>significant effect on total symptoms score, nasal congestion, facial pain, sinus headache: significantly superior to placebo and amoxicillin</td>
<td>not done</td>
<td>Ib</td>
</tr>
</tbody>
</table>
blind, randomised study in parallel groups the efficacy and toler-
ance to prednisone administered for 3 days in addition to cefpo-
doxtim in adult patients presenting with an acute bacterial rhi-
nosinusitis (proven by culture) with severe pain. The assess-
ments made during the first 3 days of treatment showed a statisti-
cally significant difference in favour of the prednisone group
regarding pain, nasal obstruction and consumption of paracetam-
ol. There was no difference between the two groups after the
end of the antibiotic treatment. The tolerance measured
throughout the study was comparable between the two groups.

Pain is significantly relieved during treatment with prednisone
but after 10 days on antibiotics there was no difference
between the two groups. Evidence level for steroids as pain
reliever: I but there is no evidence for a more positive long
term outcome compared to placebo.

7-1-2 Prophylactic treatment of recurrent episodes of acute rhinosi-
inusitis

In a study by Puhakka et al. (616) FP (200 μg four times daily) or
placebo were used for 6 days in 199 subjects with an acute
common cold, 24-48 hours after onset of symptoms to study
the preventive effects of FP on risk for development of ARS.
Frequency of sinusitis at day 7 in subjects positive for rhi-
navirus, based on x-ray, was 18.4% and 34.9% in FP and place-
bo group respectively (p=0.07) thus indicating a non-significant
effect of FP.

Cook et al. randomized, as a continuation of an acute episode
of rhinosinusitis, patients with at least 2 episodes of rhinosi-
inusitis in the previous 6 months or at least 3 episodes in the
last 12 months for a double blind, placebo-controlled study
with FP, 200 mcg QD. 227 subjects were included. Additionally
cefuroxime axetil 250 mg BID was used for the first 20 days.
39% had a recurrence in the placebo group and 25% in the FP
group (p=0.016) during the seven week follow-up period. Mean
number of days to first recurrence was 97.5 and 116.6 respec-
tively (p=0.011) (617).

There is very low evidence for a prophylactic effect of nasal
corticosteroids to prevent recurrence of ARS episodes.

7-1-3 Chronic rhinosinusitis without nasal polyps

7-1-3-1 Topical corticosteroid chronic rhinosinusitis without
nasal polyps

Parikh et al. (618) performed a randomized, double blind, place-
bo-controlled trial on patients with chronic RS on two groups
with respectively 9 and 13 subjects (2 subjects in each group
with nasal polyps) to test fluticasone propionate for 16 weeks.
No significant improvement was seen, as measured by symp-
tom scores, diary card, acoustic rhinometry or endoscopy. No
side effects were seen in either group.

In another double blind placebo controlled study on patients
with CRS (without NP) with allergy to house dust mite and
who had recently been operated on but still had signs of
chronic RS, 256 ug budesonide (BUD) or placebo was instilled
into the maxillary sinus once a day through a sinus catheter for
three weeks (619). A regression of more than 50% of total nasal
symptom scores was seen in 11/13 in the BUD group and 4/13
in placebo group. The effect was more long term in BUD
group, i.e. 2-12 months compared with less than 2 months in
the placebo group (who had experienced an effect during the
catheter period). A significant decrease was also seen in BUD
group after three weeks treatment for CD-3, eosinophils and
cells expressing IL-4 and IL-5.

In a study by Cuenant et al. (620) trixocortol pivalate was given as
endonasal irrigation in combination with neomycin for 11 days
in a double blind placebo controlled in patients with chronic
RS. Maxillary ostial patency and nasal obstruction was signifi-
Significantly improved in the tixocortol group compared to placebo. Patients with CRS without allergy responded better to topical steroids than those with allergy.

Sykes et al (621) looked on 50 patients with mucopurulent CRS and allocated them to 3 groups for local treatment with sprays with either dexamethasone + tramazoline + neomycin/dexamethasone + tramazoline/placebo 4 times daily for 4 weeks and evaluation was performed double blinded. Treatment in both active groups was more effective than placebo (discharge, blockage and facial pain and x-ray) but no difference was seen with the addition of neomycin to dexamethasone.

A recent multicentre double-blinded placebo-controlled randomised trial of 134 patients with CRS without nasal polyps treated with topical budesonide for 20 weeks showed significant improvement in a number of parameters including symptom score and nasal inspiratory peak flow (622). Quality of life assessments did not change however.

There is some evidence for an effect of topical intranasal steroids in CRS, particularly with intramaxillary instillation of steroids. No side effects were seen, including no increased signs of infection with intranasal corticosteroid treatment.

7-1-3-2 Oral corticosteroid chronic rhinosinusitis without nasal polyps
There are no data showing efficacy of oral corticosteroids in chronic rhinosinusitis without nasal polyps.

7-1-4 Chronic rhinosinusitis with NP
In studies on the treatment of NP, it is of value to look separately at the effect on rhinitis symptoms associated with polyposis and the effect on the size of nasal polyps per se. Only placebo controlled studies will be referred to.

7-1-4-1 Topical corticosteroid chronic rhinosinusitis with nasal polyps
Mygind et al (623) showed that beclomethasone dipropionate (BDP) 400ug daily for three weeks reduced nasal symptoms in 19 patients with NP compared to a control group of 16 patients treated with placebo aerosol. Reduction of polyp size did not differ in this short treatment study.

In another study with BDP 400 ug daily for four weeks (double blind, cross over with 9 and 11 subjects in each group), Deuschl and Drettner (624) found a significant improvement in nasal symptoms of blockage and nasal patency as measured with rhinomanometry. Difference in size of polyps was, however, not seen.

Holopainen et al (625) showed in a randomized, double blind, parallel, placebo controlled study with 400 mcg budesonide (n=19) for 4 months that total mean score and nasal peak flow were in favour for budesonide. Polyps also decreased in size in the budesonide group.

Tos et al (626) also showed that budesonide in spray (128 mcg) and powder (140 mcg) were both significantly more effective than placebo (multicentre) concerning reduction of polyp size, improvement of sense of smell, reduction of symptom score and overall assessment compared to placebo.

Vendelo Johansen (627) tested BUD 400ug daily compared to placebo for three months in a multicentre, randomized, double blind study in patients with small and medium-sized eosinophilic nasal polyps (grade 1-2). Polyps decreased in the BUD group while an increase was seen in the placebo group. The difference in polyp score between the groups was significant (p<0.01). Both nasal symptoms (blockage, runny nose, sneezing) and peak nasal inspiratory flow (PNIF) improved significantly in BUD group.

Lildholt et al (629) compared BUD 400 or 800 ug daily with place-
bo for four weeks (n=40, 34, 42 respectively). Symptom relief was significant in both BUD groups compared to placebo but there was no significant difference in polyp size between the groups as measured by the investigators. Peak nasal inspiratory flow (PNEF) was significantly improved in the BUD groups and increased during the study. No difference was noted for sense of smell. No dose-response correlation was seen.

Holmberg et al\(^{(629)}\) used FP 400ug, BDP 400ug and placebo for 26 weeks in a double blind, parallel group, single centre study. Patients with bilateral polyps, grade 1-2, n=19, 18 and 18 respectively in each group were investigated. There was a significant improvement in symptoms and PNIF for both steroid groups compared to placebo. No statistically significant differences between the two active groups were seen.

Keith et al\(^{(630)}\) compared fluticasone propionate (FP) nasal drops (FPND) 400 ug daily to placebo in a placebo controlled, parallel-group, multicentre, randomized study (n=52 in both groups) for 12 weeks. Polyp reduction was not significant but nasal blockage and PNIF were significantly improved in FPND group. A few more cases of epistaxis in the FPND group were seen. No other side effects were reported.

Penttila et al\(^{(631)}\) tried FPND 400 and 800 ug and placebo daily for 12 days in a randomized, double-blind, multi-centre study for a dose-response analysis. Nasal symptoms were significantly reduced in both FP groups as well as PNIF. 800 ug FP improved PNIF more than the lower dose and reduced polyp size significantly (p<0.01) which was not seen in the 400 ug group.

Lund et al\(^{(632)}\) compared FP 400 ug, BDP 400ug and placebo (n=10, 10, 9) for 12 weeks in a double-blind, randomized, parallel-group, single-centre study. Polyp score was significantly improved in FP group. Nasal cavity volume measured with acoustic rhinometry improved in both active groups. Morning PNIF improved in both active groups but was quicker with FP. Overall rhinitis symptoms did not differ statistically between the groups after 12-weeks treatment.

Hadfield et al\(^{(633)}\) looked at treatment of NP in patients with cystic fibrosis in a randomised, double-blind, placebo controlled study. Betamethasone drops were used in 46 patients for 6 weeks out of which 22 completed the course. There was a significant reduction in polyp size in the group treated with betamethasone but no significant difference was seen in the placebo group.

Mometasone furoate (MF) has been tried in a number of studies as reported by Small et al\(^{(634)}\). 354 subjects were divided in three groups to have either MF 200 ug once or twice daily or placebo for four months. In both MF groups significant polyp reduction was seen as well as improvement in loss of smell, rhinorrhea and congestion. Twice daily was superior to once daily regarding congestion/obstruction and both doses significantly increased PNIF.

A comparable study was performed by Stjärne et al\(^{(635)}\), finding 200 ug twice daily had a significant effect in reducing polyp size while 200ug once daily was not statistically effective compared to placebo. Both MF doses significantly improved congestion/obstruction as well as PNIF but no improvement in sense of smell was seen after four months.

A third study also by Stjärne et al\(^{(636)}\) compared in 298 subjects with mild-to-moderate nasal polyposis, treatment with mometasone furoate nasal spray (MFNS) 200 ug once daily (QD) in the morning during 16 weeks with placebo. They found a significantly decrease in nasal congestion, polyp size, and improved sense of smell, peak nasal inspiratory flow and quality of life.

Aukema et al.\(^{(637)}\) sought to investigate in a 12-week, double-blind, placebo-controlled study whether treatment with fluticasone propionate nasal drops (FPNDs) can reduce the need for surgery, as measured by signs and symptoms of nasal polyposis and chronic rhinosinusitis, in fifty-four patients with severe nasal polyposis/chronic rhinosinusitis who were on the waiting list for functional endoscopic sinus surgery (FESS). FESS was no longer required in 13 of 27 patients treated with FPNDs versus 6 of 27 in the placebo group (P <.05). Six patients from the placebo group dropped out versus 1 from the FPND group. Symptoms of nasal obstruction, rhinorrhea, postnasal drip, and loss of smell were reduced in the FPND group (P <.05). Peak nasal inspiratory flow scores increased significantly (P <.01).

Topical corticosteroids sprays have a documented effect on bilateral NP and also on symptoms associated with NP such as nasal blockage, secretion and sneezing but the effect on the sense of smell is not high. There is a high evidence level (Ia) for effect on polyp size and nasal symptoms associated with nasal polyposis. For individual symptoms blockage responds best to corticosteroids but improvement in sense of smell is not so obvious. Nasal drops are more effective than nasal spray and have a significant positive effect on smell (Ib).

7.1-4.2 Side effects of topical corticosteroid for chronic rhinosinusitis with nasal polyps
Intranasal administration of corticosteroids is associated with minor nose bleeding in a small proportion of recipients. This effect has been attributed to the vasoconstrictor activity of the corticosteroid molecules, and is considered to account for the very rare occurrence of nasal septal perforation\(^{(638)}\). However, it should be remembered that minor nose bleeds are common in the population, occurring in 16.5% of 2197 women aged 50-64 years over a one year study\(^{(639)}\). Nasal biopsy studies do not show any detrimental structural effects within the nasal mucosa.
Supplement 20

Much attention has focused on the systemic safety of intranasal application. The systemic bioavailability of intranasal corticosteroids varies from <1% to up to 40-50% and influences the risk of systemic adverse effects. Potential adverse events related to the administration of intranasal corticosteroids are effects on growth, ocular effects, effects on bone, and on the hypothalamic-pituitary-adrenal axis. Because the dose delivered topically is small, this is not a major consideration, and extensive studies have not identified significant effects on the hypothalamic-pituitary-adrenal axis with continued treatment. A small effect on growth has been reported in one study in children receiving a standard dosage over 1 year. However, this has not been found in prospective studies with the intranasal corticosteroids that have low systemic bioavailability and therefore the judicious choice of intranasal formulation, particularly if there is concurrent corticosteroid inhalation for asthma, is prudent.

### Table 7-5. Treatment with nasal corticosteroids in chronic rhinosinusitis with nasal polyposis

<table>
<thead>
<tr>
<th>Study</th>
<th>Drug</th>
<th>Number</th>
<th>Treatment Time (weeks)</th>
<th>Effect on Nasal Symptoms (stat sig)</th>
<th>Objective Measures (stat sig)</th>
<th>Effect on Polyps</th>
<th>Level of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mygind, 1975</td>
<td>BDP</td>
<td>35</td>
<td>3</td>
<td>Total symptom score*</td>
<td>N.S.</td>
<td></td>
<td>Ib</td>
</tr>
<tr>
<td>Deuschl, 1977</td>
<td>BDP</td>
<td>20</td>
<td>2x4 weeks</td>
<td>Blockage*</td>
<td>Rhinomanometry*</td>
<td>N.S.</td>
<td>Ib</td>
</tr>
<tr>
<td>Holopainen, 1982</td>
<td>Bud</td>
<td>19</td>
<td>16</td>
<td>Total symptom score*</td>
<td>Nasal peak flow*</td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Vendelo Johansen, 1993</td>
<td>Bud</td>
<td>91</td>
<td>12</td>
<td>Blockage* Sneezing* Secretion* Sense of smell N.S.</td>
<td>Nasal peak inspiratory flow*</td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Lilholt, 1995</td>
<td>Bud</td>
<td>116</td>
<td>4</td>
<td>Blockage* Sneezing* Secretion* Sense of smell N.S.</td>
<td>Nasal peak expiratory flow*</td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Holmberg, 1997</td>
<td>FP/BDP</td>
<td>55</td>
<td>26</td>
<td>Over all assessment*</td>
<td>Nasal peak inspiratory flow*</td>
<td>Yes in BDP</td>
<td>Ib</td>
</tr>
<tr>
<td>Tos., 1998</td>
<td>Bud</td>
<td>138</td>
<td>6</td>
<td>Total symptom score* Sense of smell*</td>
<td></td>
<td></td>
<td>Ib</td>
</tr>
<tr>
<td>Lund, 1998</td>
<td>FP/BDP</td>
<td>29</td>
<td>12</td>
<td>Blockage* Rhinitis N.S.</td>
<td>Nasal peak inspiratory flow* Acoustic rhinometry*</td>
<td>Yes FP</td>
<td>Ib</td>
</tr>
<tr>
<td>Keith, 2000</td>
<td>FPND</td>
<td>104</td>
<td>12</td>
<td>Blockage* Rhinitis* Sense of smell N.S.</td>
<td>Nasal peak inspiratory flow* Olfactory test N.S.</td>
<td>N.S.</td>
<td>Ib</td>
</tr>
<tr>
<td>Penttilä, 2000</td>
<td>FP</td>
<td>142</td>
<td>12</td>
<td>Blockage* Rhinitis* Sense of smell N.S.</td>
<td>Nasal peak inspiratory flow* Olfactory test*</td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Hadfield, 2000</td>
<td>Betametasone</td>
<td>46 CF</td>
<td>6</td>
<td>N.S.</td>
<td></td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Aukema 2005</td>
<td>Fluticasone propionate nasal drops</td>
<td>54</td>
<td>12</td>
<td>Nasal obstruction* Rhinorrhea* Postnasal drip* and loss of smell*</td>
<td>Nasal peak inspiratory flow* CT scan</td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Small et al 2005</td>
<td>Mometasone</td>
<td>354</td>
<td>16</td>
<td>Obstruction* Loss of smell* Rhinorrhea*</td>
<td>Nasal peak inspiratory flow*</td>
<td>Yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Stjärne et al 2006</td>
<td>Mometasone</td>
<td>310</td>
<td>16</td>
<td>Obstruction* Loss of smell N.S. Rhinorrhea*</td>
<td>Nasal peak inspiratory flow*</td>
<td>Yes in BDP</td>
<td>Ib</td>
</tr>
<tr>
<td>Stjärne et al 2006</td>
<td>Mometasone</td>
<td>298</td>
<td>16</td>
<td>Obstruction* Loss of smell * Rhinorrhea* QOL</td>
<td>Nasal peak inspiratory flow*</td>
<td>Yes</td>
<td>Ib</td>
</tr>
</tbody>
</table>

with long-term administration of intranasal corticosteroids. Much attention has focused on the systemic safety of intranasal application. The systemic bioavailability of intranasal corticosteroids varies from <1% to up to 40-50% and influences the risk of systemic adverse effects. Potential adverse events related to the administration of intranasal corticosteroids are effects on growth, ocular effects, effects on bone, and on the hypothalamic-pituitary-adrenal axis. Because the dose delivered topically is small, this is not a major consideration, and extensive studies have not identified significant effects on the hypothalamic-pituitary-adrenal axis with continued treatment. A small effect on growth has been reported in one study in children receiving a standard dosage over 1 year. However, this has not been found in prospective studies with the intranasal corticosteroids that have low systemic bioavailability and therefore the judicious choice of intranasal formulation, particularly if there is concurrent corticosteroid inhalation for asthma, is prudent. In summary, intranasal corticosteroids are highly effective; nevertheless, they are not completely devoid of systemic effects. Thus, care has to be taken, especially in children, when long-term treatments are prescribed.

7-1-4-3 Systemic corticosteroids in chronic rhinosinusitis with nasal polyps

Traditionally systemic steroids have been used in patients with NP although no placebo-controlled studies or dose-effect stud-
ies have supported the concept. The clinical acceptance that systemic steroids have a significant effect on NP are supported by open studies where a single injection of 14 mg betametason has been compared with snare polypectomy surgery. In these studies, effects are seen on nasal polyp size, nasal symptom score and nasal expiratory peak flow but it is difficult to differentiate the effect of systemic steroids from that of topical treatment since both treatments were used at the same time. The control groups underwent surgery during the study period.

In another open study, oral prednisolone was given in doses of 60 mg to 25 patients with severe polyposis for four days and for each of the following 12 days the dose was reduced by 5 mg daily. Antibiotics and antacids were also given. 72% experienced a clear improvement due to involution of polyps and in 52% a clear improvement was seen on CT. In particular nasal obstruction and the sense of smell were reported to improve. Out of 22 subjects treated, 10 were polyp free based on anterior rhinoscopy 2 weeks –2 months after therapy.

Damm et al. showed a good effect with combined treatment using topical steroids (budesonide, unknown doses) and oral treatment with fluocortolone 560 mg or 715 mg in 2 different groups of patients with 20 severe cases of CRS with NP. This study was not controlled. A large improvement of symptoms was seen (80%) and improvement on MRI (>30% reduction of MRT-pathology) was observed in 50%.

Recently, however, two well designed studies have shown effect of systemic steroids in NP. Benitez et al. performed a randomized placebo controlled study with prednisone for two weeks (30 mg 4 days followed by a 2-day reduction of 5 mg). After two weeks on prednisone or placebo, the prednisone group continued for ten weeks on intranasal BUD. After two weeks treatment a significant polyp reduction was seen, several symptoms improved and anterior rhinomanometry improved compared to the placebo group. After 12 weeks a significant reduction of CT-changes were seen in the steroid treated group.

In a double-blind randomized, placebo controlled study, Hissaria et al. compared 50 mg prednisolone daily for 14 days with placebo. A significant improvement was found in nasal symptoms (obstruction, secretion, sneezing, sense of smell), endoscopic findings of polyp size and MRI scores supporting the effect of systemic steroids on NP.

There is no study available on depot injection of corticosteroids or local injection into polyps or the inferior turbinate. These types of treatment are actually obsolete, because of the risk of fat necrosis at the site of the injection or blindness following endonasal injection.

Studies on systemic steroids in NP has recently been published giving support to the clinical impression that they are effective after two weeks use in doses acceptable for a majority of patients. As well as symptom relief, an effect on polyp size and MRI changes are seen. Evidence level: Ib.

7-1-4-4 Side effects of systemic corticosteroids in chronic rhinosinusitis with nasal polyps
The anti-inflammatory effects of corticosteroids cannot be separated from their metabolic effects as all cells use the same glucocorticoid receptor; therefore when corticosteroids are prescribed measures should be taken to minimize their side effects. Clearly, the chance of significant side effects increases with the dose and duration of treatment and so the minimum dose necessary to control the disease should be given.

As a guide for oral treatment, the approximate equivalent doses of the main corticosteroids in terms of their glucocorticoid (or anti-inflammatory) properties are listed below.

7-1-5 Postoperative treatment with topical corticosteroids for chronic rhinosinusitis with NP to prevent recurrence of polyps
There are a couple of studies on nasal steroids used after surgical resection of polyps. Drettner et al. used flunisolide 200 μg daily for 3 months in a double-blind, placebo controlled study with 11 subjects in both groups. A statistically significant effect was seen on nasal symptoms but not on polyp score.

Virolainen and Puhakka tested 400 μg BDP in 22 patients

<table>
<thead>
<tr>
<th>study</th>
<th>drug</th>
<th>number</th>
<th>dose/time</th>
<th>effect symptoms</th>
<th>effect polyps</th>
<th>level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lildholt, 1988 (641)</td>
<td>betametamethasone/BDP</td>
<td>53</td>
<td>?/52w</td>
<td>yes</td>
<td>yes</td>
<td>III</td>
</tr>
<tr>
<td>Lildholt, 1997 (493)</td>
<td>betametamethasone/budesonide</td>
<td>16</td>
<td>14mg/52w</td>
<td>yes</td>
<td>yes</td>
<td>III</td>
</tr>
<tr>
<td>van Camp, 1994 (492)</td>
<td>prednisolone 60 mg</td>
<td>25</td>
<td>2 weeks</td>
<td>72%</td>
<td>yes (10/22)</td>
<td>III</td>
</tr>
<tr>
<td>Lildholt, 1997 (493)</td>
<td>betametamethasone/budesonide</td>
<td>16</td>
<td>14mg/52w</td>
<td>yes</td>
<td>yes</td>
<td>III</td>
</tr>
<tr>
<td>Damm, 1999 (493)</td>
<td>budesonide + fluocortolone</td>
<td>20</td>
<td>?</td>
<td>yes</td>
<td>?</td>
<td>III</td>
</tr>
<tr>
<td>Benitez, 2006 (644)</td>
<td>prednisone + Budesonide</td>
<td>84</td>
<td>2 weeks/10 weeks</td>
<td>yes</td>
<td>yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Hissaria, 2006 (756)</td>
<td>prednisolone</td>
<td>41</td>
<td>50mg/2 weeks</td>
<td>yes</td>
<td>yes</td>
<td>Ib</td>
</tr>
</tbody>
</table>
and placebo in 18 in a randomized, double blind study. After one year of treatment 54% in BDP group were polyp free compared to 13% in the placebo group. No statistics were given. 86% in BDP group were free of nasal symptoms compared to 60% in placebo group.

Karlsson and Rundkrantz (648) treated 20 patients with BDP and 20 were followed with no treatment for NP (no placebo treatment) for 2.5 years. BDP was given 400 μg daily for the first month and then 200 μg daily. There was a statistically significant difference between the groups after 6 months in favour of BDP, which increased during the study period of 30 months.

Dingsor et al. (649) used flunisolide 2x25 μg on both sides twice daily (200 μg) after surgery in a placebo controlled study for 12 months (n=41). Flunisolide was significantly better than placebo at both 6 and 12 months both with respect to number and size of polyp recurrence.

Hartwig et al. (650) used budesonide 6 months after polypectomy in a double blind parallel-group on 73 patients. In the budesonide group, polyp scores were significantly lower than controls after 3 and 6 months. This difference was only significant for patients with recurrent polyposis and not for those operated on for the first time.

Dijkstra et al. (651) performed a double-blind placebo-controlled randomized study in 162 patients with CRS with or without nasal polyps after FESS following failure of nasal steroid treatment. Patients were randomized and given FPANS 400 microg b.i.d., FPANS 800 μg b.i.d. or placebo b.i.d. for the duration of 1 year after FESS combined with peri-operative systemic corticosteroids. No differences in the number of patients withdrawn because of recurrent or persistent diseases were found between the patients treated with FPANS and patients treated with placebo. Also no positive effect was found for FPANS compared with placebo in several subgroups such as patients with nasal polyps, high score at FESS or no previous sinus surgery.

Rowe Jones et al (652) studied a similar group of one hundred nine patients studied prospectively for 5 years postoperatively. Seventy two patients attended the 5 year follow-up visit. The patients were entered into a randomised, stratified, prospective, double-blind placebo controlled study of fluticasone propionate aqueous nasal spray 200μg twice daily, commencing 6 weeks after FESS. The change in overall visual analogue score was significantly better in the FPANS group at 5 years. The changes in endoscopic oedema and polyp scores and in total nasal volumes were significantly better in the FPANS group at 4 years but not 5 years. Last value carried forward analysis demonstrated that changes in endoscopic polyp score and in total nasal volume was significantly better in the FPANS group at 5 years. Significantly more prednisolone rescue medication courses were prescribed in the placebo group.

Postoperative effect on recurrence rate of NP after polypectomy with intranasal steroids is well documented and the evidence level is Ib. Two studies describe the effect after FESS in a group of patients who underwent FESS after inadequate response to at least three months topical corticosteroid treatment. The studies show conflicting results though the reasons are not clear.

7-1-6 Side-effects of corticosteroids

Table 7-7. Equivalence table of oral corticosteroids

<table>
<thead>
<tr>
<th>Corticosteroid</th>
<th>Equivalent Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Betamethasone</td>
<td>0.75 mg</td>
</tr>
<tr>
<td>Cortisone acetate</td>
<td>25 mg</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>0.75 mg</td>
</tr>
<tr>
<td>Hydrocortisone</td>
<td>20 mg</td>
</tr>
<tr>
<td>Methylprednisolone</td>
<td>4 mg</td>
</tr>
<tr>
<td>Prednisolone</td>
<td>5 mg</td>
</tr>
<tr>
<td>Prednisone</td>
<td>5 mg</td>
</tr>
<tr>
<td>Triamcinolone</td>
<td>4 mg</td>
</tr>
</tbody>
</table>

Table 7-8. Nasal corticosteroids in the post operative treatment of persitent rhinosinusitis to prevent recurrences of NP

<table>
<thead>
<tr>
<th>Study</th>
<th>Drug</th>
<th>Number</th>
<th>Treatment time (weeks)</th>
<th>Effect on nasal symptoms</th>
<th>Effect on polyp recurrence</th>
<th>Level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virolainen, 1980</td>
<td>BDP</td>
<td>40</td>
<td>52</td>
<td>blockage</td>
<td>anterior rhinoscopy - yes</td>
<td>IV</td>
</tr>
<tr>
<td>Drettner, 1982</td>
<td>flunisolide</td>
<td>22</td>
<td>12</td>
<td>total nasal score (blockage, secretion sneezing)*</td>
<td>anterior rhinoscopy N.S.</td>
<td>Ib</td>
</tr>
<tr>
<td>Karlsson, 1982</td>
<td>BDP</td>
<td>40</td>
<td>120</td>
<td>not described</td>
<td>anterior rhinoscopy - yes</td>
<td>IIa</td>
</tr>
<tr>
<td>Dingsor, 1985</td>
<td>flunisolide</td>
<td>41</td>
<td>52</td>
<td>blockage* sneezing*</td>
<td>anterior rhinoscopy - yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Hartwig, 1988</td>
<td>BUD</td>
<td>73</td>
<td>26</td>
<td>blockage N.S.</td>
<td>anterior rhinoscopy - yes</td>
<td>Ib</td>
</tr>
<tr>
<td>Dijkstra 2004</td>
<td>fluticasone propionate</td>
<td>162</td>
<td>52</td>
<td>not seen</td>
<td>nasal endoscopy not seen.</td>
<td>Ib</td>
</tr>
<tr>
<td>Rowe-Jones 2005</td>
<td>fluticasone propionate</td>
<td>109</td>
<td>5 years</td>
<td>overall visual analogue score</td>
<td>endoscopic polyp score and in total nasal volume</td>
<td>Ib</td>
</tr>
</tbody>
</table>
The safety of nasal and oral corticosteroids has been the subject of concern in medical literature since many patients with chronic sinus disease are prescribed these drugs due to their good efficacy. Suppression of the hypothalamic-pituitary-adrenal axis, osteoporosis or changes in bone mineral density, growth retardation in children, cataracts and glaucoma have been reported to be the main adverse effects of corticosteroid treatment. In relation to adverse effects of corticosteroids, it is obvious that a clear distinction needs to be made between nasal and oral corticosteroids.

Nasal corticosteroid treatment represents one of the long-term treatment modalities in patients with chronic sinus disease. It is well established that absorption into the systemic circulation takes place after nasal administration of corticosteroids. However, several factors influence the systemic absorption, like the molecular characteristics of the corticosteroid, the prescribed dose, the mode of delivery and the severity of the underlying disease. There is insufficient evidence from the literature to relate the use of nasal corticosteroids at licensed doses to changes in bone mineral biology, cataract and glaucoma. Adrenal suppression may occur with some nasal corticosteroids at licensed doses, but the clinical relevance remains uncertain. Overuse of nasal corticosteroids may be responsible for adrenal insufficiency and decrease in bone mineral density. Of note, inhaled corticosteroids are the mainstay of treatment for children and adults with asthma and are more often associated with systemic side effects than the nasal route of treatment for rhinosinusitis.

Nasal corticosteroid-induced septal perforation is rarely described in literature. Whether septal perforation relates to repeated traumas of the nasal mucosa and septal cartilage by the nasal device, to the underlying nasal disorder for which corticosteroids were prescribed or to a direct adverse effect of the steroid used, remains unclear. Short treatment with oral corticosteroids is effective in chronic rhinosinusitis with nasal polyps. It is obvious that repeated or prolonged use of oral corticosteroids is associated with a significantly enhanced risk of the above mentioned side effects.

7-2 Treatment of rhinosinusitis with antibiotics

7-2-1 Acute community acquired rhinosinusitis

Although more than 2000 studies on the antibiotic treatment of ARS have already been published, only 49, involving 13,660 participants, meet the Cochrane Board criteria for placebo control, statistical analysis, sufficient sample sizes, and the description of clinical improvements or success rates.

Primary outcomes were:
- clinical cure;
- clinical cure or improvement.

Secondary outcomes were:
- radiographic improvement;
- relapse rates;
- dropouts due to adverse effects.

Major comparisons were antibiotic versus control (n=3); newer, non-penicillin antibiotic versus penicillin class (n=10); and amoxicillin-clavulanate versus other extended spectrum antibiotics (n=17), where n is the number of trials. Most trials were conducted in otolaryngology settings. Only 8 trials described adequate allocation and concealment procedures; 20 were double-blinded.

Compared to control, penicillin improved clinical cures [relative risk (RR) 1.72; 95% confidence interval (CI) 1.00 to 2.96]. For the outcome of cure or improvement, 77.2% of penicillin-treated participants and 61.5% of control participants were responders. Individuals treated with penicillin were more likely to be cured [RR 1.72; 95% CI 1.00 to 2.96] or cured/improved [RR 1.24; 95% CI 1.00 to 1.53]. Rates for cure or improvement were 82.3% for amoxicillin and 68.6% for placebo. Participants treated with amoxicillin were not more likely to be cured than with placebo [RR 2.06; 95% CI 0.65 to 6.53] or cured/improved [RR 1.26; 95% CI 0.91 to 7.94] but there was significant variability between studies. Radiographic outcomes were improved by antibiotic treatment.

Comparisons between newer non-penicillins (cephalosporins, macrolides, minocycline), versus penicillins (amoxicillin, penicillin V) showed no significant differences [RR for cure 1.07; 95% CI 0.99 to 1.17]; Rates for cure or improvement were 84% for both antibiotic classes. Drop-outs due to adverse events were infrequent, and these rates were not significantly different [RR 0.61; 95% CI 0.33 to 1.11]. Cumulative meta-analysis of studies ordered by year of publication (a proxy for prevalence of beta-lactamase-producing organisms) did not show a trend towards reduced efficacy of amoxicillin compared to newer non-penicillin antibiotics.

Because macrolides are bacteriostatic and cephaplorins bactericidal, subgroup analyses were performed to determine if one of these two classes were superior to penicillins. In the subgroup analyses, cephalosporins and macrolides showed similar response rates compared to penicillins.

Sixteen trials, involving 4818 participants, compared a newer non-penicillin antibiotic (macrolide or cephalosporin) to amoxicillin-clavulanate. Three studies were double-blind. Rates for cure or improvement were 72.7 % and 72.9 % for newer non-penicillins and amoxicillin-clavulanate respectively. Neither cure rates (RR 1.03; 95% CI 0.96 to 1.11) nor cured/improvement rates (RR 0.98; 95% CI 0.95 to 1.01), differed between the groups. Compared to amoxicillin-clavulanate, dropouts due to adverse effects were significantly lower for cephalosporin antibiotics (RR 0.47; 95% CI 0.30 to 0.73). Relapse rates within one month of successful therapy were 7.7% and did not differ between the groups.
pants, compared a tetracycline (doxycycline, tetracycline, minocycline) to a heterogeneous mix of antibiotics (folate inhibitor, cephalosporin, macrolide, amoxicillin). No relevant differences were found.

The reviewers conclude that in acute maxillary sinusitis confirmed radiographically or by aspiration, current evidence is limited but supports the use of penicillin or amoxicillin for 7 to 14 days. Clinicians should weigh the moderate benefits of antibiotic treatment against the potential for adverse effects.

It is interesting to see that in this review the local differences in susceptibility of micro-organisms to the antibiotics used is not acknowledged, although total cumulative meta-analysis of studies ordered by year of publication did not show a trend towards reduced efficacy of amoxicillin compared to newer non-penicillin antibiotics. Resistance patterns of predominant pathogens like Streptococcus pneumoniae, Haemophilus influenzae and Moraxella catarrhalis, vary considerably. The prevalence and degree of antibacterial resistance in common respiratory pathogens are increasing worldwide. The association between antibiotic consumption and the prevalence of resistance is widely assumed. Thus the choice of agent may not be the same in all regions, as selection will depend on local resistance patterns and disease aetiology.

Moreover one might wonder whether the limited benefits of antibiotic treatment outweigh the considerable threat of antibiotic resistance. In 1995, upper respiratory tract infection was the most frequent reason for seeking ambulatory care in the United States, resulting in more than 37 million visits to physician practices and emergency departments.

Since the publication of the Cochrane review a number of new studies have been published. Most are non-inferiority studies comparing two or three antibiotics. These non-inferiority studies also show that a short short course of antibiotics is as good as a long course of antibiotics.

Two studies comparing “real life” ARS treatment, with the diagnosis based on symptoms but not bacteriologically proven both showed no benefit treating patients with acute rhinosinusitis with antibiotics. Although more and more data point to a very limited effect of antibiotics in ARS, there are a limited group of patients, e.g. patients with immunodeficiencies that do benefit from antibiotics. We are in need of simple tests in the general practice that can discriminate the small group who would potentially benefit from antibiotics from the large group that has no benefit from the treatment but puts a burden on the resistance problems.

Relevant for the discussion about the efficacy of antibiotics in ARS is the recently published paper from the (mainly US) Rhinosinusitis Initiative: Revising our clinical practice for ARS. This group of experts gave advice to determine the effect of a treatment intervention on the clinical course of ARS, as measured by time to resolution of symptoms. Because most antimicrobial trials have demonstrated clinical cure rates of 80% to 90% at 14 days, the Rhinosinusitis Initiative committee believed that it was important to demonstrate superiority to existing therapies by showing significant differences in time to symptom resolution or time to significant improvement based on total symptom score.

7-2-2 Antibiotics in chronic rhinosinusitis

7-2-2-1 Introduction

It is significantly more difficult to evaluate the efficacy of antibiotic treatment in CRS compared to ARS, because of the conflicts in terms of terminology and definition of the clinical picture of CRS in the literature. In most studies, no radiological diagnosis, such as CT, has been performed confirm the diagnosis of chronic rhinosinusitis. The data supporting the use of antibiotics in this condition, however, are limited and lacking in terms of randomized placebo controlled clinical trials.
7-2-2-2 Short-term treatment with antibiotics in chronic rhinosinusitis

In a retrospective study, McNally et al. (674) reported patient symptoms and physical examination findings in a cohort of 200 patients with CRS who were treated with a combination of 4 weeks of oral antibiotics, as well as topical corticosteroids and other adjunctive medications. All patients subjectively improved in response to therapy after 1 month.

Subramanian et al. (675) retrospectively studied a group of 40 patients with CRS who were treated with a combination of 4 to 6 weeks of antibiotics and a 10-day course of systemic corticosteroids. Outcome measures, including comparison of pre- and post-treatment CT scan, as well as patient symptom scores, revealed improvement in both outcome parameters in 36 of 40 patients. In the latter study, 24 of 40 patients had sustained improvement for at least 8 weeks, which would seem to imply that whatever infection was present was fully eradicated in these patients.

In a prospective study by Legent et al. (676), 251 adult patients with CRS were treated in a double-blind manner with ciprofloxacin vs. amoxicillin/clavulanic acid for 9 days. Only 141 of the 251 patients had positive bacterial cultures from the middle meatus at the beginning of the study. At the end of the treatment period, nasal discharge disappeared in 60% of the patients in the ciprofloxacin group and 56% of those in the amoxicillin/clavulanic acid group. The clinical cure and bacteriological eradication rates were 59% and 89% for ciprofloxacin versus 51% and 91% for amoxicillin/clavulanic acid respectively. These differences were not significant. However, amongst patients who had a positive initial culture and who were evaluated 40 days after treatment, ciprofloxacin recipients had a significantly higher cure rate than those treated with amoxicillin/clavulanic acid (83.3% vs. 67.6%, p = 0.043). Clinical tolerance was significantly better with ciprofloxacin (p = 0.012), largely due to a large number of gastro-intestinal related side-effects in the amoxicillin/clavulanic acid group (n = 35). Ciprofloxacin proved to be at least as effective as amoxicillin/clavulanic acid.

The efficacy and safety of amoxicillin/clavulanic acid (AMX/CA) (875/125 mg b.i.d. for 14 days) were compared with that of cefuroxime axetil (500 mg b.i.d. for 14 days) in a multicentre, open, parallel-group, randomized clinical trial in 206 adults with chronic or acute exacerbation of CRS by a polish group. Clinical response was similar, with 95% of AMX/CA-, and 88% of cefuroxime-treated, clinically evaluable patients cured. In bacteriologically evaluable patients, cure rates, defined as eradication of the original pathogen with or without re-colonization with non-pathogenic flora, were also similar, with 65% of AMX/CA- and 68% of cefuroxime-treated patients cured. However, clinical relapse was significantly higher in the cefuroxime group: 8% (7/89) of clinically evaluable patients, compared with 0% (0/98) in the AMX/CA (p=0.0049) group (677).

Table 7-9. “Short Term” Antibiotics in Chronic Rhinosinusitis

<table>
<thead>
<tr>
<th>study</th>
<th>drug</th>
<th>number</th>
<th>time/dose</th>
<th>effect on symptoms</th>
<th>evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huck et al, 1993</td>
<td>cefaclor vs. amoxycillin</td>
<td>56 ARS</td>
<td>2x 500mg/3x500mg for 10 days</td>
<td>clinical improvement: ARS 86% recured 56% CRS. no statistics</td>
<td>Ib (-) = study with negative outcome</td>
</tr>
<tr>
<td>Legent et al, 1994</td>
<td>ciprofloxacin vs. amoxycillin clavulanate</td>
<td>251</td>
<td>9 days</td>
<td>nasal discharge disappeared: cipro 60% amx/clav: 56% clinical: cipro 59% amx/clav 51% bacteriological eradication: cipro 91% amx/clav 89%</td>
<td>Ib (-) = study with negative outcome</td>
</tr>
<tr>
<td>McNally et al, 1997</td>
<td>oral antibiotics</td>
<td>200</td>
<td>4 weeks</td>
<td>yes, subjectively after 4 weeks</td>
<td>III</td>
</tr>
<tr>
<td>Subramanian et al; 2002</td>
<td>antibiotics</td>
<td>40</td>
<td>4 - 6 weeks</td>
<td>yes, pre-/ posttreatment CT in 24 patients also improvement after 8 weeks</td>
<td>III</td>
</tr>
<tr>
<td>Namyslowski et al, 2002</td>
<td>amoxycillin clavulanate vs. cefuroxime axetil</td>
<td>206</td>
<td>875/125mg for 14 days 500mg for 14 days</td>
<td>clinical cured: amx/ca 95% cefurox 88% bacterial eradication: amx/ca 65% cefurox 68% clinical relapse: amx/ca 0/98 cefurox 7/89</td>
<td>Ib (-) = study with negative outcome</td>
</tr>
</tbody>
</table>
Huck et al. compared in a double-blind, randomized trial compared cefaclor with amoxicillin in the treatment of 56 acute, 25 recurrent, and 15 chronic maxillary sinusitis: Whether treated with cefaclor or amoxicillin, clinical improvement occurred in 86% of patients with ARS and 56% of patients with recurrent RS. Patients with CRS were too few to allow statistical analysis. The susceptibility of organisms isolated to the study drugs was unrelated to outcome. To summarize, at the moment no placebo-controlled studies on the effect of antibiotic treatment are available. Studies comparing antibiotics have level II evidence and do not show significant differences between ciprofloxacin vs. amoxyccillin/clavulanic acid, and cefuroxime axetil. The few available prospective studies show effect on symptoms in 56% to 95% of the patients. It is unclear which part of this effect is regression to the mean because placebo controlled studies are lacking. There is urgent need for randomized placebo controlled trials to study the effect of antibiotics in CRS and exacerbations of chronic rhinosinusitis.

7-2-2-3 Long-term treatment with antibiotics in chronic rhinosinusitis

The efficacy of long term treatment with antibiotics in diffuse panbronchiolitis, a disease of unclear aetiology, characterized by chronic progressive inflammation in the respiratory bronchioles inspired the Asians in the last decade to treat CRS in the same way. Subsequently a number of clinical reports have stated that long-term, low-dose macrolide antibiotics are effective in treating CRS incurable by surgery or glucocorticosteroid treatment, with an improvement in symptoms varying between 60% and 80% in different studies. The macrolide therapy was shown to have a slow onset with ongoing improvement until 4 months after the start of the therapy. In animal studies macrolides have increased mucociliary transport, reduced goblet cell secretion and accelerated apoptosis of neutrophils, all factors that may reduce the symptoms of chronic inflammation. There is also increasing evidence in vitro of the anti-inflammatory effects of macrolides. Several studies have shown macrolides inhibit interleukin gene expression for IL-6 and IL-8, inhibit the expression of intercellular adhesion molecule essential for the recruitment of inflammatory cells. However, it remains to be established if this is a clinically relevant mechanism.

There is also evidence in vitro, as well as clinical experience, showing that macrolides reduce the virulence and tissue damage caused by chronic bacterial colonization without eradicating the bacteria. In addition long term treatment with antibiotics has been shown to increase ciliary beat frequency. In a prospective RCT from the same group ninety patients with polyloid and nonpolyoid CRS were randomised to medical treatment with 3 months of an oral macrolide (erythromycin) or endoscopic sinus surgery and followed over one year. Outcome assessments included symptoms (VAS), the SinoNasal Outcome Test (SNOT-22), Short Form 36 Health Survey (SF36), nitric oxide, acoustic rhinometry, saccharine clearance time and nasal endoscopy. Both the medical and sur-

Table 7-10. Long-term treatment with antibiotics in chronic rhinosinusitis

<table>
<thead>
<tr>
<th>study</th>
<th>drug</th>
<th>number</th>
<th>time/dose</th>
<th>effect symptoms</th>
<th>level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gahdhi et al, 1993</td>
<td>prophylactic</td>
<td>26</td>
<td>not mentioned</td>
<td>19/26 decrease of acute exacerbation by 50%</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>antibiosis</td>
<td></td>
<td></td>
<td>7/26 decrease of acute exacerbation by less than 50%</td>
<td></td>
</tr>
<tr>
<td>Nishi et al, 1995</td>
<td>clarithromycin</td>
<td>32</td>
<td>400mg /d</td>
<td>pre- and post-therapy assessment of nasal clearence</td>
<td>III</td>
</tr>
<tr>
<td>Scadding et al 1995</td>
<td>oral antibiotic</td>
<td>10</td>
<td>3 month</td>
<td>increased ciliary beating</td>
<td>III</td>
</tr>
<tr>
<td>Ichimura et al 1996</td>
<td>roxithromycin</td>
<td>20</td>
<td>150mg /d</td>
<td>clinical improve-ment and polyp-shrinkage in 52%</td>
<td>III</td>
</tr>
<tr>
<td></td>
<td>and azelastine</td>
<td>20</td>
<td>for at least 8 weeks 1mg /d</td>
<td>clinical improve-ment and polyp shrinkage in 68%</td>
<td></td>
</tr>
<tr>
<td>Hashiba et al, 1996</td>
<td>clarithromycin</td>
<td>45</td>
<td>400mg /d for 8 to 12 weeks</td>
<td>clinical improvement in 71%</td>
<td>III</td>
</tr>
<tr>
<td>Suzuki et al, 1997</td>
<td>roxithromycin</td>
<td>12</td>
<td>150mg /d</td>
<td>CT scan pre- and post-therapy: improvment in the aeration of nasal sinuses</td>
<td>III</td>
</tr>
<tr>
<td>Ragab et al 2004</td>
<td>erythromycin v ESS</td>
<td>45 in each arm</td>
<td>3 months</td>
<td>improvement in upper &amp; lower RT symptoms, SF36, SNOT-22, NO, Ac Rhin, SCT, nasal endoscopy at 6 &amp; 12 months</td>
<td>Ib</td>
</tr>
<tr>
<td>Wallwork 2006</td>
<td>roxithromycin</td>
<td>64</td>
<td>3 months</td>
<td>improvements in global rating of patients</td>
<td>Ib</td>
</tr>
</tbody>
</table>

RT: respiratory tract; SF 36: Short Form 36 QoL; SNOT-22: SinoNasal Outcome Test; NO:expired nitric oxide, Ac Rhin: acoustic rhinometry; SCT: saccharine clearance time.
The benefit of long-term, low-dose macrolide treatment seems to be that it is, in selected cases, effective when topical steroids and short courses of antibiotics fail. The exact mechanism of action is not known, but it probably involves downregulation of the local host immune response as well as a downgrading of the virulence of the colonizing bacteria. Placebo-controlled studies should be performed to establish the efficacy of macrolides if this treatment is to be accepted as evidence-based medicine.

### 7-2-3 Exacerbations of chronic rhinosinusitis

#### 7-2-3-1 Short-term treatment with oral antibiotics in acute exacerbations of chronic rhinosinusitis

In open trials, oral antibiotics have an effect on the symptomatology of acute exacerbations of CRS (671, 692). In some of these studies patients with ARS or CRS are combined with patients with acute exacerbations of CRS (685, 684). No studies have shown efficacy of antibiotics in acute exacerbations of CRS in a double-blind placebo controlled manner.

In conclusion data on the treatment of acute exacerbation of CRS are mostly level IV evidence and include oral and local antibiotics. Double-blind data show a positive effect of the addition of topical corticosteroid treatment to oral antibiotics in the treatment of acute exacerbation of CRS.

#### 7-2-3-2 Short-term treatment with local antibiotics in acute exacerbations of chronic rhinosinusitis

Some studies have compared the effects of local antibiotics in CRS and acute exacerbation of CRS (620, 695-697).

Desrosiers studied in a randomized, double-blind trial of tobramycin-saline solution versus saline-only solution administered thrice daily to the nasal passages by means of a large-particle nebulizer apparatus for 4 weeks in twenty patients with CRS refractory to medical and surgical therapy. He found no significant difference between the groups and concluded that large-particle nebulized aerosol therapy may offer a safe and effective management alternative for patients with refractory rhinosinusitis irrespective of the addition of gentamicin (686).

Sykes found no additional effect with the addition of neomycin to a spray containing dexamethasone and tramazoline four times daily to both nostrils for 2 weeks (622).

However, Mosges and Leonard did find differences between local antibiotics and placebo (685, 697). Mosges showed a positive effect for fusafungine nasal spray as early as the first 24h of treatment which was not seen in the placebo group. The antimicrobiological effect of this preparation is unclear.

Schienberg et al. studied the effectiveness of aerosol delivery of antibiotics to the sinuses via a nebulizer in 41 patients who had chronic, recurrent rhinosinusitis that had persisted despite endoscopic sinus surgery (ESS) and that had not responded to multiple courses of oral antibiotics. Following 3 to 6 weeks of treatment, 34 patients (82.9%) experienced either an excellent or good response to treatment. Side effects were infrequent, mild, and transient. They concluded that nebulized antibiotics should be considered for all patients with CRS who have undergone ESS and who have failed to respond to oral antibiotics or who do not tolerate them (699).

Further studies with better characterized patient populations are needed.

#### 7-2-4 Side-effects of antibiotics

Common side effects of antibiotics include sickness, diarrhoea, and, in women, vaginal yeast infections. Some side effects are more severe and, depending on the antibiotic, may influence kidney and liver function. Rarely the bone-marrow or other organs are affected. Blood tests are used to monitor such adverse reactions.

Some people who receive antibiotics develop colitis, an inflammation of the large intestine. The colitis results from a toxin produced by the bacterium, Clostridium difficile, which grows unchecked when other antibacteria are killed by the antibiotics.

Antibiotics can cause allergic reactions. Most are mild allergic reactions and consist of an itchy rash or slight wheezing. Patients claiming allergic reactions to antibiotics actually mean side-effects. This is important to realize because on one hand severe allergic reactions (anaphylaxis) can be life threatening, on the other hand some patients claim to be allergic to many different classes of antibiotics making treatment difficult. Most adverse events related to antimicrobials are reversible rapidly on cessation of the medication. Irreversible toxicities include...
aminoglycoside-induced ototoxicity, Stevens-Johnson syndrome, and toxicity secondary to nitrofurantoin. Another important consequence of the use of antibiotics is the development of resistance. Resistance to antibiotics is a major public-health problem and antibiotic use is being increasingly recognised as the main selective pressure driving this resistance. Prescription of antibiotics in Europe varies greatly: the highest rate was in France and the lowest was in the Netherlands (700). A shift from the old narrow-spectrum antibiotics to the new broad-spectrum antibiotics is being seen. Higher rates of antibiotic resistance are found in high consuming countries, probably related to this higher consumption.

7-3 Other medical management for rhinosinusitis

Standard conservative treatment for ARS and CRS is based on short or long-term antibiotics and topical steroids with the addition of decongestants - mostly in a short term regimen and for the acute attack itself. Many other types of preparations have been investigated, but substantial evidence for their benefit is poor. These medications include antral washings, isotonic/hypertonic saline as nasal douche, antihistamines, antimycotics, mucolytic agents/phytomedical preparations, immunomodulators/immunostimulants and bacterial lysate preparations. For selected patients with CRS and gastroesophageal reflux, the impact of antireflux treatment on sinus symptom scores has been studied. Topical nasal application of furosemide and capsaicin have also been considered in the treatment of nasal polyposis and prevention of recurrence.

7-3-1 Decongestants

7-3-1-1 Acute rhinosinusitis

Nasal decongestants are applied in the treatment of ARS in order to decrease congestion and in the hope of improving better sinus ventilation and drainage and symptomatic relief of nasal congestion. Experimental trials on the effect of topical decongestants by CT (701) and MRI scans (702) on ostial and ostiomeatal complex patency have confirmed marked effect on congestion of inferior and middle turbinates and infundibular mucosa, but no effect on ethmoidal and maxillary sinus mucosa. Experimental studies suggested beneficial anti-inflammatory effect of xylometazoline and oxymetazoline by decreasing nitric oxide synthetase (702) and anti-oxidant action (703). In contrast to previous in vitro trials on the effect of decongestants on mucociliary transport, a controlled clinical trial (II) by Inanli et al. suggested improvement in mucociliary clearance in vivo, after 2 weeks of oxymetazoline application in acute bacterial rhinosinusitis, compared to fluticasone, hypertonic saline and saline, but it did not show significant improvement compared to the group where no topical nasal treatment was given, and the clinical course of the disease between the groups was not significantly different (704). This is in concordance with previous randomized controlled trial in adult acute maxillary sinusitis (Ib), which did not prove significant impact of decongestant when added to antibiotic treatment in terms of daily symptoms scores on headache and obstruction and sinus x-ray scores, although decongestant and placebo were applied through a bellow, which should have enabled better dispersion of the solution in the nasal cavity (705). Decongestant treatment did not prove superior to saline, when added to antibiotic and antihistamine treatment in a randomized double-blind placebo-controlled trial for acute paediatric rhinosinusitis (Ib) (706). However, a double blind, randomized, placebo controlled trial demonstrated a significant protective effect of 14-day nasal decongestant (combined with topical budesonide after 7 days) in the prevention of the development of nosocomial maxillary sinusitis in mechanically ventilated patients in the intensive care unit (707). Radiologically confirmed maxillary sinusitis was observed in 54% of patients in the active treatment group and in the 82% of the controls, respectively, while infective maxillary sinusitis was observed in 8% and 20%, respectively (708). Clinical experience, however, supports the use of topical application of decongestants to the middle meatus in ARS but not by spray or drops (evidence level IV).

7-3-1-2 Chronic rhinosinusitis without nasal polyps

The use of decongestants for adult CRS has not been evaluated in a randomized controlled trial. Decongestants and sinus drainage did not prove to be superior to saline in chronic paediatric maxillary sinusitis in terms of subjective or x-ray scores (709).

7-3-1-3 Chronic rhinosinusitis with nasal polyps

CT studies before and after decongestant application in patients with nasal polyposis did not show any densitometric changes in the sinuses or polyps, only decongestion of the inferior turbinates (710). A randomized double blind placebo controlled trial did not show any difference between placebo, epinephrine and naphazoline on polypl size at endoscopy and lateral imaging (711).

7-3-1-4 Side effects of decongestants

The most frequent adverse event related to topical nasal decongestants is rebound nasal congestion in patients with prolonged treatment or overuse of vasoconstrictive topical medications. The effect occurs due to tachyphylaxis after 5 to 7 days of medication use. Shorter duration of decongestion and rebound effect results in increased daily dose and may lead to rhinitis medicamentosa (712). Significantly greater nasal reactivity, compared to placebo, was demonstrated after few weeks of nasal decongestant.

Major adverse effects are more related to systemic decongestants, ranging in severity from tremor and headache to individual reports of stroke, myocardial infarction, chest pain, seizures, insomnia, nausea and vomiting, fatigue, and dizziness. There are even some case reports reporting on similar side effects of topical decongestants, especially in patients with increased cardiovascular risks (713-716).
7-3-2 Mucolytics

7-3-2-1 Acute rhinosinusitis
Mucolytics were used as adjuncts to antibiotic treatment and decongestant treatment in ARS in order to reduce the viscosity of sinus secretion. The benefit of such treatment has not been evaluated in many trials. In paediatric rhinosinusitis, a RCT (Ib) did not prove bromhexine superior to saline in inhalation for children with CRS (717). A second RCT (Ib) suspected bromhexine was superior to placebo (718).

7-3-2-2 Chronic rhinosinusitis
A cohort study in a mixed group of 45 ARS and CRS patients suggested beneficial effect of adding mucolytic to standard rhinosinusitis treatment in terms of reducing treatment duration (719)(evidence level III).

7-3-2-3 Nasal polyps
No clinical trials have tested the effect of mucolytics in nasal polyp treatment.

7-3-3 Antihistamines, cromones

7-3-3-1 Acute rhinosinusitis
The beneficial effect of loratadine in terms of symptom reduction for the treatment of ARS in patients with allergic rhinitis was confirmed in a multicentre randomized double-blind, placebo controlled trial (Ib)(720). Patients receiving loratadine as an adjunct to antibiotic treatment suffered significantly less sneezing and obstruction on daily VAS scores, and overall improvement was confirmed by their physicians. Cromolyn did not prove better than saline in a RCT (Ib) for treatment of acute hyperreactive sinusitis measured by subjective scores and ultrasound scans, leading to 50% improvement in both groups (721). A RCT (Ib) for acute paediatric rhinosinusitis did not confirm any benefit of oral antihistamine-nasal decongestant drops (722).

7-3-3-2 Chronic rhinosinusitis
Although generally not recommended as rhinosinusitis treatment, an evaluation study of CRS treatment in the USA revealed antihistamines as rather often prescribed medication in patients with CRS (an average of 2.7 antibiotic courses; nasal steroids and prescription antihistamines 18.3 and 16.3 weeks, respectively, in a 12-month period) (722). However, no evidence of beneficial effects of antihistamine treatment for CRS is found, as there are no controlled trials evaluating such treatment.

7-3-3-3 Nasal polyps
Cetirizine in a dose of 20 mg/day for three months, significantly reduced sneezing, rhinorrhoea and obstruction compared to placebo in the postoperative treatment of recurrent polyposis but with no effect on polyph size (Ib) (723).

7-3-3-4 Antihistamines
Unlike first generation antihistamines, where central nervous system and peripheral muscarinic side effects are significant, frequency of side effects in newer second generation antihistamines is low. The most commonly reported events during treatment with second generation antihistamines were upper respiratory tract infection, wheezing, vulvitis, cough, headache, migraine, drowsiness, sedation and injury, most of them reported in 1 to 5% of the treated population, however, not necessarily related to medication. Although caution with cardiotoxicity and potential for interaction with drugs metabolised by the hepatic cytochrome P450 system, applied to older non-sedating antihistamines (like terfenadine or astemizole), this risk seems to be absent in newer compounds (desloratadine, levocetirizine, fexofenadine), at least in recommended treatment regimens.

7-3-4 Antimycotics
Antimycotics are used as topical and systemic treatment, as an adjunct to sinus surgery, in allergic fungal, and invasive fungal rhinosinusitis, especially in immunocompromized patients (724). Surgery is considered the first line treatment for allergic fungal (725) and invasive fungal rhinosinusitis (726). Although the use of antimycotics in the treatment of allergic fungal rhinosinusitis has not been tested in controlled trials, high dose postoperative itraconazole, combined with oral and topical steroids in a cohort of 139 patients with AFS reduced the need for revision surgery rate to 20.5% (727). The state-of-art treatment for invasive fungal sinusitis is based on small series of patients and case reports, which do not meet the criteria for meta-analysis and may be considered as level IV evidence.

7-3-4-1 Acute rhinosinusitis
No controlled trials for antimycotic treatment for ARS was found on the Medline search.

7-3-4-2 Chronic rhinosinusitis
The fungal hypothesis, based of the premise of an altered local immune (non-allergic) response to fungal presence in nasal/sinus secretions resulting in the generation of chronic eosinophilic rhinosinusitis and nasal polyposis (148), has led to idea of treating CRS with and without NPs with a topical antimycotic. Although the presence of fungus in sinus secretions was detected in a high proportion (<90%) of patients with CRS, as well as in a control disease-free population in a few study centres (148), it cannot be taken as proof of aetiology. Until recently a few case studies (level IV) had been conducted (728,729). Ponikau et al, in a group of 51 patients with CRS, including polyposis patients, treated patients with topical amphotericin B as nasal/sinus washing, without placebo or other control treatment. The treatment resulted in 75% subjective improvement and 74% endoscopic improvement (729). As the authors stated, antifungal treatment should be evaluated in a controlled trial to be justified.
In a recent small randomized, placebo-controlled, double-blind, trial using amphotericin B to treat 30 patients with CRS with or without NP Ponikau et al (730) were also not able to show significant effect on symptomatology although did show a reduced inflammatory mucosal thickening on both CT scan and nasal endoscopy and decreased levels of intranasal markers for eosinophilic inflammation in patients with CRS (a significant difference in the reduction of eosinophil derived neutrotoxin (EDN), but not IL-5). The study by Weschta et al (731) did not reveal difference between amphotericin B and placebo treatments in the reduction of eosinophil cationic protein and tryptase, and no difference was found between cellular activation markers whether fungal elimination was achieved or not (for patients where fungal elements were detected), which supports the hypothesis that fungi are innocent bystanders and not the trigger for inflammatory (presumably eosinophil) cells activation (731). Both trials used antimycotic solutions high above minimal inhibitory concentration for fungal elimination. However, the Ponikau trial used nasal lavage twice daily for 6 months (with significant endoscopic improvement after 3 and 6 months), while Weschta et al used nasal spray 4 times daily for 3 months. While difference in drug application and small sample size left the question of treatment success and different objective outcomes between the trials open, a multicentre randomised, placebo-controlled, double-blind, trial (156), in 120 patients (80% with polyps) using nasal lavage for 3 months and confirmed no benefit with amphotericin B added to nasal lavage compared with placebo lavage in the treatment of CRS with and without NPs. No difference between amphotericin B and placebo was found in terms of subjective and objective measures of improvement, i.e. mean VAS score, SF-36, Rhinosinusitis Outcome Measure-31 (RSOM-31), endoscopy scores, SF-36, PNIF and polyp scores. Patients on placebo improved in total VAS, postnasal drip VAS, rhinorrhea VAS in non-asthma subgroup; PNIF deteriorated significantly on amphotericin B, though did not in those on placebo (156).

Oral antifungal treatment with high dose terbinafine for 6 weeks in a randomized, placebo-controlled, double-blind, multi-centre trial, also did not find any subjective or objective benefit after antifungal treatment, comparing outcomes in 53 adult patients with CRS (732). No difference was found in CT scores improvement, sinus symptom scores and therapeutic evaluation, and confirmed the previous findings by Weschta et al that the presence of fungi in nasal mucus (fungus positive in 41/53 patients) made no difference to treatment outcomes (732).

### 7.3-4-3 Nasal polyposis

Another case study (as the previous trials also included patients with nasal polyposis) combined topical steroid treatment with amphotericin B in 74 patients with nasal polyposis for 4 weeks (733) and found 48% disappearance of the polyps at endoscopy in previously endoscopically operated patients.

In a double blind randomized placebo controlled trial in 60 patients with CRS with nasal polyps, topical treatment with amphotericin B was not superior to saline in CT scores (p 0.2) and subjective scores, which were (significantly) worse in active treatment group (731).

A recent open randomized trial, comparing protective effects of lysine aspirin (LAS) and LAS combined with amphotericin B on nasal polyp recurrence in patients who underwent medical (depot i.m. steroid) or surgical polypectomy, suggested that adding amphotericin B to lysine aspirin in a long-term topical treatment may add benefit in terms of recurrence protection (734). Recurrence after 20 months was found in 13/25 patients treated with LAS after surgery, in 15/25 after medical polypectomy and LAS, while 5/16 after surgical polypectomy and 7/23 after medical polypectomy protected with LAS and amphotericin B, respectively. Fungi were detected in 8/39 patients in LAS+ampho B treated groups, and in none of 50 only LAS treated patients. Low fungal detection indicate that the presumption of protective effect of amphotericin B, added to LAS treatment may not be due to antifungal effect but the complexities of this study make any conclusions difficult (734).

### Table 7-11. Treatment with antimycotics in chronic rhinosinusitis

<table>
<thead>
<tr>
<th>study</th>
<th>indication</th>
<th>treatment</th>
<th>number</th>
<th>duration</th>
<th>symptoms</th>
<th>objective</th>
<th>level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weschta, 2004</td>
<td>NP</td>
<td>amphotericin B spray vs placebo 4 times daily</td>
<td>60</td>
<td>8 weeks</td>
<td>significantly worse on amphotericin B</td>
<td>no difference in CT, endoscopy, ECP and tryptase in lavage</td>
<td>Ib (-)</td>
</tr>
<tr>
<td>Ponikau, 2005</td>
<td>CRS + NP</td>
<td>amphotericin B lavage vs. placebo twice daily</td>
<td>30</td>
<td>6 months</td>
<td>no difference</td>
<td>CT less mucosal thickening and EDN, but not IL-5 in lavage for active treatment</td>
<td>Ib (+ only for CT)</td>
</tr>
<tr>
<td>Kennedy, 2005</td>
<td>CRS</td>
<td>625mg/ day oral terbinafine vs. placebo</td>
<td>53</td>
<td>6 weeks + 9 week follow up</td>
<td>no difference in symptoms and RSOM-31 patient and physician</td>
<td>no difference in CT, MRI, endoscopy</td>
<td>Ib (-)</td>
</tr>
<tr>
<td>Ebbens, 2006</td>
<td>CRS + NP</td>
<td>amphotericin B lavage vs. placebo</td>
<td>116</td>
<td>3 months</td>
<td>no difference</td>
<td>no difference in polyp scores, PNIF, RSOM-31, SF-36 between groups</td>
<td>Ib (-)</td>
</tr>
</tbody>
</table>
7-3-4-4 Side effects of antifungal drugs
Adverse events reported after long-term oral antifungal treatment most frequently are nausea, headache, skin rash, vomiting, abdominal pain and diarrhoea. Major adverse events, like serious liver dysfunction is rare, and mostly seen in patients at risk and due to drug interactions.

Frequency of adverse events during 3 to 6 months topical amphotericin B treatment in 3 randomized placebo controlled trials was similar in the active and placebo groups. However, major adverse events were more common in the active treatment group (9% in active vs. 0% in placebo group respectively) although only 1 was judged to be drug-related (asthma attack). Oral treatment with terbinafine for 6 weeks did not induce more adverse events than placebo, none were drug-related, and no difference in liver function was observed between active and placebo group after 6 weeks.

The effect of amphotericin B on sinus mucosa may be explained by some other modes of action. In common with other polyene antibiotics and antifungal agents, amphotericin B acts on cellular membrane permeability, which may reduce the size of nasal polyps by reducing oedema, leading to subjective improvement (739). These studies were not placebo controlled and had short observation periods. Amphotericin B is a cytotoxic drug and long-term topical application may have systemic effect. On the other hand, nasal washings with hypertonic solution (without antifungal medication) offer up to 60% improvement (see under chapter 7-4-7 Nasal and antral irrigation - saline, hypertonic saline).

Another concern regarding the use of amphotericin B as topical treatment for CRS and nasal polyposis is the possibility that widespread use may lead to resistance. Amphotericin B remains a valuable antifungal systemic treatment for potentially life-threatening invasive mycoses and increased selective pressure with topical treatment, may give rise to increased drug resistance in common fungal pathogens, like Candida (776-778). This is a real possibility due to different drug distribution pattern in the sinus cavities (some spaces have sub-therapeutic drug concentration), and, in time we may lose valuable antifungal systemic drug, which still demonstrates low resistance.

7-3-5-1 Chronic rhinosinusitis
Bacterial lysates were tested in the treatment of acute recurrent rhinosinusitis and the outcomes measured were the reduced rate of acute episodes and antibiotic treatment. Enterococcus faecalis autolysate treatment for 6 months in 78 patients (3x30 drops daily) resulted in 50 relapses during 6 months treatment and 8 months follow-up compared to 79 placebo treated group with 90 recurrences. The time interval to the first relapse was clearly longer in the active arm (513 days) compared with placebo (311 days) (779). A RCT of the effect of 6 months treatment with ribosomal fractions of Klebsiella pneumoniae, Streptococcus pneumoniae, Streptococcus pyogenes, and the membrane fraction of Kp (740), and mixed bacterial lysate (741) in terms of the reduction of the number of acute relapses in CRS, the period between the relapses and need for antibiotic treatment, have been tested in multicentre, placebo controlled RCTs (Ib) (779-780).

7-3-5-2 Chronic rhinosinusitis
Six months treatment with mixed bacterial lysate was tested in a multicentre randomized double-blind placebo-controlled trial in 284 patients with CRS (diagnosed by persistent nasal discharge, headache, and x-ray criteria). Reduction in symptom scores and over-all severity score, including cough and expectation were significant during the treatment period (742).

Table 7-12. Treatment with bacterial lysates in chronic rhinosinusitis

<table>
<thead>
<tr>
<th>study</th>
<th>indication</th>
<th>treatment</th>
<th>number</th>
<th>duration</th>
<th>symptoms</th>
<th>objective</th>
<th>level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habermann, 2002 (739)</td>
<td>recurrent ARS</td>
<td>Enterococcus faecalis</td>
<td>157</td>
<td>6+8 months</td>
<td>reduced acute episodes</td>
<td>50 vs. 90 recurrences, 513 vs. 311 days to first relapse</td>
<td>Ib</td>
</tr>
<tr>
<td>Serrano, 1997 (740)</td>
<td>recurrent ARS</td>
<td>Ribomunyl</td>
<td>327</td>
<td>6 months</td>
<td>reduced acute episodes</td>
<td>39% reduction in antibiotic courses and 32% days on antibiotics</td>
<td>Ib</td>
</tr>
<tr>
<td>Heintz, 1989 (740)</td>
<td>CRS</td>
<td>Bronchovaxom</td>
<td>284</td>
<td>6 months</td>
<td>improved upper and lower airways</td>
<td>no of patients with total x-ray opacification drop 54 to 9 active vs. 46 to 25 on placebo</td>
<td>Ib</td>
</tr>
</tbody>
</table>
7-3-5-3 Nasal polyposis
No data could be found on treatment with bacterial lysates in nasal polyposis.

7-3-6 Immunomodulators/immunostimulants
Treatment with filgrastim, recombinant human granulocyte colony stimulating factor, was tested in a RCT (Ib) in a group of CRS patients refractory to conventional treatment, which did not confirm significantly improved outcomes after such expensive treatment (742). A pilot study (III) with interferon gamma suggested this treatment may be beneficial in treating resistant CRS, but the number of patients was not adequate to provide evidence to justify such treatment (740). Certain groups of antibiotics may be regarded as immunomodulators, like quinolones (740) and macrolides (740).

7-3-7 Nasal and antral irrigation (saline, hypertonic saline)
A number of randomized controlled trials have tested nasal and antral irrigation with isotonic or hypertonic saline in the treatment of acute and chronic rhinosinusitis. Although saline is considered as a control treatment itself, patients in these randomized trials were assigned to different modalities of application of saline or hypertonic saline, or hypertonic compared to isotonic saline. The results between the groups were compared. Most of them offer evidence that nasal washouts or irrigations with isotonic or hypertonic saline are beneficial in terms of alleviation of symptoms, endoscopic findings and HRQL improvement in patients with CRS. Hypertonic saline is preferred to isotonic treatment for rhinosinusitis by some authors in the USA, mostly based on a paper indicating it significantly improves nasal mucociliary clearance measured by saccharine test, in healthy volunteers (740).

7-3-7-1 Acute rhinosinusitis
A randomized trial (Ib) by Adam et al (740) with two controls, compared hypertonic nasal saline to isotonic saline and no treatment in 119 patients with common cold and ARS (which were the majority). Outcome measures were subjective nasal symptoms scores (congestion, secretion, headache) at day-3, day-8-10 and the day of symptom resolution. Rhinosinusitis patients (98%) were also treated with antibiotics. There was no difference between the groups and only 44% of the patients would use the hypertonic saline spray again. Thirty-two percent noted burning, compared with 13% of the normal saline group.

Antral irrigation (Ib) did not offer significant benefit when added to standard 10-day antibiotic treatment in (4 antibiotics+ decongestants vs. antral washouts; 50 patients per group) ARS, demonstrating approximately 5% better cure rate in each group for washouts than for decongestants, which was not significant (740).

7-3-7-2 Chronic rhinosinusitis
A randomised controlled trial (RCT) by Bachmann (Ib), comparing isotonic saline and EMS solution (baloneotherapeutic water) in the treatment of CRS in a double-blind fashion revealed improvement in both groups, with no difference between them (741). In the 7-days follow-up, nasal air flow was not improved significantly. Subjective complaints, endonasal endoscopy, and radiology results revealed a significant improvement in both groups (P = 0.0001). A similar RCT by Taccariello et al (Ib), with a longer follow-up confirmed that nasal washing with sea water and alkaline nasal douche produced benefit over standard treatments. Douching per se improved endoscopic appearances (p = .009), and quality of life scores (p = .008) (749). These measures did not change in a control group (n = 22) who received standard treatment for CRS, but no douche. There were significant differences between the two douching preparations - the alkaline nasal douche improved endoscopic appearances but did not enhance quality of life, whereas the opposite was true for the spray. Rabago et al. (Ib) tested benefit from daily hypertonic saline washings compared to standard CRS treatment (control) for 6 months in a RCT using subjective scores instruments: Medical Outcomes Survey Short Form (SF-12), the Rhinosinusitis Disability Index (RSDI), and a Single-Item Sinus-Symptom Severity Assessment (SIA). Experimental subjects reported fewer 2-week periods with sinus-related symptoms (P <.05), used less antibiotics (P <.05), and used less nasal spray (P =.06) (740). On the exit questionnaire 93% of study subjects reported overall improvement of sinus-related quality of life, and none reported worsening (P <.001); on average, experimental subjects reported 57 +/- 4.5% improvement measured by Medical Outcomes Survey Short Form (SF-12), the Rhinosinusitis Disability Index (RSDI), and a Single-Item Sinus-Symptom Severity Assessment (SIA). A double blind RCT (Ib) compared the effect of nasal wash with hypertonic saline (3.5%) versus normal saline (NS) (0.9%) for the 4 weeks in treatment of paediatric CRS using cough and nasal secretions/postnasal drip as subjective and a radiology score as objective outcome measures (751). Hypertonic saline demonstrated significant improvement for all the scores (13/15 for cough, 13/15 postnasal drip, 14/15 x-ray scores), while saline improved only postnasal drip. A recent double blind randomized controlled trial in 57 patients with CRS, with minimum persistence of symptoms for 1 year and previously unsuccessfully treated with conventional medical treatment, demonstrated significantly better improvement after nasal lavage for 60 days with hypertonic Dead sea salt (DSS) solution compared to conventional hypertonic saline, in terms of rhinosinusitis symptoms scores and rhinoconjunctivitis quality-of-life scores which was attributed to the presence of magnesium and other oligominerals known to have an effect in nskin conditions. (581). Similar results were found in a recent case trial in 31 patients with resistant CRS. (720).

A randomized controlled clinical trial of nasal washing with normal saline, hypertonic buffered saline and no treatment in 60 patients after endoscopic sinus surgery did not prove any of the treatment superior. Hypertonic saline induced greater discharge during the first 5 postoperative days and increased pain
scores, compared to normal saline and no treatment. However, no objective evaluation was done in this trial (753).

Comparison of treatment with antral washouts in the treatment of chronic adult (754) and paediatric rhinosinusitis (755) did not prove benefit from such treatment. In a RCT by Pang et al. patients received either antral washouts followed by antibiotics and topical nasal steroids or antibiotics and topical nasal steroids alone. In each group 51.6 per cent and 50 per cent of patients respectively improved with treatment (756).

Instead of using saline or hypertonic solution, a few non-controlled pilot trials in a small number of patients analyzed the effect of active medication used intrasinusally. A trial in 12 patients was done using N-chlorotaurine, an endogenous oxidant with antimicrobial properties against bacteria and fungi. The intrasinusal application of N-chlorotaurine was done 3 times a week, during 4 weeks (12 applications) using a Yamik catheter and improvement of symptoms was found in 75 to 90% of patients, however, no improvement was found on the sinus CT scans, before and after the treatment (756). Although saline washes are frequently recommended post-operatively, level I evidence to support this is lacking.

7-3-7-3 Nasal polyps
Nasal saline has been used as a control treatment in trials on nasal polyposis with topical steroid, but there are no controlled trials on saline/hypertonic saline treatment alone in nasal polyposis.

7-3-7-4 Side effects
Side effects of saline, hypertonic saline nasal washings are not often reported. However, randomized controlled trial comparing isotonic and hypertonic saline for ARS or common cold reported significantly higher rate of nasal irritation for hypertonic saline (32% vs. 13% for saline, respectively), while dry nose was more common in patients using saline (36%), than in those using hypertonic saline (21%) (746).

Uncommon side effects were nausea caused by drainage, burning, cough, drowsiness and tearing. Interestingly, side effects of HS were less common in the treatment of CRS (6 months): nasal irritation, nasal burning, tearing, nosebleeds, headache, or nasal drainage were reported by 23% of the subjects, 80% of those who reported side effects, regarded them as not significant (750).

7-3-8 Capsaicin
Capsaicin, the active substance from red hot chilli peppers, is a neurotoxin which depletes substance P with some other neurotransmitters and neuropeptides, leading to long lasting damage of unmyelinated axons and thinly myelinated axons when repeatedly applied to the respiratory mucosa. Substance P was found effective in reducing nasal symptoms after cumulative topical applications in the treatment of non-allergic hyperreactive rhinitis, probably acting as desensitizer of nasal mucosa due to depletion of SP and neurokinins. The hypothesis that neurogenic inflammation may play a role in the pathogenesis of nasal polyps has led to trials on capsaicin treatment of nasal polyposis.

7-3-8-1 Acute and chronic rhinosinusitis without nasal polyps
No trials of treatment of acute or chronic rhinosinusitis with capsaicin could be found.

### Table 7-13. Nasal irrigation (saline, hypertonic saline, Dead sea solution, balneotherapeutic water) randomized controlled trials

<table>
<thead>
<tr>
<th>Study</th>
<th>Indication</th>
<th>Solution</th>
<th>Number</th>
<th>Duration</th>
<th>Symptoms</th>
<th>Objective</th>
<th>Level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam, 1998 (746)</td>
<td>ARS</td>
<td>saline vs. HS vs. NT</td>
<td>119</td>
<td>10 days</td>
<td>no difference</td>
<td>not done</td>
<td>Ib</td>
</tr>
<tr>
<td>Bachmann, 2000 (748)</td>
<td>CRS</td>
<td>saline vs. EMS</td>
<td>40</td>
<td>7 days</td>
<td>improved, no difference saline vs EMS</td>
<td>endoscopy, plain X-ray improved</td>
<td>Ib</td>
</tr>
<tr>
<td>Taccariello, 1999</td>
<td>CRS</td>
<td>sea water vs. Alkaline vs. NT</td>
<td>62</td>
<td>30 days</td>
<td>improved</td>
<td>endoscopy, HRQL improved</td>
<td>Ib</td>
</tr>
<tr>
<td>Rabago, 2002 (749)</td>
<td>CRS</td>
<td>HT vs. NT</td>
<td>76</td>
<td>6 months</td>
<td>improved</td>
<td>significantly less antibiotics, nasal sprays</td>
<td>Ib</td>
</tr>
<tr>
<td>Shoseyov, 1998 (750)</td>
<td>CRS in children</td>
<td>saline vs. HS</td>
<td>40</td>
<td>4 weeks</td>
<td>HS all symptoms improved, saline PND only</td>
<td>x-ray improved after HS</td>
<td>Ib</td>
</tr>
<tr>
<td>Friedman, 2006 (751)</td>
<td>CRS</td>
<td>HS vs. DSS</td>
<td>57</td>
<td>2 months</td>
<td>DSS significantly improved, better than HS</td>
<td>DSS - HRQL significantly improved</td>
<td>Ib</td>
</tr>
<tr>
<td>Pinto, 2006 (752)</td>
<td>CRS after ESS</td>
<td>saline vs. HS vs. NT</td>
<td>60</td>
<td>5 postop. days</td>
<td>higher discharge and pain in HS group</td>
<td>not done</td>
<td>Ib</td>
</tr>
</tbody>
</table>

Legend. HS: hypertonic saline; DSS: Dead Sea salt solution; NT: no treatment; ESS: endoscopic sinus surgery; HRQL: health related quality of life.
7-3-8-2 Nasal polyps
A case study (III) by Filiaci et al. has demonstrated significant reduction in the size of nasal polyps after five (weekly) topical applications of capsaicin (30 mmol/L) solution in patients with nasal polyposis (757). The authors noted increased nasal eosinophilia after the treatment, which was not correlated to the polyp size. A case study by Baudoin et al. has demonstrated significant reduction of sinonasal polyposis after 5 consecutive days treatment with increasing doses (30-100 mmol/L) of topical capsaicin in massive polyposis measured by CT scans at entry and after 4 weeks (III) (758). ECP in nasal lavage was not influenced by the treatment. Protection of polyp recurrence following endonasal surgery by 5 topical applications of capsaicin in 51 patient after surgery with a 9 months follow-up has confirmed significant recurrence protection and significantly better nasal patency in the active group in a randomized, double blind, placebo controlled trial by Zheng et al (759). The authors used 70% ethanol 3x10-6E ml capsaicin solution, which may explain the high rate of recurrence in the control group after ESS, which received only 70% ethanol. They noted 40% polyp stage 0 (Malm) and 45% stage 1 in the active treatment group, while controls demonstrated 45% stage 2 and 40% stage 3 polyposis following treatment at 9 months observation. The low cost of capsaicin treatment was noted as a certain advantage compared to other postoperative treatments. As capsaicin is NF kappa B antagonist in vitro, some other modes of action may be proposed (760).

7-3-8-3 Side effects
The most common side effect following nasal capsaicin application, if not previously topically anaesthetized, is severe burning sensation in the nose and lips, and lacrimation. However, previous topical nasal anaesthesia with 10% xylocaine spray in placebo-controlled trial completely blinded the active treatment (761). In the trials of nasal capsaicin treatment for idiopathic rhinitis, some other side effects were reported: dyspnoea, headache, cough, epistaxis, dryness of nasal mucosa and exanthema (762,763).

7-3-9 Furosemide
The protection of the hyper-reactive response to different challenges (propranolol) (764), metabisulphite (765); and exercise (766) in asthmatics was demonstrated after inhalation of furosemide, suggesting bronchoprotective effects, similar to the effect of cromones.

7-3-9-1 Acute and chronic rhinosinusitis without nasal polyps
No trials of treatment of acute or chronic rhinosinusitis with furosemide have been found.

7-3-9-2 Nasal polyps
Protection against nasal polyp recurrence following surgery with 1-9 years follow-up, comparable to the effect of the topical steroid, was demonstrated after topical application of furosemide in 97 patients postoperatively versus mometasone furoate in 33 patients, in a prospective non-randomized controlled trial (IIa) by Passali et al (767), which had been previously reported by the same group in a case study. Relapses were recorded in 17.5% in the furosemide, 24.2% in the mometasone and 30% in the no treatment group, suggesting that furosemide, as a much cheaper medication than steroids, might be considered as a prophylaxis to polyp recurrence.

A recent randomized controlled trial compared the effect of short term pre-operative treatment with oral methylprednisolone (1mg/kg) versus inhalation of 10 ml of 6.6 mmol furosemide solution in 40 patients with nasal polyposis. Both were effective but no difference was found between the two treatment modalities after 7-day treatment, in terms of polyp size reduction on endoscopy, nasal symptom scores (except for olfaction, which was better in steroid group) and intraoperative bleeding. Histological analysis of the polyps at surgery suggested a strong anti-inflammatory effect of oral steroid (in terms of eosinophil count reduction), while furosemide treatment demonstrated only an effect on oedema (768).

Randomized placebo-controlled trials, especially long term treatment, are however lacking.

7-3-10 Proton pump inhibitors
Numerous trials during the past decade indicated an association between extraoesophageal reflux and airway disease, and beneficial effect of PPI treatment on upper airway symptoms, including some symptoms of CRS, was suggested. Postnasal drip, a relevant CRS symptom, was established as one of the symptoms responding to PPI treatment. However, sensation of postnasal drip (PND) was confirmed in groups of patients with idiopathic rhinitis, without evidence of rhinosinusitis, and in patients without rhinitis and sinusitis (769), and greater exposure to gastric acid was demonstrated in patients with PND than in the controls. As PPI treatment reduces acidity, it is a dilemma if PPI acts on rhinitis, rhinosinusitis or sensation of PND. Most reviews on current evidence on the association between reflux and sinus disease advocate higher quality of controlled trials on both etiology and treatment, in pediatric and adult population. As PPI treatment of extraesophageal reflux disease (like laryngitis) is based on long-term high-dose regimen, potential side effects should be considered.

7-3-10-1 Acute rhinosinusitis
There are no trials with proton pump inhibitors for ARS.

7-3-10-2 Chronic rhinosinusitis
There is no evidence for benefits in the general population suffering from rhinosinusitis following treatment with proton pump-inhibitors, although subjective improvement was noted in patients with laryngopharyngeal reflux (proved by pHmetry) and rhinosinusitis. Grade C evidence for a positive association between gastroesophageal reflux and rhinosinusitis was found in a meta analysis of the literature for this co-mor-
bidity (57 articles screened, 14 articles included \cite{778,779}). A number of case trials of rhinosinusitis, especially paediatric \cite{778}, have tested the efficacy of anti-reflux treatment with proton pump inhibitors on the clinical course and symptoms of rhinosinusitis. Increased rates of reflux were detected in CRS in adults unresponsive to standard treatment \cite{772,773}. Further research is expected in this field, and such treatment should be justified by randomized controlled trials. Non-controlled trials, especially in children, indicate the effect on some symptoms of rhinosinusitis, presumably postnasal drip and cough. However, a recent meta-analysis of randomized controlled trials of outcomes of the treatment of non-specific cough with proton pump inhibitors confirmed that it is insufficient evidence to definitely conclude that reflux treatment with PPI is universally beneficial for cough associated with reflux in adults. The beneficial effect was only seen in sub-analysis and its effect was small \cite{774}.

7-3-10-3 Nasal polyps
There are no data on proton-pump inhibitors in nasal polyposis.

7-3-11 Antileukotrienes
Leukotrienes are upregulated in asthma and nasal polyposis, especially in aspirin-sensitive disease.

7-3-11-1 Acute rhinosinusitis
No trials were done on the antileukotrienes treatment in ARS.

7-3-11-2 Chronic rhinosinusitis and nasal polypos
Open studies suggest that anti-leukotrienes might be of benefit in nasal polyposis \cite{779,780,781}. Antileukotriene treatment in 36 patients with CRS with or without NP, added to standard treatment, resulted in statistically significant improvement in scores for headache, facial pain and pressure, ear discomfort, dental pain, purulent nasal discharge, postnasal drip, nasal congestion and obstruction, oifaction, and fever. Overall improvement was noted by 72% of the patients and side-effects occurred in 11% of the patients \cite{779}. In a selected group of 15 ASA triad patients, addition of antileukotriene treatment resulted in 9/15 with sinusitis experiencing improvement and over-all benefit in 12/15 patients, which was confirmed by endoscopy \cite{781}. In a group of patients with nasal polyposis, significant subjective improvement in nasal symptoms occurred in 64% aspirin tolerant patients and 50% aspirin sensitive patients. Significant improvement in peak flow occurred only in aspirin tolerant patients, while acoustic rhinometry, nasal inspiratory peak flow and nitric oxide levels did not change \cite{779}. A prospective double blind comparative study on 40 patients compared the effects of the leukotriene receptor antagonist, montelukast and beclomethasone nasal spray on the post-operative course of patients with sinonasal polypos. No significant differences were found between these two post-operative treatments in the year after surgery \cite{781}.

Results of these studies indicate that there is a need for (larger) controlled trials of antileukotriene treatment in CRS with or without NP.

7-3-12 Aspirin desensitization

7-3-12-1 Acute and chronic rhinosinusitis without nasal polypos
No controlled trials of aspirin desensitization treatment for acute and chronic rhinosinusitis were found.

7-3-12-2 Chronic rhinosinusitis and nasal polypos with aspirin intolerance
Systemic aspirin desensitisation or topical lysine-aspirin treatment (the only truly soluble form of aspirin) may be implicated in protection against chronic rhinosinusitis with nasal polypsis recurrence. Sixty-five aspirin-sensitive patients with aspirin sensitive asthma underwent aspirin challenge, followed by aspirin desensitization and daily treatment with aspirin over 1 to 6 years (mean, 3.1 years). There were significant reductions in numbers of sinus infections per year and an improvement in olfaction. Numbers of sinus and polyp operations per year were significantly reduced and doses of nasal corticosteroids were significantly reduced. There were reductions in hospitalizations for treatment of asthma per year and reduction in use of systemic corticosteroids \cite{770,771,772}.

Nucera et al. have followed three groups of patients with nasal polyposis (about 50% aspirin sensitive), the first with 76 consecutive nasal polypectomy patients who had a topical lysine-acetylsalicylate-therapy afterwards, the second 49 patients with 40 mg triamcinolone retard (“medical polypectomy”) and also further lysine-acetylsalicylate-therapy and the third with 191 control patients who underwent only polypectomy but received no placebo. The group treated with lysine-acetylsalicylate postoperatively had a recurrence rate of 6.9% after 1 year and 65% after six years postoperatively, while controls experienced recurrence in 51.3% at 1 year and 93.5% at six years after the operation, indicating a significant protection against recurrence from the lysine-acetyl salicylate treatment. Systemic corticoid therapy and nasal lysine-acetylsalicylate-therapy resulted in 33% with unchanged polyp size after three years compared to 15% in the operated-not treated group, but this was not statistically significant \cite{782}.

A case controlled trial of treatment with lysine aspirin to one nostril and placebo to the other in 13 patients with bilateral nasal polyposis resulted in delayed polyp recurrence and 8 remained symptom free at 15 months observation period, which was significantly better than results of the patients previously treated with steroid for recurrence protection. Endoscopy and acoustic rhinometry indicated minor polyp size on the aspirin treated side \cite{783}.
A double blind, randomized, placebo controlled trial did not demonstrate any effect on nasal airway using 16mg of intranasal lysine aspirin every 48 hours, compared to placebo treatment, in aspirin sensitive patients, after 6 months treatment (786). Outcomes included subjective symptom scores, acoustic rhinometry, PNIF and PEF. However, final outcomes were analysed in only 11 available patients, and pathohistologic analysis revealed significant decrease of CylLT 1 receptor in the turbinate mucosa of the patients with active treatment, compared to placebo, so further trials were suggested. However, addition of intranasal lysine aspirin in doses up to 50mg daily to routine therapy reduced polyp size and did not adversely affect asthma (Ogata N, Darby Y, Scadding G. Intranasal lysine-acetylsalicylate (LAS) administration decreases polyp volume in patients with aspirin intolerant asthma. J Laryngol Otol 2007 in press). The mechanisms of desensitisation probably involve reduction of leukotriene receptors (392).

7-3-13 Phytopreparations
Treatment of rhinosinusitis by alternative medicine, including herbal preparations is common in the general population. A study by interview in a random telephone sample population suffering from CRS and asthma revealed that 24% were taking herbal preparation (787). Lack of randomized controlled trials comparing such treatment to standard medication in rhinosinusitis patients should be a concern to health care providers.

7-3-13-1 Acute rhinosinusitis
A standardized myrtol oil preparation was proven superior to other essential oils, and both were superior to placebo in a RCT for uncomplicated ARS. A need for antibiotic treatment after myrtol was 23%, compared to 40% for placebo (788). With Andrographis paniculata in a fixed combination, Kan Jang showed significantly improved nasal symptoms and headache in ARS compared to placebo (789).

7-3-13-2 Chronic rhinosinusitis
Guaifenesin, a phytopreparation known for its mucolytic properties, was tested in a RCT on a selected population of HIV patients with CRS, demonstrating 20% higher improvement in subjective scores compared to placebo in this population (790).

7-3-13-3 Nasal polyps
No controlled trials on nasal polyp treatment with phytopreparations were found.

7-3-14 Anti-IL-5 antibodies
The first small study using humanized mouse anti-IL-5 antibodies in patients with nasal polyps (791) showed no significant treatment effect. However it indicated that local IL-5, but not IL-5 receptor concentrations, predicted the clinical response.

7-3-15 Conclusion
The results are summarized in the next table.

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### Table 7-14. Other medical management for rhinosinusitis. Results from the treatment studies summarised

<table>
<thead>
<tr>
<th></th>
<th>acute</th>
<th>chronic without nasal polyps</th>
<th>chronic with nasal polyps</th>
</tr>
</thead>
<tbody>
<tr>
<td>treatment</td>
<td>study</td>
<td>level of evidence</td>
<td>clinical importance</td>
</tr>
<tr>
<td>decongestant</td>
<td>1 RCT, 1 CT</td>
<td>Ib (−)</td>
<td>no.</td>
</tr>
<tr>
<td>mucolytic</td>
<td>2 RCT</td>
<td>Ib (one +, one −)</td>
<td>no</td>
</tr>
<tr>
<td>phytotherapy</td>
<td>1 RCT</td>
<td>Ib (−)</td>
<td>no</td>
</tr>
<tr>
<td>immuno-mo-</td>
<td>no trial</td>
<td>none</td>
<td>no</td>
</tr>
<tr>
<td>dulator</td>
<td>1 RCT allergic</td>
<td>yes (in allergic only)</td>
<td>no trial</td>
</tr>
<tr>
<td>antileukotriene</td>
<td>no trial</td>
<td>none</td>
<td>no</td>
</tr>
<tr>
<td>proton pump inhibitor</td>
<td>no trial</td>
<td>none</td>
<td>no</td>
</tr>
<tr>
<td>lysine aspirin desensitisation</td>
<td>no trial</td>
<td>none</td>
<td>no</td>
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<tr>
<td>furosemide</td>
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<td>none</td>
<td>no</td>
</tr>
<tr>
<td>capsaicin</td>
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<td>none</td>
<td>no</td>
</tr>
<tr>
<td>anti-IL-5</td>
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<td>no</td>
</tr>
</tbody>
</table>

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### 7-4 Evidence based surgery for rhinosinusitis

7-4-1 Introduction
In this chapter, systematic reviews on sinus surgery efficacy in CRS are first presented, followed by a description of comparative trials of sinus surgery with medical treatment. The role of various surgical modalities is then briefly reviewed, and reports on the
effects of concomitant diseases on sinus surgery outcomes are detailed. There is evidence that CRS with and without polyps are distinct subgroups of chronic inflammatory diseases of the upper airway mucosa (see chapters 2 to 4). Approximately 20% of patients with CRS develop nasal polyps \(^{(797)}\), which may predispose to less favourable results of sinus surgery \(^{(798, 799)}\). Accordingly, reviewed articles are grouped into CRS without polyps and CRS with polyps, when the authors differentiated between these two subgroups. Except for a few reports on limited sinus surgery in recurrent ARS \(^{(800)}\), sinus surgery is generally restricted to chronic rhinosinusitis (CRS). Therefore, currently available data do not suffice to judge the role of surgery in acute or acute recurrent rhinosinusitis. For surgical interventions in complications of ARS see chapter 8, for paediatric sinus surgery see chapter 9, for a detailed description of complications of sinus surgery refer to chapter 7, and for postoperative medical treatment please refer to chapter section 7-1-5.

It is difficult to generalise about sinus surgery studies because surgery is indicated in selected patients who are not sufficiently responsive to medical treatment. Moreover, only a few publications on sinus surgery qualify for evidence based evaluation \(^{(801)}\) and frequently studies included in systematic reviews are assigned low evidence levels \(^{(798, 799)}\). This is in part due to specific problems in conducting surgical trials. In general, surgery is difficult to estimate or standardise, particularly in multi-centre trials, and the type of treatment is difficult to conceal (blinding). Randomization may pose ethical problems unless narrow inclusion criteria are set \((514)\). Low budget investigator initiated trials not monitored by professional clinical research organisations are the rule.

In addition, a variety of confounders make it difficult to obtain homogenous patient groups with comparable therapeutic procedures for unbiased evaluation of sinus surgery outcomes. Possible relevant surgical factors include whether an external or endonasal approach is chosen, whether a functional or conventional surgical procedure is selected, if the extent of the surgical intervention is limited, extended or radical, and what kind of instruments are employed. Patient dependent factors include age, extent and duration of disease, previous surgery, presence of polyps, concomitant diseases such as ASA-intolerance, asthma, or cystic fibrosis, and particular aetiologies including dental, autoimmune, immune, and fungal disease \((800-803)\). Moreover, mode and duration of pre- and post-operative drug therapy may alter the outcome.

7-4-2 Effectiveness of sinus surgery and comparison with medical treatment

7-4-2-1 Systematic reviews and outcomes research on sinus surgery effectiveness

Several reviews did not differentiate between CRS with and without polyps such as Terris and Davidson who analysed 10 case series. Patients' judgement of outcome using an unbalanced three item verbal rating scale was employed \(^{(804)}\). A 'very good' result was defined as complete resolution of symptoms or less than 2 rhinosinusitis episodes per year, a 'good' result was improvement but without complete resolution of symptoms or 2-5 sinusitis episodes per year, and a 'poor' result was no improvement or deterioration. Articles reporting a total of 1,713 patients were evaluated. Subjectively, 63% of patients reported a very good result, 28% a good result, and 9% an unsatisfactory result. Twelve percent of patients required revision surgery and complications occurred in 1.6% of patients. With 1.5%, bleeding was most the most common complication (level IV).

In a systematic review, 12 case series of endoscopic sinus surgery were evaluated and compared with 6 case series of conventional techniques \(^{(797)}\). In patients with CRS with or without polyps, overall success rates ranging from approximately 70% to 90% after sinus surgery were reported. Revision surgery was reported in 7% to 10%. If reported, complications were below 1% (level IV).

In a recent meta-analysis, the impact of endoscopic sinus surgery on sinus symptoms and quality of life was evaluated in adults after failed medical treatment \(^{(800)}\). Articles dealing with both or not differentiating between CRS with and without polyps were included. Forty-five of 886 screened articles were included for full review. The reasons for exclusion were not detailed. Of the included articles, 1 article qualified for level II evidence, 42 for level IV evidence and 2 for level V evidence. The authors conclude that there is substantial level IV evidence with supporting level II evidence that endoscopic sinus surgery is effective in improving symptoms and QoL in adult patients with CRS.

In a recent Cochrane review, 3 randomized controlled sinus surgery studies were included\(^{(805)}\). The authors conclude that FESS, as practiced in the included trials, is not superior to medical treatment with or without sinus irrigation in patients with CRS.

7-4-2-1-1 CRS without polyps

In 2000 the Clinical Effectiveness Unit of the Royal College of Surgeons of England conducted a National Comparative Audit of the Surgery for Nasal Polyposis and Chronic Rhinosinusitis covering the work of 298 consultants working in 87 hospital sites in England and Wales \(^{(821)}\). Patients undergoing sinus surgery were prospectively enrolled and followed up in this observational study at 3, 12 and 36 months post-operatively using the SNOT-22 as the main outcome measure. One third \((321)\) of the 3128 patients participating in this study had CRS without nasal polyps and 2176 suffered from CRS with polyps. Outcomes are reported separately for the two rhinosinusitis subgroups. CRS-patients without polyps less frequently suffered from concomitant asthma and ASA-intolerance, had less previous sinonasal surgery, their mean CT score was lower and their mean SNOT-22 symptom score was slightly higher than that of CRS patients with polyps. All forms of sinus surgery...
were considered though the majority were performed endoscopically. Overall there was a high level of satisfaction with the surgery and clinically significant improvement in the SNOT-22 scores were demonstrated at 3, 12 and 36 months. Revision surgery was indicated in 4.1% at 12 months and 10.4% at 36 months (Level IIc).

In addition to this outcomes research study, 2 recent case series are also presented to supplement outcome data on CRS without polyps. In a retrospective analysis, 123 patients with CRS without nasal polyps who underwent primary FESS with a minimum 1-year follow-up period were evaluated \(^{807}\).

Outcome parameters included the Sino-Nasal Outcome Test (SNOT-20) questionnaire, the Lund-Mackay CT-scoring system, and the need of revision surgery. SNOT-20 scores were 26.5 preoperatively with significant improvement to 5.1 at 6 months and 5.0 at 12 months postoperatively (85% improvement) (level IV). In a case series of 77 patients with CRS without polyps, symptom and endoscopy scores were followed between 3 and 9 years after FESS \(^{808}\). Saline douches and nasal steroids were postoperatively administered as required. After at least 3 years, more than 90% of the patients reported symptom improvement of 80% or more. Revision surgery was performed in 15%. At the end of the follow up period, 5 patients (7%) received nasal steroids.

7-4-2-1-2 CRS with polyps

Within the framework of the NHS R&D Health Technology Assessment Programme, the clinical effectiveness of functional endoscopic sinus surgery to treat CRS with polyps was reviewed. The authors screened 444 articles and evaluated 33 articles published between 1978 and 2001 \(^{809}\). Major reasons for exclusion were the narrative character of the publication or less than 50 patients with polyps. The authors reviewed 3 RCT studies comparing different surgical modalities (n=2699), 3 non-randomized studies comparing functional sinus surgery with Caldwell Luc or conventional endonasal procedures (n=240), 3 non-randomized studies also comparing different surgical modalities (n=2699) and 27 case series (n=8208). Consistently, patients judged their symptom ‘improved’ or ‘greatly improved’ in 75 to 95 percent (level IV). The percentage of overall complications was 1.4% for FESS compared to 0.8% for conventional procedures.

Two thirds (2176) of the 3128 patients participating in the National Comparative Audit had CRS with nasal polyps \(^{821}\). CRS patients with polyps had no longer duration of disease, no higher previous steroid treatment, nor ratings of their general health before surgery than CRS patients without polyps. Irrespective of extent of surgery, clinically significant improvement in the SNOT-22 scores were demonstrated at 3, 12 and 36 months. Polyp patients benefited more from surgery than the chronic rhinosinusitis without polyps. Revision surgery was indicated in 3.6% at 12 months and 11.8% at 36 months. Major complications were rare (Level IIc). In this context, a case series study of CRS patients with particularly extensive polyposis is worth mentioning \(^{822}\). Of the 118 patients reviewed, 59 (50%) had asthma, and 93 (79%) had documented allergy. All patients received extensive bilateral nasal polypectomy, complete anterior and posterior ethmoidectomy, and maxillary sinusotomy. One hundred (85%) also had frontal or sphenoid sinusotomy. Follow-up ranged from 12 to 168 (median 40) months. Despite pre- and postoperative nasal and systemic steroid treatment in the majority of patients, 71 (60%) developed recurrent polyposis, 55 (47%) were advised to undergo revision surgery, and 32 (27%) underwent revision surgery. History of previous sinus surgery or asthma predicted higher recurrence and revision surgery rates. History of allergy also predicted recurrence and need for revision.

Conclusion: One major outcomes research study (level II) and more than a hundred reviewed case series (level IV) with highly consistent results suggest that patients with CRS with and without polyps benefit from sinus surgery. Major complications occur in less than 1%, and revision surgery is performed in approximately 10% within 3 years.

7-4-2-2 Combined surgical and medical treatment vs. sole medical treatment

CRS may be cured with medical treatment alone. Moreover, sinus surgery is almost always preceded and/or followed by various forms of medical treatment including nasal douches, nasal steroids, systemic steroids, and systemic antibiotics. Few studies compared sinus surgery, which was always combined with medical treatment, with medical treatment alone. In two studies, CRS patients with and without polyps were not differentiated.

In a prospective trial, 160 CRS patients with or without polyps were enrolled and treated with either medical therapy alone or medical therapy plus endonasal sinus surgery \(^{846}\). Group allocation was not randomized and the non-surgical cohort had less males, less concomitant diseases, less polyps, and less severe disease. Outcome parameters included the SF-36 and Chronic Rhinosinusitis Survey (CSS) questionnaire. At follow up after 3 months, the surgically treated group improved more than the non-surgically treated group, however, improvement was not adjusted for pre-treatment scores (level IV).

In a prospective observational study conducted by the Cooperative Outcomes Group for ENT of the American Academy of Otolaryngology – Head and Neck Surgery, 31 otolaryngologists enrolled 276 CRS patients with or without polyps \(808\). Follow up was 207, 164 and 117 patients after 3, 6 and 12 months, respectively. Success was defined as 40% or more improvement in a subset of the CSS. Based on judgment of the participating physicians, 83 patients received functional endoscopic sinus surgery and 118 patients received medical treatment only. Surgically treated patients had a 3 times higher chance for success than patients treated only medically (p<0.01), however, this disproportion disappeared when corrected for baseline CSS-scores in a logistic regression approach (level IV).
7-4-2-2-1 CRS without polyps
In a prospective, randomized, controlled trial, Ragab and coworkers enrolled 90 patients with CRS \(^{(536)}\). Of the 90 included patients, 55 suffered from CRS without polyps and are reported separately. During a run in phase, all patients received a 6-week regimen of dexamethasone-21-isonicotinate and trazamaloyl hydrochloride (DRS) spray and an alkaline nasal douche. Patients who remained symptomatic after this treatment were then randomized to a medically or a surgically treated arm. In the medically randomized group, all patients received a 12-week course of erythromycin, alkaline nasal douche, and intranasal corticosteroid preparations. In the surgically randomized group, FESS was performed tailored to the extent of disease. After endoscopic sinus surgery, all patients were prescribed a 2-week course of erythromycin, DRS spray, and alkaline nasal douche, followed by a 3-month course of fluticasone propionate intranasal spray. After that, topical corticosteroid spray was given as needed. Outcome parameters included the SNOT-20, SF-36, nasal NO and acoustic rhinometry measurements. At follow up visits after 6 months and at 1 year, significantly improved outcome parameters were observed in both treatment arms, with no significant difference being found between the medical and surgical groups (P>0.05), except for the rhinometrically assessed total nasal volume, in which the surgical treatment demonstrated greater improvements (Level Ib).

7-4-2-2-2 CRS with polyps
In an open, randomized trial, Lildholdt and co-workers included 53 patients with nasal polyps \(^{(540)}\). All patients received nasal steroid spray during the 12 month study period. Snare polypectomy was additionally performed in 26 patients, whereas 27 patients received an intramuscular depot betamethasone injection. After 1 year, no relevant difference in the main outcome parameters including sense of smell, PNIF, and disease recurrence were observed (level Ib). In a second open RCT, Lildholdt and co-workers included 34 patients with nasal polyps who did not improve after participation in a preceding placebo controlled trial comparing two doses of intranasal budesonide \(^{(536)}\). Sixteen patients received a single depot injection of 14 mg betamethasone and 18 patients underwent intranasal snare polypectomy. Outcomes were assessed after 11 months additional nasal steroid treatment and again after 12 months without any treatment. Snare polypectomy and systemic betamethasone outcome 12 months after treatment were remarkably similar as measured by mean nasal improvement score, polyp score or mean score of sense of smell (P>0.05). Within 1 year without nasal steroid treatment, 50% of the patients experienced further nasal polyps, however the authors did not differentiate polyp recurrence by medical or surgical treatment (level Ib).

In a study by Blomqvist and coauthors, 32 CRS patients with polyps were pretreated with systemic steroids (prednisolone for fourteen days) and budesonide for 4 weeks \(^{(539)}\). Thereafter, FESS was performed on one side while the other side remained untouched employing a randomized prospective matched samples design. Following surgery, intranasal steroids were given for an additional 12 months on both sides. The sense of smell was tested for each nostril separately. It improved after treatment with systemic and topical steroids without additional improvement on the operated side. Surgery had an additional beneficial effect on nasal obstruction and secretion that persisted over the study period. However, 25% percent of the patients required surgery also on the yet unoperated side. The authors conclude that surgical treatment is indicated after steroid treatment, if nasal obstruction persists but not if hyposmia is the primary symptom (Level Ib).

In the prospective, randomized, controlled trial by Ragab and co-authors already described \(^{(536)}\), 35 CRS patients with polyps remained symptomatic after a 6-week intensive medical regimen and were randomized into the study. At follow up visits after 6 months and at 1 year, both treatment arms reported significantly improved outcome parameters, with no significant difference being found between the medical and surgical groups (P>0.05), except for the total nasal volume, in which the surgical treatment demonstrated greater improvements (Level Ib).

In a recent RCT, 109 patients with CRS with extensive nasal polyps were included \(^{(537)}\). Fifty-three patients were randomly allocated to receive oral prednisone for 2 weeks (30 mg/day for 4 days followed by a two days reduction of 5 mg) and 56 to undergo endoscopic sinus surgery. All patients additionally received intranasal budesonide for 12 months. Patients were evaluated for nasal symptoms, polyp size, and QoL employing the SF-36 questionnaire. At 6 and 12 months, a significant improvement in all SF-36 domains, nasal symptoms and polyp size was observed after both medical and surgical treatment. A significant advantage for the surgically treated group was observed for nasal obstruction, loss of smell and polyp size 6 months after randomization and for polyp size also 12 months after randomization (level Ib).

Conclusion: In the majority of CRS patients, appropriate medical treatment is as effective as surgical treatment. Sinus surgery should be reserved for patients who do not satisfactorily respond to medical treatment.

7-4-3 Surgical modalities
7-4-3-1 Endonasal versus external approach
Endonasal approaches include surgical procedures performed through the nostril, irrespective of the extent of surgery and the kind of visualization of the surgical field. Today, endonasal procedures are predominantly performed employing endoscopes. The most commonly performed external surgical procedures include the sublabial transfacial Caldwell Luc approach with or without transantral ethmoidectomy and sphenoidecetomy, and transfacial frontoethmoidectomy. In a few
studies, outcomes of external and transnasal procedures were compared though not differentiating between CRS patients with and without polyps. Penttila and co-workers randomized 150 CRS patients after failed antimicrobial therapy and antral irrigations for chronic maxillary sinusitis to either endonasal endoscopic sinus surgery \((n=75)\) or an external Caldwell Luc approach \((n=75)\). The percent changes of symptom scores before and one year following surgery were evaluated (Level Ib). Functional endoscopic sinus surgery revealed significant advantages in the relief of nasal obstruction, hyposmia and rhinorrhea, but not facial pain. Patients overall judgement and rate of complication also significantly favoured the endonasal approach \((816, 818)\). The study population was re-evaluated 5 to 9 years later with 85% of the former study participants responding to a questionnaire. In both surgical groups, approximately 80% were asymptomatic or distinctly improved without relevant intergroup differences \((812)\). However, postoperative cheek pain and paresthesia were noted in 23% of Caldwell Luc group, which is a frequent complication of this approach \((813)\). The histopathology of maxillary sinus specimens obtained before and 1 year after surgery from patients of the two treatment arms of the Penttila-studies were evaluated by Forsgren et al., indicating a greater reduction in inflammatory parameters in the mucosa of the maxillary sinus after the Caldwell-Luc approach \((814)\). In a retrospective evaluation, Unlu and coauthors randomly selected 37 Caldwell-Luc-operated and 40 endonasally operated patients. Outcome was assessed with nasal endoscopy and CT-scans \((815)\). CT was normal in 12% of Caldwell-Luc-operated patients in comparison to 75% of endoscopically operated patients. Endoscopy revealed a patency rate of the antral window in 48% Caldwell-Luc-operated and 86.7% in endonasally operated patients. The authors conclude superiority of the endonasal approach. (Level IV).

Videler and co-authors treated 23 CRS patients refractory to repeated endonasal procedures, Caldwell Luc and intensive medical treatment via an Caldwell Luc approach with removal of the medial maxillary wall \((817)\). Clinical improvement was observed the majority of patients (level IV).

7-4-3-1-1 CRS without polyps

No studies comparing endonasal surgery with external fontoethmoidectomy or Caldwell-Luc approach in patients with CRS without polyps were found.

7-4-3-1-2 CRS with polyps

No studies comparing endonasal surgery with external fontoethmoidectomy were identified. In several studies, endonasal sinus surgery was compared with the Caldwell-Luc approach in CRS patients with polyps. In the NHS R&D Health Technology Assessment Programme evaluation, an overall symptomatic improvement was reported in approximately 80% after endoscopic sinus surgery and in 43 to 84% after conventional surgery including Caldwell Luc. Disease recurrence was 8% for FESS compared to 14% for Caldwell-Luc approach \((806)\). McFadden and co-workers evaluated the long term outcome (up to 11 years) in 25 patients with extensive nasal polyps and ASA-intolerance. Sixteen patients were operated via an extended endonasal approach and 9 via a Caldwell Luc approach with radical sphenoidectomy. Of the endonasally operated patients, 6 underwent a revision surgery via a Caldwell Luc approach whereas none of the patients who had received a Caldwell Luc approach initially was reoperated \((822)\).

Conclusion: Long term symptom relief in chronic sinusitis can be obtained by the endonasal endoscopic and the Caldwell-Luc approach, however, results favour the endonasal approach. The Caldwell-Luc approach carries a higher risk of early postoperative facial swelling and infraorbital nerve irritation. Comparative studies of endonasal versus external frontoethmoid approaches are currently not available.

7-4-3-2 Conventional endonasal surgery versus functional endonasal sinus surgery

Conventional sinus surgery is a collective term for surgical techniques already used before the devlopment of functional sinus surgery. They include external approaches, maxillary sinus irrigation, simple (snare) polypectomy, inferior meatal antrostomy, and radical transnasal sphenoido-ethmoidectomy with or without middle turbinate resection. Unlike functional techniques, conventional sinus procedures do not proceed along the natural pathways of sinus ventilation and mucociliary transport revealed by the fundamental work of Messerklinger \((816)\). Restoring ventilation and mucociliary transport by functional surgery along the natural ostia allows recovery of the diseased sinus mucosa, which is not resected \((817, 818)\). Concurrently with the development of the functional approach, rigid endoscopes became available, which improved visualization during endonasal surgery. The evolving concept of functional endoscopic sinus surgery (FESS) spread worldwide by the efforts of Stammberger and Kennedy \((819, 820)\). In two studies, a conventional approach was compared with functional sinus surgery in CRS patients with or without polyps. In a prospective controlled trial, Arnes and coauthors performed an inferior meatal antrostomy on one side and a middle meatal antrostomy in the opposite nasal cavity in 38 patients with recurrent acute or chronic maxillary sinusitis \((821)\). The laterality was randomized. After an observation period ranging between 1 and 5 years, no significant side differences in symptom scores or radiological findings were observed (level Ib).

In a randomized controlled trial, 25 patients after functional endoscopic sinus surgery were compared with 25 after conventional surgery. Conventional surgery included antral puncture, intranasal ethmoidectomy, and Caldwell-Luc procedures. Follow up ranged from 15-33 months with a mean of 19 months, at the end of which 76% of the functional group had
complete relief of symptoms, 16% partial relief and 8% no relief as compared to 60%, 16%, 24% in the conventionally treated group \(^{(822)}\). However, this study is flawed by an elusive method of randomization, lack of information on homogeneity of patients groups, and high variability of procedures performed. (no level applied).

7-4-3-2-1 CRS without polyps
Eighty-nine patients with chronic sinusitis confined to the maxillary sinus without nasal polyps were enrolled in a prospective randomized controlled trial \(^{(823)}\). After antibiotic therapy for at least 4 weeks prior to inclusion, 45 patients received sinus irrigation only and 44 patient sinus irrigation followed by FESS. Patients were followed in regular intervals up to one year. The per protocol analysis included 36 ‘irrigation only’ and 41 ‘irrigation and FESS’ patients. In 13 ‘irrigation only’ patients and 2 ‘irrigation and FESS’ patients, second surgery was performed due to lack of efficacy (p<0.001). Moreover, outcomes for purulent discharge and loss of smell showed significant improvement in ‘irrigation and FESS’ group as compared with those obtained by sinus irrigation alone after one year’s observation. Scores for other sinusitis symptoms did not differ significantly between the groups (Level Ib).

7-4-3-2-2 CRS with polyps
In the NHS R&D Health Technology Assessment Programme evaluation \((806)\), polyp recurrence was 28% following functional-endoscopic ethmoidectomy compared to 35% following intranasal polypectomy. The percentage of overall complications was 1.4% for FESS compared to 0.8% for conventional procedures.

Hopkins and co-workers analyzed 1848 patients with nasal polyps, a subgroup of 3128 patients who participated in the National Comparative Audit of Surgery for Nasal Polyposis and Rhinosinusitis \(^{(826)}\). The authors compared the SNOT-20 supplemented with two additional items (SNOT-22) after simple polypectomy and after more extensive surgery both largely performed endoscopically in addition to medical treatment. The SNOT-scores did not differ significantly between the two treatment arms after 12 and 36 months, if adjusted for relevant confounders. Revision surgery was carried out more frequently in the polypectomy only group in the first 12 months after surgery (p=0.04), but this difference was not significant at 36 months. Complication rates did not differ significantly.

Conclusion: Functional endoscopic surgery is superior to minimal conventional procedures including polypectomy and antral irrigations, but superiority to inferior meatal antrostomy or conventional sphenoidectomy is not yet proven.

7-4-3-3 Extent of surgery
Extent of surgery may vary from mere uncinectomy to radical sphenoidectomy with middle turbinate resection. In several studies, the extent of sinus surgery on various outcome parameters was investigated in CRS patients, not differentiating between CRS with and without polyps. In a prospective trial, 65 CRS patients with and without polyps were randomized to undergo limited endonasal functional surgery (infundibulectomy) and a more extensive functional procedure including sphenoidectomy and wide opening of the frontal recess. Disease extent was similar in both treatment arms. Outcome parameters included symptom scores, rhinoscopy scores and nasal saccharin transport time \(^{(825)}\). Recall rates were below 60%. Outcome parameters revealed no relevant differences after 3, 6 and 12 months (level Ib).

Based on the concept that diseased sinus prechambers, not small sinus ostia, are the cause for chronic sinus inflammation, minimal invasive sinus surgery (MIST) is advocated by some authors \(^{(820)}\). Basically, sinus ostia are exposed during MIST, but not enlarged. In a prospective, uncontrolled trial, Catalano and Roffman followed 85 patients with CRS for a mean 24 months. Changes in the CSS score served as outcome parameter and revealed significant improvements similar to FESS studies (level IV).

Some authors advocate partial resection of the middle turbinate to expand the surgical approach \(^{(827)}\), while others modify it only in case of abnormalities and leave as much as possible of the middle turbinate intact as a landmark in case revision surgery is needed \(^{(817)}\). In a retrospective evaluation including 100 FESS patients, Giacchi and coauthors preserved the middle turbinate on one side and partially resected it on the other side \(^{(828)}\). The authors observed no side differences in the outcome parameters studied (level Ib).

In a randomized trial, 1,106 matched CRS patients with and without polyps, who underwent similar functional endonasal sinus surgery with (509 patients) or without (597 patients) partial middle turbinate resection \(^{(829)}\). Partial middle turbinate resection was associated with less synchia formation (p<0.05) and less revision surgeries (p<0.05) than middle turbinate preservation. Complications particularly caused by partial middle turbinate resection were not observed (level Ib).

In a prospective, randomized trial, uncinctomy was performed in 295 patients with chronic maxillary sinusitis. In 140 patients, a large middle meatal window (diameter > 16 mm) was either unilaterally or bilaterally created, whereas in 140 patients small middle meatal antral windows (diameter < 6 mm) were produced. In 170 patients, no preoperative CT was available. Follow up visits were attended by 133 (45%) patients 12 to 38 months after surgery. Outcome parameters included patients judgment of symptom change (absent, improved, unchanged, worsened) and various endoscopic findings. Symptom relief, endoscopy findings and antral window size did not depend on the surgically created antral window diameter \(^{(830)}\).

7-4-3-3-1 CRS without polyps
No reports comparing less or more extensive surgical procedures explicitly in CRS patients without polyps could be identified.

7-4-3-3-2 CRS with polyps
The patency rate after large middle meatal antrostomy and undisturbed maxillary ostium in endoscopic sinus surgery for nasal Polyposis was compared in 60 patients with bilateral nasal polyps and chronic maxillary sinusitis \(^{(31)}\). A large middle meatal antrostomy was performed on one side, whereas on the other side an uncinctomy preserving the natural maxillary ostium was done. The sides were chosen randomly. The patency rates of a large middle meatal antrostomy were significantly higher 3 months after surgery when compared with undisturbed maxillary ostium. This difference became insignificant after 12 months (level IV).

Jankowski and co-authors retrospectively compared a case series of 37 CRS patients with extensive nasal polyps treated with FESS with a historical group of 36 patients with similar disease extent treated with radical sphenoethmoidectomy and middle turbinate resection \(^{(20)}\). Outcome parameters assessed 5 years following surgery included a mailed questionnaire on nasal symptoms, the number of patients with revision surgery, and nasal endoscopy scores at a follow up visit. Recall was below 80% and differed significantly between the two groups. The radical surgical procedure yielded better symptom scores, less recurrences, and better endoscopy scores at the follow up visit (level IV).

Conclusion: In CRS patients not previously operated, extended surgery does not yield better results than limited surgical procedures. Although not based evidence, the extent of surgery is frequently tailored to the extent of disease, which appears to be a reasonable approach. In primary parasinal surgery, surgical conservatism is recommended.

### 7-4-3-4 Revision surgery

Approximately 10% operated patients respond insufficiently to sinus surgery with concomitant medical therapy and eventually require a secondary surgical procedure \(^{(37)}\). Middle turbinate lateralisation, synechiae and scar formation in the middle meatus, an incompletely resected uncinate process, and retained ethmoid cells are frequent findings in patients undergoing revision surgery \(^{(204,205)}\). Previous revision surgery, extensive polyps, bronchial asthma, ASA-intolerance and cystic fibrosis are predictors for revision surgery \(^{(76,80,437,440)}\). Inflammatory involvement of underlying bone may also be of significance \(^{(239)}\). Technical issues of sinus revision surgery have recently been reported by Cohen and Kennedy \(^{(241)}\). A more extensive surgical procedure and also external approaches may be indicated \(^{(73,82,420)}\). Success rates of revision endoscopic sinus surgery has been reported to range between 50 and 70% \(^{(114,115)}\) (level IV). Complication rates of revision surgery are higher when compared with initial surgery and approximate 1%, but may be as high as 7% \(^{(157,340)}\).

#### 7-4-3-4-1 CRS without polyps

In a case series of CRS patients without polyps, 15% were surgical revisions \(^{(250)}\). These patients had higher CT scores before their initial surgery and also before the revision surgery than patients undergoing primary surgery (level IV). McMains and Kountakis reported a series of 125 patients with a follow up of at least 2 years after revision endonasal sinus surgery \(^{(239)}\). Outcome parameters included the SNOT-20 and an endoscopy score. Of these patients, 66 suffered from CRS without nasal polyps. These patients experienced a significant improvement of their outcome parameters comparable with the results after primary surgery reported in other trials (level IV).

#### 7-4-3-4-2 CRS with polyps

McMains and Kountakis also reported the results of 59 CRS patients with nasal polyps after revision surgery \(^{(335)}\). Consistent with the results of the National Comparative Audit \(^{(296)}\) and the comparative study by Deal and co-workers \(^{(79)}\), CRS patients with polyps had lower SNOT scores preoperatively (less severe symptoms), more previous surgeries, and a higher CT score preoperatively than CRS patients without polyps. However, the improvement of outcome parameters after revision surgery was significant and comparable with the improvement in CRS patients without polyps.

Conclusion: Revision endonasal sinus surgery is only indicated, if medical treatment is not sufficiently effective. Substantial symptomatic improvement is generally observed in both, CRS with and without polyps, though the improvement is somewhat less than after primary surgery. Complication rates and particularly the risk of disease recurrence are higher than after primary surgery. Some patients still suffer from CRS symptoms after several extensive surgical procedures. CT scans frequently show mucosal alterations adjacent to hypersclerotic bony margins in an extensively operated sinus system. As a rule, revision surgery is not indicated in these patients.

### 7-4-3-5 Instruments

In recent years, numerous instruments have been developed for sinus surgery. Cutting forceps may improve controlled mucosal resection and help to avoid mucosal tearing. Powered instruments may facilitate controlled resection, particularly of large nasal polyps. Continuous suction/irrigation of microdebriders improve visualisation of the surgical field. Moreover, lasers have been employed for mucosal excisions and bone ablation. Given the number of devices available, only a few comparative studies have been published. In these reports, CRS patients with and without polyps were not differentiated.

#### 7-4-3-6 Cutting instruments

In a prospective double blind trial, 100 consecutive patients were followed after endoscopic sinus surgery \(^{(242)}\). Cutting forceps had been randomly used on one side and non-cutting forceps on the other side. Lateralised symptoms (headache, maxillary pressure, nasal obstruction and secretions) and endoscopic findings (secretion, pus, blood, crusts, oedema, polyps and adhesions) were evaluated on both sides 1 year postoperative-
ly. Both types of instruments gave satisfactory healing situations. No significant difference in the global symptom and endoscopic score between the 2 types of instruments was found (level Ib).

7-4-3-7 Powered instruments
Microdebriders were initially developed for arthroscopic surgery. They consist of a suction based powered instrument with a blunt end and guarded inner 90° oscillating or rotating blade, frequently supplemented with a device for irrigation. Cutting and removing only tissue suctioned into the instrument opening while blood and tissue debris are removed by suction/irrigation, they provide excellent control and precision of soft tissue resection (844).

In a retrospective case series study, a group of 250 patients undergoing surgery with a microdebrider was compared with a group of 225 patients undergoing endoscopic sinus surgery with conventional instruments (845). The assignment of patients to each group was arbitrary and non-random, with the majority of the standard technique patients being treated earlier in the study. The use of the microdebrider demonstrated faster healing with less crusting than standard techniques, as well as decreased bleeding, synechia formation, lateralization of the middle turbinate, and ostial reocclusion (level IV).

In a prospective randomized trial, 24 CRS patients were treated with microdebriders on one side and with conventional instruments on the other side (846). The authors were unable to demonstrate an advantage of mechanical debriders over conventional instrumentation (level Ib).

Hackman and Ferguson reviewed both, positive and negative tissue effects secondary to powered instrumentation (847). The authors conclude that microdebriders will continue to advance the field of endoscopic surgery, providing clearer operative fields and causing less tissue trauma in experienced hands. However, their literature review also illustrates the potential severity of complications, when orbital and cerebral contents are rapidly aspirated by the powered instrument (no level applied).

7-4-3-8 Laser
In a randomized controlled trial, outcomes for holmium-YAG assisted sinus surgery were evaluated in 32 patients with CRS undergoing ESS (848). Following a randomization plan, one side was operated with conventional instruments and the contralateral side with laser. The use of holmium-YAG laser in ESS resulted in significantly lower blood loss during surgery and less post-operative crust formation than conventional ESS, but long term subjective outcomes did not show significant differences between the methods (level Ib).

In a similar experimental setup, the application of KTP lasers in endoscopic sinus surgery was investigated in 24 patients (849). Laser-assisted FESS was performed on one side and FESS with conventional instruments on the other side. Patient symptoms were recorded using a self-administered questionnaire preoperatively, and postoperatively on weeks 1, 4, 12 and 24. Of the parameters assessed in the course of healing, oedema prevailed on the laser-assisted side, while crusting was characteristic in the traditional operation site. Overall, KTP-laser-assisted FESS was as effective as endonasal sinus surgery with conventional instruments. Disadvantages of the laser-assisted procedure included the investment for the instrument and the additional time needed for laser surgery (level Ib).

Conclusion: Laser assisted endonasal surgery, powered instruments or sharp forceps offer some advantages over conventional instruments but may be associated with some particular risks. Currently, there is no evidence that they improve sinus surgery outcomes.

7-5 Influence of age concomitant diseases on sinus surgery outcome

7-5-1 Sinus surgery in the elderly
Previous survey data ranks rhinosinusitis the sixth most common chronic condition of elderly persons, occurring more frequently than cataracts, diabetes and general visual impairment (840). In a case series study, 56 CRS patients between 61 and 80 years old were followed after functional endoscopic sinus surgery with nasal endoscopy and the SNOT-20 (846). Outcomes were comparable to reports from younger patient populations, no severe complication occurred (level IV). In a retrospective case control study, functional endonasal sinus surgery outcome in 46 CRS patients >65 years were compared with 522 CRS patients who were 18-64 years old (846). In the elder patient group, complications occurred significantly more frequently than in the younger patients group. In particular orbital complications were frequently observed in the elder patient group (level III). Jiang and Su retrospectively compared complication rates of 171 CRS patients elder than 65 years with 837 adult patients and 104 patients younger than 16 years. They found that the geriatric group experienced a disproportionately larger share of operative complications. Outcomes were similar in all three groups (850).

Conclusion: CRS is a common condition in the elderly. Reported sinus surgery outcomes do not differ from a younger patient population. However, higher surgical complication rates were found in 2 reports. Moreover, general anaesthesia bears higher risks and the capacity to recover from a severe surgical complication such as a CSF leak may be impaired.

7-5-1-1 Asthma
Bronchial asthma is frequently associated with CRS with and without polyps and may have influence on sinus surgery outcomes. A trend for more severe sinus disease in CRS patients with concomitant asthma without aspirin intolerance has been reported by Kennedy (844). Clinically, CRS patients with polyps and asthma have higher CT-scores, more severe nasal obstruction and hyposmia, and more severe asthma, while CRS
patients without polyps and asthma experience more severe headache and postnasal discharge. Investigations of concomitant asthma on sinus surgery outcomes in CRS patients with or without nasal polyps yielded inconsistent results. Concomitant asthma was associated with worse postoperative endoscopy findings in two retrospective analyses, but had no independent influence on other outcome parameters (level IV). Consistently, symptom scores improved significantly in both asthmatics and non-asthmatics postoperatively, but asthmatics exhibited significantly worse postoperative endoscopic outcomes in 21 asthmatic compared with 77 non-asthmatic. No difference was found in other outcome parameters between the two groups (level IV).

In 3 other studies on various predictors of treatment success of sinus surgery, asthma had no independent influence on outcome parameters.

7.5-1-1 CRS without polyps
Concomitant asthma is frequent in patients with sinusitis without polyps. In a retrospective evaluation, 13 of 73 CRS patients without polyps had also asthma. However, concomitant asthma did not influence sinus surgery outcomes in this study. In a case series studies, Dunlop and coworkers followed the course of 50 CRS patients with bronchial asthma after sinus surgery. In this group, 16 CRS patients without polyps had concomitant asthma. Their sinusitis symptoms improved significantly following sinus surgery (level IV).

7.5-1-1-1 CRS without polyps
Concomitant asthma is frequent in patients with sinusitis without polyps. In a retrospective evaluation, 13 of 73 CRS patients without polyps had also asthma. However, concomitant asthma did not influence sinus surgery outcomes in this study. In a case series studies, Dunlop and coworkers followed the course of 50 CRS patients with bronchial asthma after sinus surgery. In this group, 16 CRS patients without polyps had concomitant asthma. Their sinusitis symptoms improved significantly following sinus surgery (level IV).

7.5-1-1-2 CRS with polyps
In a prospective outcome analysis, 79 patients underwent endoscopic sinus surgery for CRS with polyps. In a subgroup of 22 CRS patients with concomitant asthma, more recurrences and less symptom score improvement was observed (level IV). In the study by Dunlop and coworkers described above, 34 CRS patients with polyps and concomitant asthma revealed improved sinus symptoms 1 year after sinus surgery (level IV).

Conclusion: Currently there is no evidence that CRS patients with asthma benefit less from sinus surgery than patients without asthma concerning their CRS symptoms.

7.5-2 Effect of sinus surgery on bronchial asthma
The incidence of self reported rhinosinusitis in asthma patients was recently evaluated employing the data of two major asthma trials. Self reported rhinosinusitis was associated with bronchial asthma in 70% of the 2500 study participants. Asthma patients with concomitant rhinosinusitis had more asthma exacerbations, worse asthma symptoms, worse cough, and worse sleep quality. The question, how sinus surgery and medical CRS treatment may alter the course of bronchial asthma, was reviewed by Lund and Scadding. The authors describe the somewhat intricate base of evidence and conclude that the weight of evidence suggests a beneficial effect. Studies published thereafter support this view. However, once again, authors did not differentiate between CRS with and without polyps.

In a follow up analysis of long term results of functional endonasal sinus surgery, 72 of 120 patients answered a questionnaire. A subgroup of 30 patients with CRS and asthma were analysed. On average 6.5 years post surgery, asthma symptom improvement, less asthma attacks, less inhaler and less oral steroid use were reported by the majority of patients (level IV).

Park and co-authors retrospectively evaluated the data of a subgroup of 79 of 134 sinus surgery patients with asthma (level IV) with a questionnaire. Improved asthma was noted by 80% of the patients (level IV).

In a controlled study, 15 patients with CRS and asthma underwent endoscopic sinus surgery and 6 patients, who rejected surgery, were treated with nasal steroids only. The authors compared peak expiratory flow (PEF) and oral steroid consumption 6 months before and after treatment. In the surgically treated patients, mean PEF improved 98±45 l/min (p<0.005) whereas no change was observed in the medically treated group. Oral steroid consumption was reduced in 7 surgically treated patients, remained unchanged in 2 and increased in 2 and was not needed before and after surgery in 4 patients (level IV).

In a prospective medical record analysis 13 patients with chronic bronchial asthma who underwent FESS and received comprehensive asthma care before and after FESS (mean, 19.3 and 33.1 months, respectively) were included. Outcomes comprised pre- and post-FESS individual and group mean asthma symptom scores, medication use scores, pulmonary function test results, and emergency department visits or hospital admissions for asthma. Following FESS, there was no statistically significant change in group mean asthma symptom scores, asthma medication use scores, pulmonary function test results, and the number of emergency department visits or hospital admissions (level IV).

In a case series study, 50 CRS patients with concomitant asthma were included. Twelve months after endoscopic sinus surgery, 40% noted asthma improvement, 54% stated that there was no difference and 6% thought their asthma control was worse. Inhaled steroids could be reduced by 20%, and were taken at the same dose as preoperatively by 64%. However, oral steroid consumption was reduced significantly (p<0.001) and hospital admissions for asthma were less frequent in the year after surgery than in the year before (p<0.025, level IV).

Dhong and co-authors followed the clinical course of 19 patients with CRS and asthma who underwent ESS for rhinosinusitis. They observed a significant improvement in diurnal and nocturnal asthma symptoms and asthma medication scores. Pulmonary function tests did not change (level IV).

Ragab and co-workers report a prospective evaluation of a subgroup of 43 asthma patients joining a randomised trial comparing the effects of sinus surgery and medical treatment in...
CRS patients with and without polyps. Outcome parameters included asthma symptoms, control, forced expiratory volume in one second (FEV1), peak flow, exhaled nitric oxide, medication use and hospitalisation at 6 and 12 months from the start of the study. Overall asthma control improved significantly following both treatment modalities, but was better maintained after medical therapy, where improvement could also be demonstrated in the subgroup with nasal polyps. Medical treatment was superior to surgery with respect to a decrease in exhaled nitric oxide and increase in FEV1 in the polypos patients. Two patients noted worsening of asthma post-operatively. Treatment of chronic rhinosinusitis, medical or surgical, benefits concomitant asthma; that associated with nasal polyps benefits more from medical therapy (level Ib).

Although asthma may accompany chronic rhinosinusitis with and without polyps, several studies particularly addressed lower airway effects of sinus surgery in CRS patients with polyps. In a prospective outcome analysis, 79 patients underwent endoscopic sinus surgery for CRS (853). Twenty-eight patients with asthma symptoms were assessed before and after surgery, using peak flow (liter/second) and medication scores. Patients showed improvement in terms of their asthma symptoms, peak flow and medication score (level IV). Palmer and co-workers retrospectively reviewed the charts of a subgroup of 15 CRS patients with steroid dependent asthma selected from a group of 75 consecutive CRS patients with asthma who underwent endoscopic sinus surgery (856). Outcome parameters included the number of days and total dose of oral prednisone and antibiotics in the year before and after surgery. Fourteen of the 15 patients meeting study criteria decreased their postoperative prednisone requirement by total number of days (preoperative 84 versus postoperative 63 days (p < 0.0001). Postoperatively, patients required an average of 1300 mg less oral prednisone (p < 0.033). Antibiotic use also decreased (p < 0.045), with an average use of antibiotic nine weeks preoperatively versus seven weeks postoperatively (level IV).

In a prospective trial, Lambelin and co-workers included 46 CRS patients with polyps and concomitant bronchial asthma (n=16) or non-symptomatic bronchial hyperresponsiveness (n=30). Outcome parameters measured at baseline (T0), after 1 year (T1) and after 4 years (T2) included nasal symptom scores, various spirometry values and a bronchial carbachol challenge (517). All patients were treated first with nasal steroids for 6 weeks (beclomethasone 600 microg/d). Eighteen patients were successfully treated with nasal steroids (nasal steroids responders) and medical CRS treatment was continued without sinus surgery. In 28 patients who did not improve with nasal steroids (nasal steroids non-responders), intranasal sinonasal excision was performed in addition to continued nasal steroid treatment. At baseline, clinical characteristics of nasal steroid responders and non-responders -including the frequency of Samter’s triad- did not reveal significant differences. Despite combined surgical and medical CRS-treatment, nasal steroid non-responders demonstrated a significant decrease of their spirometry values at T1 (p < 0.05) and at T2 (p < 0.0005), whereas no significant change was observed in nasal steroid responders. BHR did not significantly change over the 4-yr follow-up period in the two groups. No change in pulmonary symptoms and/or asthma severity occurred.

Conclusion: Apparently, various confounders not yet sufficiently defined influence the effects of surgical CRS treatment on concomitant asthma. In studies published in recent years, predominantly positive effects of surgical CRS treatment on concomitant asthma severity were reported. However, the level of evidence is low.

7.5.2.1 ASA intolerance

Intolerance to acetylsalicylic acid derived compounds such as aspirin or other acid NSAIDs frequently manifests as Samter’s triad characterized by bronchial asthma, aspirin sensitivity, and CRS with polyps. The majority of CRS patients with aspirin intolerance have diffuse, extensive rhinosinusitis. In an early report, poorer outcome in 11 patients with ASA-intolerance of out of 120 prospectively followed patients treated with sinus surgery was observed (854). However, when stratified for extent of disease, ASA-intolerance did not adversely affect outcome (Level IV). In more recent trials, ASA-intolerance was rather consistently found to adversely affect sinus surgery outcomes.

In a case series study, 80 patients with ASA-intolerance and mostly extensive polyps were followed after sinus surgery. Sinus symptoms and asthma severity improved in more than 80% of the patients. Before surgery, more than 30% were steroid dependent due to asthma severity and less than 10% after surgery. However, a significant incidence of revision surgery was observed in this patient group (level IV).

A higher number of repeat operations was also observed in a retrospective case control trial including 18 patients with and 22 patients without ASA-intolerance (level IV).

In a retrospective chart review, 17 patients who underwent ESS with nasal polyps and steroid-dependent asthma with or without aspirin sensitivity and a minimum of 1 year postoperative follow-up were evaluated. Nine patients were ASA sensitive, and eight patients were ASA tolerant. The postoperative Lund-Mackay scores were evaluated. Nine patients were ASA sensitive, and eight patients were ASA tolerant. The postoperative Lund-Mackay scores were evaluated (p<0.001), the forced expiratory volume at 1 second (FEV1, p<0.05), and systemic steroid consumption (p<0.05) improved significantly in the 17 patients. Unlike ASA tolerant patients, the 9 ASA sensitive patients did not have a significant improvement in postoperative FEV1 and sinonasal symptoms (level IV).

In a multivariate analysis of various outcome predictors, 119 adult patients with CRS were prospectively followed-up for 1.4 +/- 0.35 years after sinus surgery. ASA intolerance was the only concomitant condition significantly worsening the outcome.

Conclusion: CRS patients with ASA-intolerance tend to suffer...
from more extensive sinus disease. They benefit from sinus surgery, but to a lesser extent than patients without ASA-intolerance. They are more prone to disease recurrence and more frequently undergo revision surgery than ASA-tolerant CRS patients.

7-5-2-2 Allergy and atopy
In most studies, the diagnosis of allergy was based solely on the presence of a positive skin prick test and/or serum specific IgE determinations. This indicates atopy, but may not suffice to diagnose allergic rhinitis (AR), particularly persistent AR (872). Walker and co-authors matched a cohort of 19,186 individuals without ENT disease registered in 1988 in the U.S. Navy Aviation Medical Data retrieval System with 678 persons with AR as the only ENT disease (872). During the period from 1990 to 1995, physcians were identified of 465 AR cases and 12,628 controls. The incidence of chronic sinusitis in the AR group was 5/465 compared to 30/12,628 in the control group (risk ratio = 4.5, 95% CI 1.7 to 11.6). Consistently, the reported incidence of atopy in CRS patients ranges between 50 and 80% which is higher than in the general population. CRS in atopic patients appears to be more severe (801, 873-878). Atopy was equally frequently associated with CRS with and without polyps (879). Conversely, in patients with positive skin prick tests to house dust mites, pathologic CT findings were significantly more frequent than in prick test negative controls (880).

In several trials not differentiating between CRS with and without polyps, atopy interfered with sinus surgery outcome. It was associated with less symptom improvement in one retrospective evaluation of several sinus surgery outcome predictors (804), but had no relevant influence on pre- or postoperative CT or endoscopy findings nor on QoL scores in an other evaluation (892). However, antiallergic treatment appears to compensate for the possible shortcomings of sinus surgery in allergic patients. Nishioka and co-authors compared postoperative middle meatal antrostomy patency, middle meatal synechia formation and polyp recurrence in 211 non-allergic CRS patients and 72 CRS patients considered allergic based on clinical history, skin prick tests and serum specific IgE (879). Of the 72 allergic patients, 66 received an allergen specific immunotherapy either before or after surgery. Allergic patients had a significantly higher incidence of recurrent sinusitis, which could be reduced by allergen specific immunotherapy. The authors conclude that allergic patients treated with surgery and concomitant immunotherapy do as well as non-allergic patients, whereas allergic patients treated with surgery alone do substantially worse (level IV).

Similarly, immunotherapy and medical allergy treatment before surgery improved the surgical success rate at a 1 year follow up in children with CRS from 64% to 84% (p=0.022) (881). The latter figure was identical to the success rate in children without allergy (level IV).

A consistent finding was reported earlier by Schlenter and Mann, who surgically treated 31 allergic and 34 non-allergic CRS patients (882). Of the 31 allergic patients, 15 underwent concomitant allergen specific immunotherapy. Surgical outcome was comparable in non-allergic and allergic patients after concomitant immunotherapy, but significantly worse in allergic patients without immunotherapy, despite antiallergic medical treatment (level IV).

7-5-2-2-1 CRS without polyps
In a prospective study, 24 CRS patients without polyps allergic to perennial allergens and 82 patients with CRS without polyps without allergy underwent endoscopic endonasal ethmoidectomy after medical pre-treatment (857). Comparing both groups, symptom scores did not differ significantly before and 6 to 18 months after surgery. Consistently, in a case series of 77 CRS patients without polyps, concomitant allergy had no influence on surgical outcome (885).

In a double-blind placebo-controlled trial, 26 CRS-patients without polyps with positive skin prick tests to house dustmite and persistent symptoms after sinus surgery received 256 microg budesonide daily or placebo through an intubation device into one of the maxillary sinuses for 3 weeks before clinical assessment and a second biopsy (879). The authors found an improvement in the symptom scores in 11 of the 13 patients who received budesonide and a decrease in CD3 positive cells (P = .02) and eosinophils (P = .002), and a decrease in the density of cells expressing interleukin 4 (P = .0001) and interleukin 5 messenger RNA (P = .006) after treatment.

7-5-2-2-2 CRS with polyps
In patients with extensive polyposis (897), allergy diagnosis predicted a worse outcome and increased recurrence rate (level IV)

Conclusion: Allergic rhinitis may predispose to and aggravate CRS. In several studies, positive skin prick tests and/or serum specific IgE to inhalant allergens were associated with poorer sinus surgery outcome, particularly in CRS with polyps. This shortcoming can be compensated for with antiallergic treatment. After confirmation of allergy by allergic history or appropriate clinical tests, allergen specific immunotherapy apparently improves sinus surgery results in atopic or allergic CRS patients.

7-5-2-3 Cystic fibrosis
This autosomal recessive genetic disease is characterized by epithelial secretory dysfunction and frequently associated with CRS. In cystic fibrosis, CRS with and without nasal polyps is observed (884). Immunologically, CRS in cystic fibrosis (CF) patients differs from CRS in patients without CF (825, 844). Persistent colonisation with Pseudomonas aeruginosa is a common finding. Vitamin K deficiency related coagulopathies
are also common (885). Reports concentrating on CRS in CF patients have mainly concerned the paediatric population, which is in part due to reduced life expectancy. Due to underlying medical issues such as acquired coagulopathies and advanced pulmonary disease, perioperative morbidity is assumed to be higher in this group (886). In 41 patients with CF undergoing 52 sinus surgeries performed by a single surgeon over a 34-month period, complication occurred in 11.5%, including 2 cases of epistaxis, 1 case of periorbital ecchymosis, and 1 case of pulmonary hemorrhage. Delayed complications included 1 case of epistaxis and 1 case of intranasal scarring (level IV). No increased perioperative risk was found by others (887) (level IV).

The paranasal sinuses may act as a reservoir from where bacteria spread to the lower respiratory tract. After lung transplantation, sinus derived graft infection with Pseudomonas aeruginosa may induce a frequently lethal bronchiolitis obliterans syndrome. In 37 patients with cystic fibrosis after lung transplantation, sinus surgery was performed and repeated sinus aspirates and bronchoalveolar lavages were obtained for microbiological examinations. Sinus surgery was successful (three or less Pseudomonas aeruginosa positive aspirates) in 54% and partially successful (4 or 5 positive aspirates) in 27% of patients (888). A significant correlation of bacterial growth in sinus aspirates and bronchoalveolar lavages was observed (p<0.0001). Successful sinus management led to a lower incidence of tracheobronchitis and pneumonia (P=0.009) and a trend toward a lower incidence (p=0.23) of bronchiolitis obliterans syndrome (Level IV).

Functional endoscopic sinus surgery with subsequent monthly antimicrobial antral lavages (n=32) were compared with a historic control group receiving conventional sinus surgery without postoperative lavages (n=19). CF-patients with CRS with and without nasal polyps were included. For repeated antral lavages, modified 19 gauge butterfly intravenous catheters were fixed in the maxillary sinus. Conventionally operated patients underwent one or more of the following procedures: polypectomy, ethmoidectomy, antrostomy, or Caldwell-Luc operation (889). The group treated with functional sinus surgery and antral lavages had fewer operations per patient, and a decrease in repeated surgery at 1 year (10% vs 47%) and 2 year follow up (22% vs 72%) (level IV).

7.5.2-3.1 CRS with polyps
Several reports explicitly describe CRS with polyps in CF patients. From a cohort of 650 patients undergoing endoscopic sinus surgery for CRS, 28 patients suffered from cystic fibrosis (885). Overall subjective improvement rate in the cohort as a whole was 91% improved, whereas 54% of the cystic fibrosis patients derived significant benefit at six month follow-up. (Level IV).

In a retrospective report, 8 CRS patients with polyps out of 16 adults with cystic fibrosis underwent sinus surgery (886). The mean number of previous surgery in the surgically treated group was 2.7. The authors report improved pulmonary function, sinus symptoms, and exercise tolerance 3 months post surgery, however, polyps recurred in all patients within 18 months (Level IV).

Rowe-Jones and Mackay performed endoscopic sinus surgery on 46 cystic fibrosis patients with chronic, polypoid rhinosinusitis (887). Their mean age at first surgery was 23±7.5 years. Follow-up ranged from 1 month to 6 years (mean, 28.2 months). Overall, 50% of the patients suffered either recurrence of preoperative severity or had to undergo second endoscopic sinus procedure (level IV).

Conclusion: CF patients frequently suffer from severe CRS, in particular with diffuse polyps refractory to medical treatment. Due to a tendency to recur, repeated sinus surgery is often needed to achieve symptomatic relief. In CF patients, the paranasal sinuses may serve as a source for Pseudomonas aeruginosa induced lung infections. Consequent local antibiotic lavages help to prevent recurrent CRS and lung infection.

7.5.2-4 Sinus surgery in the immune compromised patient
Immune deficiency states are frequently associated with CRS include HIV-infection, bone marrow transplantation and humoral immunodeficiencies.

7.5.2-4.1 HIV
Rhinosinusitis in the HIV-infected is an increasingly common problem. The gradual depression of humoral and cellular immunity, delayed mucociliary transport, nasopharyngeal lymphoid tissue hyperplasia and a tendency towards increased IgE levels may contribute to sinusitis development. Particularly at CD4-counts below 50 cells per mm3, Pseudomonas aeruginosa is a common pathogen (906). Cytomegalovirus may cause sinusitis in HIV-infected patients and they have an increased risk to develop invasive fungal sinusitis. Thus CT scans, and sinus lavages with special stains, cytologies and cultures are required in refractory sinusitis or patients with low CD4 counts (890). The first line treatment of sinusitis in HIV-positive patients is medical, in refractory cases targeted to the identified organisms. Surgical treatment is reserved for patients who do not respond to targeted medical treatment.

Sabini and co-authors retrospectively reviewed their experience performing endoscopic sinus surgery in 16 acquired immune deficiency (AIDS) patients (117). At an average follow-up time of 16 months, 14 of the endoscopic sinus surgery patients reported improvement from their preoperative condition (level IV).

In a retrospective case series study, 106 HIV+ patients who underwent sinus surgery between 1987 and 1998 were evaluated (906). Between 1987 and 1991, 36 patients were treated with minimal invasive sinus surgery just addressing the involved sinus with only 20% clinical improvement. Since 1992, the authors treated their HIV+ patients with more extensive surgery including sphenoidectomy, middle meatal...
antrostomy and drainage of the frontal recess, which resulted in a clinical improvement rate of 75%, irrespective of the CD4 counts (level IV).

In two case series, Murphy and co-workers observed the clinical outcome of 30 HIV-positive CRS patients refractory to medical treatment (909). Outcome parameters included olfactory tests, symptom scores, and a quality of well-being assessment. Symptom and well-being scores improved significantly following endoscopic sinus surgery, whereas olfactory thresholds did not improve significantly (level IV).

Patients with AIDS may develop acute invasive fungal sinusitis. If detected early, combined surgical and antifungal treatment may be beneficial (910).

7-5-2-4-2 Bone marrow transplant
Bone marrow transplantation (BMT) is a frequent cause of acquired immune deficiency. Both, cellular and humoral immunity are impaired. Particularly allogeneic BMT requires intense immunosuppression to allow initial engraftment and to prevent graft versus host disease. Allogeneic BMT is associated with acute and chronic CRS in approximately 40% (911). Sinus microbiology was investigated in 18 BMT patients who developed sinusitis evaluating 41 microbiological specimens obtained by antral puncture and nasal swabs from the middle meatus (912). Agents most commonly isolated were gram-negative bacteria including Pseudomonas aeruginosa and Serratia marcescens. Gram positive bacteria were isolated in 27%.

Various fungi were isolated in 16% of the specimens. Micorbiological results of antral punctures and nasal swabs were consistent in 5 of 41 specimens.

Kennedy and co-workers report on 29 bone marrow transplant recipients with documented invasive fungal infections of the sinuses and paranasal tissues (1.7% of 1692 bone marrow transplants performed). All patients received medical management, such as amphotericin, rifampin, and colony-stimulating factors, in addition to surgical intervention (913). Surgical management ranged from minimally invasive procedures to extensive resections including medial maxillectomies. The mortality rate from the initial fungal infection was 62%. Twenty-seven percent resolved the initial infections but subsequently died of other causes. Prognosis was poor when cranial and orbital involvement and/or bony erosion occurred. Extensive surgery was not superior to endoscopic functional surgery (level IV).

Sinus surgery was performed in 28 of 311 bone marrow transplant patients retrospectively evaluated (914). No fungal sinusitis was observed. An aggressive surgical approach yielded a high mortality rate whereas limited surgical approaches with intensive postoperative care proved appropriate (level IV).

7-5-2-4-3 Non-acquired immunodeficiencies
Patients with humoral immunodeficiencies including common variable immunodeficiency, ataxia telangiectasia, or X-linked agammaglobulinemia are at increased risk to develop CRS (915-917). In patients with CRS refractory to medical and surgical treatment, non-acquired immune deficiencies may affect humoral, cellular, and frequently both immune response pathways. Chee and co-workers selected 79 out of 316 patients with CRS with and without polyps, who suffered from severe CRS refractory to medical treatment (918). Fifty-seven patients had undergone one or more previous sinus surgeries. Approximately 30% of the 79 included patients suffered from decreased T-cell function and approximately 20% had some form of immunoglobulin deficiency. Common variable immunodeficiency was diagnosed in 10%. Accordingly, in a high number of patients with long lasting rhinosinusitis, humoral deficiencies were identified, particularly of the IgG3-subclass (919, 920). However, in unselected patients with sinus fungus ball, CRS with and without polyps, humoral deficiencies were not more frequent than in the general population (921).

Recently, the relevance of isolated immunoglobulin or IgG subclass deficiencies has been challenged and vaccine response to protein and capsular polysaccharides has been suggested superior to assess humoral immune function in CRS patients (922-924). One publication reporting on sinus surgery results in 11 patients with humoral deficiencies was identified (925), and resolution of sinus symptoms was observed in 5 of 9 evaluable patients under concomitant IV immunoglobulin therapy (level IV).

Conclusion: IN HIV-positive patients, three case series suggest beneficial effects of sinus surgery refractory to medical treatment. In patients sinusitis before or after bone marrow transplantation and in non-acquired immunodeficiency syndromes, current data to judge the role of sinus surgery are insufficient.

7-6 Complications of surgical treatment

7-6-1 Introduction
After the introduction of endoscopic sinus surgery, the indication for operations in this region expanded, the number of operators increased together with an increase in the numbers of operations, but also increasing the absolute number of iatrogenic complications. As a consequence, for a period of time in the United States, paranasal sinus surgery was the most frequent source of medicolegal claims (926).

7-6-2 Complications of sinus surgery
Factors responsible for complications are the variability of the anatomy of this region, the proximity of the brain and orbita and last but not least the ability of the operator to maintain orientation especially in revision surgery.

The typical complications are listed in table 7-15.

7-6-3 Epidemiology of complications of sinus surgery using non-endoscopic techniques
The following table presents the number of complications in several studies using non-endoscopic sinus surgery.

7-6-4 Epidemiology of complications of sinus surgery using endo-
The following table (8.6) presents the number of complications in studies using endoscopic sinus surgery and which included a minimum of 100 patients. Meta-analysis of these data suggests major complications occur in about 0.5% and minor complications in about 4% of cases. In a recent prospective multicentre study of 3,128 patients undergoing endoscopic sinus surgery, major complications occurred in 0.4% of patients. Of note, the complication rate was linked to the extent of the disease in terms of symptom severity and health-related quality of life, the extent of nasal polyps, levels of opacity of the sinuses on CT scans and the presence of comorbidity, but not to surgical characteristics (521).

7-6-5 Comparison of various techniques
Comparison of non-endoscopic and endoscopic techniques shows similar frequencies of complications. Differences in

Table 7-15. Complications following paranasal sinus surgery

<table>
<thead>
<tr>
<th>location</th>
<th>minor complications</th>
<th>major complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>orbital</td>
<td>orbital emphysema</td>
<td>orbital hematoma loss of visual acuity/blindness</td>
</tr>
<tr>
<td></td>
<td>ecchymosis of the eyelid</td>
<td>diplopia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>enophthalmia</td>
</tr>
<tr>
<td>intracranial</td>
<td>CSF leak - uncomplicated</td>
<td>CSF leak</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pneumocephalus (Tension)</td>
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<tr>
<td></td>
<td></td>
<td>encephalocele</td>
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<tr>
<td></td>
<td></td>
<td>brain abcess</td>
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<tr>
<td></td>
<td></td>
<td>meningitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>intracranial (subarachnoid) bleeding</td>
</tr>
<tr>
<td>bleeding</td>
<td>small amount of bleeding</td>
<td>damage to anterior ethmoidal artery</td>
</tr>
<tr>
<td></td>
<td>stopped with packing</td>
<td>damage to sphenopalatine artery</td>
</tr>
<tr>
<td></td>
<td>no need for blood transfusion</td>
<td>damage to internal carotid artery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bleeding which requires transfusion</td>
</tr>
<tr>
<td>other</td>
<td>synechiae</td>
<td>toxic-shock syndrome</td>
</tr>
<tr>
<td></td>
<td>slight exacerbation of pre-existent asthma</td>
<td>anoma</td>
</tr>
<tr>
<td></td>
<td>hyposmia</td>
<td>severe exacerbation of pre-existent asthma</td>
</tr>
<tr>
<td></td>
<td>local infection (osteitis)</td>
<td>or broncospasm</td>
</tr>
<tr>
<td></td>
<td>post-FESS MRSA infection</td>
<td></td>
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<tr>
<td></td>
<td>atrophic rhinitis</td>
<td></td>
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<tr>
<td></td>
<td>myosferulosis</td>
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<tr>
<td></td>
<td>temporary irritation of infraorbital nerve</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hyperaesthesia of lip or teeth</td>
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</tbody>
</table>

Table 7-16. Epidemiology of complications following paranasal surgery, using non-endoscopic techniques

<table>
<thead>
<tr>
<th>author/year</th>
<th>N</th>
<th>orbita</th>
<th>intracranial</th>
<th>bleeding</th>
<th>others</th>
<th>minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freedman and Kern, 1979 (915)</td>
<td>565</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Taylor et al, 1982 (916)</td>
<td>284</td>
<td>1</td>
<td>3</td>
<td>-</td>
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<td>8</td>
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<tr>
<td>Stevens and Blair, 1988 (917)</td>
<td>87</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>8</td>
</tr>
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<td>Eichel, 1982 (918)</td>
<td>123</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Sogg, 1989 (919)</td>
<td>146</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Friedman and Katzantonis, 1990 (920)</td>
<td>1163</td>
<td>-</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>Lawson, 1991 (921)</td>
<td>600</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Sogg and Eichel, 1991 (922)</td>
<td>3000</td>
<td>-</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td>288</td>
</tr>
</tbody>
</table>
meningitis, 54% permanent diplopia, 66% intraorbital hematoma, 87% lost of vision, 46% intracranial lesions, 40% death in relation with the operation).

Between 1985 and 1990 the following complication rates were seen:

The complication rate in this study was significantly lower in the hands of experienced operators with 11 to 20 years experience.

In Australia Kane (945) did a similar review, presenting an overall major complication rate of 0.03% (12 major orbital complications and 22 intracranial complications in 10,000 FESS operations).

7-6-6 Risk factors for complications in sinus surgery
The risk of complications in sinus surgery depends on several factors:
α extent of the pathology (ie requiring infundibulotomy or complete pansinus operation);
α first or revision surgery (loss of landmarks, dehiscent lamina papyracea);
α right- or left sided pathology (right side most often affected);
α operation under local or systemic anaesthesia (feedback from patient!);
α amount of bleeding during the operation;
α expertise of the operator (learning curves).

With respect to the last point, a structured training program for beginners in sinus surgery is recommended, including cadaver dissection, hands-on training and supervision during the first operations.

7-6-7 Conclusion

Table 7-17. Epidemiology of complications following paranasal surgery, using endoscopic techniques (adapted from (923))

<table>
<thead>
<tr>
<th>author/year</th>
<th>N</th>
<th>orbital</th>
<th>intracranial*</th>
<th>bleeding</th>
<th>others</th>
<th>minor</th>
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</thead>
<tbody>
<tr>
<td>Schaefer et al, 1989 (924)</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14</td>
</tr>
<tr>
<td>Toffel et al, 1989 (925)</td>
<td>170</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Rice, 1989 (926)</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
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<tr>
<td>Stamnberger and Posawetz, 1990 (927)</td>
<td>500</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>Salman, 1991 (928)</td>
<td>118</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>28</td>
</tr>
<tr>
<td>Wigand and Hoseman, 1991 (929)</td>
<td>500</td>
<td>-</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Lazar et al, 1992 (930)</td>
<td>210</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Vleminckx et al, 1992 (931)</td>
<td>593</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>38</td>
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<tr>
<td>Weber and Draf, 1992 (932)</td>
<td>589</td>
<td>20</td>
<td>15</td>
<td>1</td>
<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Kennedy, 1992 (933)</td>
<td>120</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>May et al, 1993 (934)</td>
<td>1165</td>
<td>-</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>94</td>
</tr>
<tr>
<td>Smith and Brindley, 1993 (935)</td>
<td>200</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16</td>
</tr>
<tr>
<td>Dessi et al, 1994 (936)</td>
<td>386</td>
<td>3</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Cumberworth et al, 1994 (937)</td>
<td>551</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>Lund and Mackay, 1994 (938)</td>
<td>650</td>
<td>1</td>
<td>1</td>
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<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Ramadan and Allen, 1995 (939)</td>
<td>337</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>34</td>
</tr>
<tr>
<td>Danielson and Oflofson, 1996 (940)</td>
<td>230</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Castillo et al, 1996 (941)</td>
<td>553</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>-</td>
<td>36</td>
</tr>
<tr>
<td>Weber et al, 1997 (942)</td>
<td>325</td>
<td>4</td>
<td>3</td>
<td>30</td>
<td>-</td>
<td>no numbers</td>
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<tr>
<td>Rudert et al, 1997 (943)</td>
<td>1172</td>
<td>3</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Dursum et al, 1998 (944)</td>
<td>415</td>
<td>12</td>
<td>1</td>
<td>12</td>
<td>-</td>
<td>56</td>
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<tr>
<td>Keef et al, 1999 (945)</td>
<td>1500</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>-</td>
<td>no numbers</td>
</tr>
<tr>
<td>Marks, 1999 (946)</td>
<td>393</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>-</td>
<td>22</td>
</tr>
<tr>
<td>Hopkins et al, 2006 (Laryngoscope 2006)</td>
<td>3128</td>
<td>7</td>
<td>2</td>
<td>2</td>
<td>-</td>
<td>207</td>
</tr>
<tr>
<td>total amount</td>
<td>14005</td>
<td>60 (0,40%)</td>
<td>65 (0,50%)</td>
<td>84 (0,60%)</td>
<td>14 (0,01%)</td>
<td>506 (3,60%)</td>
</tr>
</tbody>
</table>

* includes CSF leaks

Table 7-18. Complications comparison of non-endoscopic and endoscopic techniques

<table>
<thead>
<tr>
<th>technique</th>
<th>major complications</th>
<th>no of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>endoscopic ethmoidectomy</td>
<td>0.41%</td>
<td>3</td>
</tr>
<tr>
<td>intranasal ethmoidectomy with headlamp</td>
<td>0.36%</td>
<td>23</td>
</tr>
<tr>
<td>external ethmoidectomy</td>
<td>0.52%</td>
<td>9</td>
</tr>
<tr>
<td>transantral ethmoidectomy</td>
<td>0.18%</td>
<td>3</td>
</tr>
</tbody>
</table>
Sinus surgery is well established and there are several techniques used to adequately treat the pathology. Nevertheless, the risk of minor or major complications exists and has to be balanced with the expected result of operative or conservative treatment. The learning curve of less-experienced operators has to be considered, as well as the complexity of the individual case.

A preoperative CT-scan is nowadays standard in the preoperative assessment and especially important in revision surgery where image guidance may have a role.

![Figure 7-2. SNOT-22 scores in the National Comparative Audit in CRS patients with and without nasal polyps (adapted from (521)).](image1)

Table 7-19. Predictive factors of sinus surgery outcomes

<table>
<thead>
<tr>
<th>Outcome parameter</th>
<th>RP</th>
<th>FP</th>
<th>An</th>
<th>A</th>
<th>S</th>
<th>PO</th>
<th>E</th>
<th>AI</th>
<th>As</th>
<th>NP</th>
<th>AI</th>
<th>PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chambers 1997 (855)</td>
<td>questionnaire, endoscopy</td>
<td>182</td>
<td>12</td>
<td>u</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gliklich (965)</td>
<td>SF-36, CSS, endoscopy</td>
<td>108</td>
<td>6</td>
<td>m2</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Kennedy (1974)</td>
<td>verbal rating, endoscopy</td>
<td>120</td>
<td>-</td>
<td>u</td>
<td>-</td>
<td>-</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>no</td>
<td>-</td>
</tr>
<tr>
<td>Kim (966)</td>
<td>endoscopy score</td>
<td>98</td>
<td>12</td>
<td>m</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>-</td>
<td>no</td>
</tr>
<tr>
<td>Marks (963)</td>
<td>improvement score</td>
<td>93</td>
<td>12</td>
<td>u</td>
<td>no</td>
<td>yes</td>
<td>0</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Marks (963)</td>
<td>endoscopy score</td>
<td>93</td>
<td>12</td>
<td>m</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>no</td>
<td>-</td>
</tr>
<tr>
<td>Marks (963)</td>
<td>revision needed</td>
<td>93</td>
<td>12</td>
<td>m</td>
<td>yes</td>
<td>no</td>
<td>-</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Smith (963)</td>
<td>endoscopy score</td>
<td>119</td>
<td>12</td>
<td>m</td>
<td>-</td>
<td>no</td>
<td>yes</td>
<td>0.09</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Smith (963)</td>
<td>RSDI</td>
<td>119</td>
<td>12</td>
<td>m</td>
<td>-</td>
<td>no</td>
<td>yes</td>
<td>0.09</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Smith (963)</td>
<td>CSS</td>
<td>119</td>
<td>12</td>
<td>m</td>
<td>-</td>
<td>yes</td>
<td>0</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>0.09</td>
<td>no</td>
</tr>
<tr>
<td>Wang (962)</td>
<td>CSS</td>
<td>230</td>
<td>6</td>
<td>m</td>
<td>-</td>
<td>yes</td>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Wang (962)</td>
<td>endoscopy score</td>
<td>230</td>
<td>6</td>
<td>m</td>
<td>-</td>
<td>yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

RP: Recall/participants; FP: Minimum follow up; An: Analysis; A: Age; S: Sex; PO: Pre-operative score; E: Extent; AI: Allergy; As: Asthma; NP: Polyps; AI: Aspirin intolerance; PS: Previous surgery
1: univariate, 2: multivariate, 3: high preoperative CSS score was associated with worse outcome, 4: stratified for disease severity, 5: less symptomatic improvement in females (p=0.008), 6: worse scores associated with more improvement, 7: associated with less improvement, 8: worse scores associated with more improvement, 9: associated with less improvement, 10: worse scores associated with more improvement.

![Figure 7-3. Forced expiratory volume in one second (FEV1) in percent of the predicted value (y-axis) in CRS-patients with polyps and concomitant asthma (n=16) and concomitant non-symptomatic bronchial hyperreactivity (BHR, n = 30) following CRS treatment. In 18 patients CRS was sufficiently controlled by medical treatment only (Steroid responsive) and 28 patients required additional endonasal surgery for sufficient CRS control (Not steroid responsive, adapted from (867)).](image2)
8. Complications of rhinosinusitis and nasal polyps

8-1 Introduction

In the pre-antibiotic era, complications of rhinosinusitis represented extremely common and dangerous clinical events. Today, thanks to more reliable diagnostic methods (CT, MRI) and to the wide range of available antibiotics, their incidence and related mortality have dramatically decreased. In some cases however, if sinus infection is untreated or inadequately treated, complications can still develop. In patients affected by acute bacterial rhinosinusitis with intracranial spread despite antibiotic therapy, there still is a high incidence of morbidity and mortality rate, estimated at between 5% and 10%.

Complications of rhinosinusitis are classically defined as orbital, osseous and endocranial though rarely some unusual complications can develop. An extremely useful test, although not specific, is the white cell count which, if elevated in ARS unresponsive to treatment, is highly suggestive of a complication.

8-2 Epidemiology of complications

Epidemiological data concerning the complications of rhinosinusitis vary widely and there is no consensus on the exact prevalence of the different types of complications. Moreover, the relationship between acute or chronic rhinosinusitis and the various complications is not clearly defined in the literature. This is probably related to the different number and methods of sampling patients in the various studies and no account is taken of local demographics. For these reasons, as Table 8-1 clearly shows, an attempt to make a comparison of the different epidemiological data available is difficult.

For example, whilst the percentage is similar in two studies that compared two different groups of selected patients affected with pansinusitis (72.4% and 75% respectively), the percentage in another is smaller (37%); this is probably due to the fact that in this sample, both acute and chronic disease were studied, whereas the other two authors focused their attention on acute cases.

In another mixed (acute and chronic) sample, Clayman highlighted the frequency of intracranial complications in patients with complicated rhinosinusitis as about 3.7%, but no data concerning the global prevalence of complications were given.

8-3 Orbital complications

8-3-1 Systemic

If there is a complication in rhinosinusitis, the eye is often involved especially in ethmoiditis, whereas this is rare in sphenoidal infection. The spread of infection directly via the thin and often dehiscent lamina papryacea; occurs with relative ease.

According to Chandler’s classification orbital complications may progress in the following steps:

- periorbital cellulitis (preseptal edema),
- orbital cellulitis,
- subperiosteal abscess,
- orbital abscess or phlegmon and cavernous sinus thrombosis.

Moreover orbital complications especially in children, often occur without pain. Orbital involvement is manifested by
swelling, exophthalmos, and impaired extra-ocular eye movements \(^909\). Periorbital or orbital cellulitis may result from direct or vascular spread of the sinus infection. As the spread of sinus infection through the orbit follows a well-described pattern, the initial manifestations are oedema and erythema of the medial aspects of the eyelid. Spread of infection from the maxillary or frontal sinus produces swelling of the lower or upper eyelid, respectively \(^904\).

### 8-3-2 Periorbital cellulitis

Periorbital cellulitis (inflammation of the eyelid and conjunctiva) \(^952\) involves the tissue anterior to the orbital septum and is readily seen on CT scan as soft tissue swelling. It is the most common complication of rhinosinusitis in children \(^967\) and it manifests itself as orbital pain, blepharal oedema and high fever \(^968\). Periorbital cellulitis usually responds to an oral antibiotic appropriate to common sinus organisms but if not aggressively treated, may spread beyond the orbital septum \(^967\).

### 8-3-3 Orbital cellulitis

As the inflammatory changes spread beyond the orbital septum, proptosis develops together with some limitation of ocular motion, indicating orbital cellulitis. Further signs are conjunctival oedema (chemosis), a protruding eyeball (proptosis), ocular pain and tenderness, and decreased movement of the extraocular muscles \(^953, 988\).

This complication requires aggressive treatment with intravenous antibiotics.

Any children with rhinosinusitis and proptosis, ophthalmoplegia, or decreased visual acuity should have a CT scan of the sinuses with orbital detail to distinguish between an orbital and periorbital (subperiosteal) abscess. Both conditions cause proptosis and limited ocular movement. Evidence of an abscess on the CT scan or progressive orbital findings after initial i.v. antibiotic therapy are indications for orbital exploration and drainage. An ophthalmologist should check visual acuity from the early stages of the illness and i.v. therapy should cover aerobic and anaerobic pathogens. It can be converted to an oral preparation when the patient has been afebrile for 48 hours \(^967\).

Blindness may result from central retinal artery occlusion, optic neuritis, corneal ulceration, or pan-ophthalmitis. In such a case the CT usually reveals oedema of the medial rectus muscle, lateralization of the periorbita, and displacement of the globe downward and laterally. When the CT scan shows obliteration of the detail of the extraocular muscle and the optic nerve by a confluent mass, the orbital cellulitis has progressed to an abscess, in which there is sometimes air due to anaerobic bacteria. Sepsis not infrequently can spread intracranially as well as anteriorly into the orbit \(^972\).

### 8-4 Endocranial complications

These include epidural or subdural abscesses, brain abscess, meningitis (most commonly), cerebritis, and cavernous sinus thrombosis \(^967, 972, 973\).

The clinical presentation of all these complications is non-specific, being characterized by high fever, frontal or retro-orbital pain, generic signs of meningeal irritation and by various degrees of altered mental state \(^969\) while intracranial abscesses are often heralded by signs of increased intracranial pressure, meningeal irritation, and focal neurologic deficits \(^966\). Although an intracranial abscess is relatively asymptomatic, subtle affective and behavioral changes often occur showing altered neurologic function, altered consciousness, gait instability, and severe, progressive headache \(^953, 967\).

Endocranial complications are most often associated with ethmoid or frontal rhinosinusitis. Infections can proceed from the paranasal cavities to the endocranial structures by two different routes: pathogens, starting from the frontal sinus most commonly or ethmoid sinus, can pass through the diploic veins to reach the brain; alternatively, they can reach the intracranial structures by eroding the sinus bones \(^968\).

All endocranial complications start as cerebritis, but as necrosis and liquefaction of brain tissue progresses, a capsule develops resulting in brain abscess. Studies show a high incidence of anaerobic organisms or mixed aerobic-anaerobic in patients with CNS complications.

A CT scan is essential for diagnosis as it allows an extremely accurate definition of bone involvement, whereas MRI is
essential when there are some degrees of soft tissues involvement such as in cavernous sinus thrombosis. Moreover, if meningitis is suspected, a lumbar puncture could be useful once an abscess has been excluded. High dose long term i.v. antibiotic therapy followed by craniotomy and surgical drainage are usually required for successful treatment. Pathogens most commonly involved in the pathogenesis of endocranial complications are Streptococcus and Staphylococcus species and anaerobes.

8-5 Cavernous sinus thrombosis

When the veins surrounding the paranasal sinuses are affected, further spread can lead to cavernous sinus thrombophlebitis causing sepsis and multiple cranial nerve involvement. Such a complication has been estimated at 9% of intracranial complications and is a fortunately rare and dramatic complication of ethmoidal or sphenoidal sinusitis.

The main symptoms are bilateral lid drop, exophthalmos, ophthalmic nerve neuralgia, retro-ocular headache with deep pain behind the orbit, complete ophthalmoplegia, papilloedema and signs of meningeal irritation associated with spiking fevers and prostration.

The cornerstone of diagnosis is high-resolution CT scan with orbit sequences which show low enhancement compared to normal. A mortality rate of 30% and a morbidity rate of 60% remain in the adult population. No data are available for the paediatric population in which the mortality rate for intracranial complications is 10% to 20%. The use of anticoagulants in these patients is still controversial but is probably indicated if imaging shows no evidence of any intracerebral haemorrhagic changes.

8-6 Osseous complications

Sinus infection can also extend to the bone producing osteomyelitis and eventually involving the brain and nervous system. Even if the most frequent intracranial spread is due to frontal sinusitis, any sinus infection can lead to such a complication. The most common osseous complications are osteomyelitis of the maxillary (typically in infancy) or frontal bones.

As vascular necrosis results from frontal sinus osteitis, an osteomyelitis of the anterior or posterior table of the frontal

### Table 8-2. Endocranial complications in rhinosinusitis

<table>
<thead>
<tr>
<th>author</th>
<th>number</th>
<th>complications</th>
<th>mortality/further defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gallagher 1998</td>
<td>176 patients</td>
<td>meningitis represented 18% cerebral abscess 14% epidural abscess 23%</td>
<td>mortality 7% morbidity 13%</td>
</tr>
<tr>
<td>Albu 2001</td>
<td>16 patients</td>
<td>6 meningitis 6 frontal lobe abscess 5 epidural abscess 4 subdural abscess 2 cavernous sinus thrombophlebitis</td>
<td></td>
</tr>
<tr>
<td>Dunham 1994</td>
<td></td>
<td>subdural empyema in 18%</td>
<td>mortality 40% surviving patients often have neurological disability</td>
</tr>
<tr>
<td>Eufinger 2001</td>
<td></td>
<td>together meningitis, empyema and brain abscess constitute 12% of all the intracranial complications</td>
<td></td>
</tr>
<tr>
<td>Oxford LE 2005</td>
<td>18 patients (mean age 12 y)</td>
<td>7 epidural abscess 6 subdural abscess 2 intracerebral abscess 2 meningitis 1 cavernous sinus thrombophlebitis</td>
<td></td>
</tr>
<tr>
<td>Germiller 2006</td>
<td>25 patients (mean age 13 y)</td>
<td>13 epidural abscess 9 subdural abscess 6 meningitis 2 encephalitis 2 intracerebral abscess 2 cavernous sinus thrombophlebitis</td>
<td>mortality 4%</td>
</tr>
<tr>
<td>Quraishi 2006</td>
<td>12 patients (mean age 14 y)</td>
<td>2 frontal lobe abscess 8 subdural abscess 1 subdural abscess 2 cavernous sinus thrombophlebitis</td>
<td>mortality 8% morbidity 16%</td>
</tr>
<tr>
<td>Hakim 2006</td>
<td>8 patients (mean age 12 y)</td>
<td>1 cerebral abscess 1 cerebral infarct 3 frontal bone osteomyelitis 4 subdural abscess 4 subdural abscess</td>
<td>no mortality</td>
</tr>
</tbody>
</table>
sinus is evident. On the anterior wall it presents clinically with “doughy” oedema of the skin over the frontal bone producing a mass (Pott’s puffy tumor) whereas from the posterior wall spread occurs directly or via thrombophlebitis of the valveless diploic veins leading to meningitis, peridural abscess or brain abscess. 

In this context, Gallagher reviewing the files of 125 patients with complicated rhinosinusitis, found that osteomyelitis developed in about 9% of cases. The sinus walls were affected in 32% of patients in Ogunleye’s data. Lang in 2001 recorded 10 cases of subdural empyema in adults and children secondary to frontal sinus infection: among them 4 had Pott’s puffy tumor and 1 had periorbital abscess.

Signs and symptoms of intracranial involvement are soft tissue oedema (especially of the superior lid), high fever, severe headache, meningeal irritation, nausea and vomiting, diplopia, photophobia, papilloedema, coma and focal neurological signs. Ocular signs can appear controlaterally. Contrast-enhanced CT scan confirms the diagnosis. A lumbar puncture, though contraindicated if intracranial pressure is elevated, can also be useful. Therapy includes a combination of i.v. broad-spectrum antibiotics administration and surgical debridement of sequestered bone and drainage.

8-7 Unusual complications of rhinosinusitis

<table>
<thead>
<tr>
<th>complication</th>
<th>author, year</th>
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<tbody>
<tr>
<td>lacrimal gland abscess</td>
<td>Mirza 2001, Patel 2003</td>
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<tr>
<td>nasal septal perforation</td>
<td>Sibbery 1997</td>
</tr>
<tr>
<td>visual field loss</td>
<td>Gouws 2003</td>
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<tr>
<td>mucocoele or mucopyocoele</td>
<td>Low 1997</td>
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<tr>
<td>displacement of the globe</td>
<td>Low 1997</td>
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<tr>
<td>sepsisemia</td>
<td>Rimal 2006</td>
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9. Special considerations: Rhinosinusitis in children special

9-1 Introduction

Rhinosinusitis is a common problem in children that is often overlooked. It is a multifactorial disease in which the importance of several predisposing factors changes with age and is different from the adult form of the disease in many respects (Table 1). The management of rhinosinusitis in children is a controversial and rapidly evolving issue.

| Table 9-1. Differences between paediatric and adult chronic rhinosinusitis |
|----------------------------------|-----------------|
| Commensal microflora             | young children  | adults  |
| Coagulase negative staphylococci | 30%             | 35%     |
| Staphylococcus aureus            | 20%             | 8%      |
| Haemophilus influenzae           | 40%             | 0%      |
| Moraxella catarrhalis            | 24%             | 0%      |
| Streptococcus pneumonia          | 50%             | 26%     |
| Corynebacterium species          | 52%             | 23%     |
| Streptococcus viridans           | 30%             | 4%      |
| Immunity                         | immature: defective response to polysaccharide antigens (IgG2, IgA) | mature, except in a subset |
| History                          | self-limited in time (improves after the age of 6-8 years) | no history of spontaneous improvement after certain age |
| Histology                        | mainly neutrophilic disease, less basement membrane thickening and mucus gland hyperplasia, more mast cells (Sobo 2003) | mainly eosinophils |
| Endoscopy                        | polyps are rare, except in CF | polyps frequently present |
| CT-scan                          | younger child more diffuse sinusitis, involving all sinus | sphenoid and posterior sinus less often involved |

9-2 Anatomy

In the newborn, the maxillary sinus extends to a depth of about 7 mm, is 3 mm wide and 7 mm high (986). In the newborn, two to three ethmoid cells are found bilaterally, and by the age of four the ethmoid labyrinth has formed. The sphenoid sinuses are also present in the neonate. Each sphenoid sinus is 4 mm wide and 2 mm high. At birth the frontal sinuses are not present, but they gradually develop from the anterior ethmoid cells into the cranium. When the upper edge of the aircell (cupola) reaches the same level as the roof of the orbit, it can be termed a frontal sinus, a situation that appears around the age of five. When a child reaches the age of 7-8 years the floor of the maxillary sinus already occupies the same level as the nasal floor.

9-3 Epidemiology and pathophysiology

Since the introduction of CT-scanning, it has become clear that a runny nose in a child is not only due to limited rhinitis or adenoid hypertrophy, but that in the majority of the cases the sinuses are involved as well. Van der Veken (220) in a CT scan study showed that in children with a history of chronic purulent rhinorrhea and nasal obstruction, 64 % showed involvement of the sinuses. In a MRI study of a non-ENT paediatric population (984) it was shown that the overall prevalence of sinusitis signs in children is 45 %. This prevalence increases in the presence of a history of nasal obstruction to 50 %, to 80 % when bilateral mucosal swelling is present on rhinoscopy, to 81 % after a recent upper respiratory tract infection (URTI), and to 100 % in the presence of purulent secretions. Also Kristo et al (982) found a similar overall percentage (50 %) of abnormalities on MRI in 24 school children. They included, however, a follow-up after 6 to 7 months, and found that about half of the abnormal sinuses on MRI findings had resolved or improved without any intervention. Epidemiologic studies on rhinosinusitis in children are limited but reveal the following information on the pathophysiology and clinically relevant factors influencing the prevalence of rhinosinusitis in children:

1. There is a clear-cut decrease in the prevalence of rhinosinusitis after 6 to 8 years of age. This is the natural history of the disease in children and is probably related to an immature immune system in the younger child (222, 223).

2. In temperate climates there is a definite increase in the occurrence of CRS in children during the autumn and in the wintertime, so that the season seems to be another important factor (222).

3. Younger children staying in day care centres show a dramatic increase in the prevalence of chronic or recurrent rhinosinusitis compared to children staying at home. See also section 1-1.

Although viruses are uncommonly recovered from sinus aspirates (985), most authors agree (984, 985) that viral infections are the trigger to rhinosinusitis. Although CT scan abnormalities can be seen up to several weeks after the onset of a URTI, one can assume that only 5 to 10 % of the URTIs in early childhood are
complicated by ARS (986). The time course (i.e., clinical symptoms) of viral to bacterial rhinosinusitis is the same as in adults.

The most common bacterial species isolated from the maxillary sinuses of patients with ARS are Streptococcus pneumoniae, Haemophilus influenzae, and Moraxella catarrhalis, the latter being more common in children (45, 46).

Antral punctures are now rarely performed in children but it is interesting to know from studies in the past there is a good correlation of bacteriology between the maxillary sinus and the middle meatal specimen (83%), and a poor correlation between those of the nasopharynx and the maxillary sinus (45%) (987).

9-4 Symptoms and signs

<table>
<thead>
<tr>
<th>Condition</th>
<th>All Forms</th>
<th>Acute</th>
<th>Chronic</th>
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<tbody>
<tr>
<td>Rhinorrhea (71 to 80%)</td>
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<tr>
<td>Cough (50 to 80%)</td>
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<td>Fever (50 to 60%)</td>
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<tr>
<td>Pain (29 to 33%)</td>
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<tr>
<td>Nasal obstruction (70 to 100%)</td>
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<tr>
<td>Mouth breathing (70 to 100%)</td>
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<tr>
<td>Ear complaints (recurrent purulent otitis media or OME in 40 to 68%)</td>
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</table>

Wald stresses that 3 common clinical developments should alert a clinician to the possibility of rhinosinusitis (990):
1. signs and symptoms of a cold that are persisting beyond 10 days (any nasal discharge, daytime cough worsening at night)
2. a cold that seems more severe then usual (high fever, copious purulent discharge, peri-orbital oedema and pain)
3. a cold that after several days of improvement worsen (with or without fever)

The neutrophil content of nasal brushings if ≥5% predicts maxillary sinusitis as judged from X-rays with a sensitivity of 91% and a predictive value of 84%, but only in non-allergic children (981).

9-5 Clinical examination

Physical examination of a child’s nose is often difficult, and only limited rhinoscopy is tolerated. The examination may be simply accomplished by lifting the tip of the nose upwards (young children have wide noses with round nostrils, allowing easy examination of the condition of the inferior turbinates). Another convenient method is the use of an otoscope (982, 983). Usually the nasal and pharyngeal mucosa appears erythematous with yellow to greenish purulent rhinorrhea of varying viscosity. A post nasal drip was seen in 60%, pus in the middle meatus in 50% in one study (988). Turbinate swelling was present in 29% in another (988). Lymphoid hyperplasia of the tonsils, adenoids and parapharyngeal wall may also be observed. The cervical lymph nodes may be moderately enlarged and slightly tender (992, 984).

Anterior rhinoscopy remains the first step but is inadequate by itself.

Endoscopy with a 2.7 mm rigid endoscope in the younger child (when possible a 4 mm in the older child) is more useful than flexible nasendoscopy, not only for the diagnosis but also for the exclusion of other conditions such as: presence of polyps, foreign bodies, tumours and septal deviations. In the younger child total anaesthesia is necessary to perform a thorough nasal endoscopy. Moreover it allows direct sampling of middle meatus flora.

9-6 Investigations

9-6-1 Microbiology

Microbiological assessment is usually not necessary in children with uncomplicated acute or chronic rhinosinusitis. Indication for microbiology are:
1. severe illness or toxic child;
2. acute illness in a child not improving with medical therapy within 48-72 hours;
3. an immuno-compromised host;
4. the presence of suppurative (intra-orbital, intracranial) complications (orbital cellulitis excepted).

Quantification of bacterial growth can also help in distinguishing contamination from real infection, and isolates should be considered positive when a type of bacteria is present in a quantity of at least 10,000 colonies/ml (986).

9-6-2 Imaging

Imaging is not necessary to confirm the diagnosis of rhinosinusitis in children. The increase in thickness of both the soft tissue and the bony vault of the palate in children under 10 years of age limits the usefulness of transillumination and ultrasonography in the younger age group (987). Plain X-rays are insensitive with limited usefulness for diagnosis or to guide surgery and correlate very poorly with CT scans. The marginal benefits are insufficient to justify the exposure to radiation (220).

CT scanning remains the imaging methodology of choice, because of its ability to resolve both bone and soft tissue, with good visualisation of the ostiomeatal complex. The indications for CT scanning in a child are the same as those given previously for a microbiology specimen with one extra indication which is if surgery is being considered after failure of medical therapy. The high incidence of asymmetrical children with CT scan abnormalities (986) must be remembered plus the fact that such children do not require treatment (997).
A number of studies suggest that the growth of the maxillary sinus is not impaired by extensive or chronic disease, unlike the temporal bone and it seems that the presence of a hypoplastic maxillary sinus per se is not an indication for surgery.  

9-6-3 Additional investigations

In the presence of recalcitrant rhinosinusitis, underlying conditions must be considered, preferably before undertaking any surgical procedure.

9-6-3-1 Allergy

The role of atopy in chronic rhinosinusitis is unclear. Many authors attribute a great deal of importance to allergy although others did not find an increased prevalence of rhinosinusitis in allergic children. In a CT scan study Iwens et al. (1994) found signs of mucosal inflammation in 61 % of atopical children (61). Ramadan (1999) showed that allergic patients had a higher CT scan score than non-allergic patients. Allergic children have more URT problems and more time off school than their non-allergic peers. Therefore in children with CRS and with a suggestive history (asthma, eczema), and/or physical examination findings (allergic salute, watery rhinorrhea, nasal blockage, sneezing, boggy turbinates), allergic assessment (skin prick, RAST) should be performed.

9-6-3-2 Immune deficiency

All young children have a physiologic primary immune deficiency. Defence against polysaccharide encapsulated bacteria via immunoglobulin G subclasses 2 and 4 may not reach adult levels until the age of 10 years. IgG subclass deficiency can lead to protracted or chronic rhinosinusitis. According to Polmar recurrent and chronic rhinosinusitis is the most common clinical presentation of common variable immunodeficiencies. Although not all patients who lack secretory IgA antibodies have an increased number of severe respiratory infections, the subject who has IgA deficiency and chronic rhinosinusitis is a difficult management problem, especially if an IgG subclass deficiency is also present. Replacement therapy cannot be provided. Patients with primary or acquired immune deficiencies (e.g. treatment for malignancies, organ transplants, maternally transmitted AIDS or blood-transmitted AIDS in haemophiliacs, drug induced conditions) are at risk for developing a difficult-to-treat rhinosinusitis with resistant or uncommon micro-organisms and fungi. Also the initial signs and symptoms may be non-specific, such as thin rhinorrhea, mild congestion, and chronic cough.

9-6-3-3 Cystic fibrosis

Cystic fibrosis is caused by a mutation of the gene FES1 encoding the cystic fibrosis transmembrane conductance regulator (CFTR). This gene contains 27 exons encompassing approximately 252 kb of DNA on chromosome 7q 31.2. The most common mutation, deletion of phenylalanine at position 508 (F508) accounts for nearly 70 % of mutations in European-derived Caucasian population.

In children with cystic fibrosis, sinusitis is a common problem. Although the prevalence of nasal disease was previously estimated to be between 6 and 20 %, Yung et al. found it to be over 50 % and Brihaye et al. reported that performing rigid endoscopy in 84 patients with cystic fibrosis, revealed inflammatory polyps in 45 % (mean age 15 years) and medial bulging of the lateral nasal wall in 12 % (mean age 5 years). In patients with cystic fibrosis and chronic rhinosinusitis, CT showed in 100 % opacification of the anterior complex (anterior ethmoid, maxillary and frontal sinus) and 57 % showed clouding of the posterior complex (posterior ethmoid and sphenoid). In all children with a medial displacement of the lateral nasal wall, there was a soft tissue mass in the maxillary antrum (large quantity of secretions surrounded by polyposal mucosa, representing a mucopurulent rhinosinusitis). In 80 % of these children the displacement was so extreme that the lateral nasal wall touched the septum, resulting in total nasal blockage. In a study by Brihaye et al. massive polyposis never occurred before the age of 5 years. Mucopurulence in the maxillary sinus occurs at a younger age (3 months to 8 years) and the maxillary sinus seems to be the first sinus affected by the disease. Recent data suggest that CF heterozygotes are over-represented in the paediatric CRS population.

9-6-3-4 Primary ciliary dyskinesia

Primary ciliary dyskinesia (PCD), an autosomal recessive disorder involving dysfunction of cilia is present in 1 of 15000 of the population and should always be considered in any neonate with respiratory or ENT problems of unknown origin. At least half of the PCD patients have symptoms when first born and especially in a term baby with no risk factor for congenital infection showing signs of rhinitis at birth, PCD should be excluded. The same applies to an infant or older child with atypical asthma, unresponsive to treatment, chronic watery rhinorrhea and sputum production, very severe gastro-oesophageal reflux, bronchiectasis, rhinosinusitis (rarely with polyposis), chronic and severe secretory otitis media, particularly with continuous, long lasting and diffuse discharge from the ears after grommet insertion. Roughly half the children with PCD have situs inversus and bronchiectasis in addition to rhinosinusitis ( Kartagener's syndrome).

There are two ways to screen for PCD: saccharine test and nasal nitric oxide. The saccharine test is a cheap and easy procedure to screen older children and adults, but is relatively unreliable Nasal nitric oxide (nNO) measurements can be made in children over 5 years old. Recent data suggests that PCD epithelia have a common defect – a lack of inducible nitric oxide synthase. In PCD values of nNO are usually less than 100; values exceeding 250 ppb have a sensitivity of 95 % for excluding the diagnosis of PCD. Since very low nNO
values can occur with severe nasal congestion the procedure should be repeated after decongestion or a brief course of oral plus topical corticosteroids. If the child is too young for the tests, if there is any doubt about the validity of the saccharine test, or the results are positive (transport time longer than 60 minutes, nNO less than 250ppb) or there exists a strong clinical suspicion, the ciliary beat frequency should be tested from a nasal epithelial biopsy.

If direct inspection of the ciliary beat frequency is abnormal (less than 11-16 Hz) an ultrastructure study of cilia is needed. The most common ciliary abnormalities in PCD are: dynein arm defects (absence or reduced number of inner, outer or both dynein arms), tubular defects (transposition and extra microtubules), radial spokes defects or absence, ciliary dysorientation (suspected if mean standard deviation of angle is larger than 20°), abnormal basal apparatus, ciliary aplasia, abnormally long cilia (1012). Many of these abnormalities on TEM (transmission electron microscopy), however, can be transient or occur secondarily after infection. Secondary ciliary dyskinesia, the acquired form (infections, inflammatory or toxic) is mostly correlated with other anomalies, such as microtubular abnormalities and composed cilia. However, there exists a great overlap of ultrastructural abnormalities between the two (1014). Therefore the study of cilia after sequential monolayer-suspension culture technique excludes the acquired form (1015).

9-6-3-5 Gastro-oesophageal reflux
The parallel existence of upper airway inflammation with ensuing problems of intractable rhinosinusitis, otitis, and gastro-oesophageal reflux (GER) has been observed and suggests a causal relationship. Barbero found in a group of patients with upper airway disease and GER, that anti-reflux measures may permit a greater well-being and that GER maybe among the variables leading to refractory chronic upper airway disease (1013). The otolaryngologist should be suspicious of GER in children complaining of chronic nasal discharge and obstruction combined with chronic cough, hoarseness and stridulous respiration. The endoscopic appearance of the laryngeal and tracheal areas are of considerable importance in conjunction with oesophageal examination, in determining the potential relationship between GER and otolaryngologic abnormalities. The diagnosis needs to be confirmed by oesophageal 24 hours pH monitoring: in 30 children with chronic sinus disease 63 % had oesophageal reflux and 32 % had nasopharyngeal reflux (772).

9-7 Management

9-7-1 Management of acute rhinosinusitis in children
Just as in adults acute rhinosinusitis in children usually only needs symptomatic treatment.

9-7-1-1 Antibiotics in ARS in children
A Cochrane meta-analysis (1010) of antibiotics for persistent nasal discharge concluded that antibiotics given for 10 days reduced the probability of persistence in the short to medium term. The benefits were modest and for 8 children treated one additional child would be cured (NNT 8, 95% CI 5 to 29). No long term benefits were documented. This meta-analysis is a combination of studies in rhinosinusitis in children with symptoms for as little as 10 days (1017) to more than 3 months (1018). Two more recent RCT comparing antibiotics to placebo or another therapy do not alter the conclusions of the meta – analysis (1019, 1020). According to the members of the consensus meeting in Brussels, 1996: Management of rhinosinusitis in children: (1021) antibiotics should be reserved largely for severe disease e.g.:

1. a severe illness or toxic condition in a child with suspected or proven suppuration complication. Intravenous administration of an appropriate agent is recommended. The antibiotic selected should be effective against the penicillin-resistant Streptococcus pneumonia, beta-lactamase producing H. influenzae and Moraxella catarrhalis
2. severe acute rhinosinusitis: in ambulatory patients for whom oral therapy is appropriate, an agent should be selected that is resistant to the action of beta-lactamase enzymes (amoxicillin-potassium clavunate or a second generation cephalosporin such as cefuroxime axetil)
3. non-severe acute rhinosinusitis: only in a child with protracted symptoms to whom antibiotics can be given on an individual basis (presence of asthma, chronic bronchitis, acute otitis media etc.)

In those children for whom antibiotic therapy is preferred, amoxycillin (45 mg/kg/day, doubled if under 2 or with risk factors for resistance) is appropriate. If the patient’s condition has not improved within 72 hours, a change of antibiotic to an agent effective against the resistant organism prevalent in the community should be considered.

Patients with a penicillin allergy should receive a suitable alternative antibiotic such as azithromycin or clarithromycin as first-line therapy.

9-7-1-2 Topical corticosteroids in ARS
Topical corticosteroids may be a useful ancillary treatment to antibiotics in childhood rhinosinusitis, effective in reducing the cough and nasal discharge earlier in the course of ARS (1021, 1022). There are a large number of studies showing that local corticosteroids are effective and safe in children with rhinitis (1023-1027).

9-7-1-3 Topical or oral decongestants
Most authors prefer topical α2 agonists (xylo- and oxymetazoline) in appropriate concentrations. Careful dosage is important when treating infants and young children, to prevent toxic manifestations.

A double blind, randomised controlled trial (RCT) by Michel (1028) (III, no power), compared isotonic EMS solution (balneotherapeutic water) with xylometazoline 0.05% solution in the treat-
ment of acute rhinosinusitis with middle ear involvement during 14 days in 66 children, aged 2-6 years, and revealed no difference in improvement in both groups, in terms of mucosal inflammation, nasal patency, middle ear function and general state of health, as outcome measures (1029). A double blind, randomised controlled trial (RCT) by McCormick (770) showed no additive effect of adding decongestant-antihistamine (nasal oxymetazoline and oral syrup containing brompheniramine and phenylpropanolamine) to amoxicillin (III, no power).

9-7-1-4 Nasal douching
Saline nose drops or sprays are popular with paediatricians (993, 1005). As long as the saline is isotonic and at body temperature, it can help in eliminating nasal secretions and it can decrease nasal oedema.

9-7-2 Management of chronic rhinosinusitis in children
Chronic rhinosinusitis in the young child does not have to be treated, as spontaneous resolution is the norm (1030). Van Buchem et al. followed 169 children with a runny nose for 6 months, treating them only with decongestants or saline nose drops. They did not find a single child who developed a clinically serious disease with general symptoms such as marked pain, pressure on sinuses, local swelling, or empyema, showing that complications of rhinosinusitis in a child are uncommon (223).

9-7-2-1 Treatment of chronic rhinosinusitis
The data on specific treatment of CRS in children very are limited. A quality of life tool for children SN-5 is now available (993, 1005).

9-7-2-2 Antibiotics
As described under 9-7-1-1 Antibiotic in ARS in children a Cochrane meta-analysis (1030) of antibiotics for persistent nasal discharge concluded that antibiotics given for 10 days reduced the probability of persistence in the short to medium term. The benefits were modest and for 8 children treated one additional child would be cured ( NNT 8, 95% CI 5 to 29). No long term benefits were documented. The only study really treating CRS was negative.

9-7-2-3 Topical corticosteroids
There are no data describing the efficacy of topical corticosteroids in paediatric CRS. There are a large number of studies showing that local corticosteroids are effective and safe in children with rhinitis (1023-1027) and one may assume that the same is true for CRS (level IV).

9-7-2-4 Nasal douching
In one double-blind RCT twenty children aged 3 to 14 years with a history of bronchial asthma complicated by chronic sinusitis were studied in a double-blind study. Patients received, at random, over a period of 2 weeks, either 2 ml saline or 2 ml bromhexine (2 mg/ml) t.i.d. by means of a home nebulizer. Both types of nebulization were equally efficient in reducing the symptom score (level III, no power) (771). A second randomized study in thirty children with CRS aged 3 to 16 years compared the effect of 4 weeks of douching with hypertonic saline (HS) (3.5%) versus normal saline (NS) (0.9%). Both treatments were effective although the HS seemed to be a little more effective than the NS (771). No data on side effects were given (level III).

9-7-2-5 GER therapy
In children with chronic rhinosinusitis and gastro-oesophageal reflux (GER) proven by 24 hours of pH monitoring Phipps et al. (772) found that most children showed improvement of sinus disease. Bothwell et al. (1031) suggested that in 89% of the children (25 out of 28) surgery could be avoided. These studies indicate that GER should be evaluated and treated in children with chronic sinus disease before sinus surgical intervention (level III).

9-7-2-6 Effect on asthma
In a study of eighteen children with sinusitis and asthma, medical treatment of sinusitis with topical corticosteroids, antibiotics and 2 days of oral steroid improved asthma and increased the interferon gamma/ IL4 ratio in nasal lavage (1031). Tsao noted that nasal douching improved bronchial hyperreactivity in asthmatic children (1032) level III.

9-7-2-7 Surgical treatment of rhinosinusitis
In chronic rhinosinusitis surgery should follow thorough investigation of underlying factors and a prolonged trial of medical therapy.

The following procedures are ineffective and therefore not recommended: antral lavage (993, 1011), inferior meatal antrostomy (995, 1034), except possibly in PCD. The Caldwell – Luc operation is contra-indicated because it can damage unerupted teeth (993, 1005).

Most of the controversies seem to centre on the indications for functional endoscopic sinus surgery in children. (FESS or paediatric FESS=PESS). The "functional" in FESS stands for the restoration of the function of the ostiomeatal complex i.e. ventilation and drainage. In 1998 an international consensus was reached concerning the indications of FESS in children (1021).

a. absolute indications:
1. complete nasal obstruction in cystic fibrosis due to massive polyposis or due to medialization of the lateral nasal wall;
2. orbital abscess;
3. intracranial complications;
4. antrochoanal polyp;
5. mucoceles or mucopyocele;
6. fungal rhinosinusitis;
b. possible indications:
in chronic rhinosinusitis with frequent exacerbations that persist despite optimal medical management and after exclusion of any systemic disease, endoscopic sinus surgery...
is a reasonable alternative to continuous medical treatment. Optimal management includes a 2-6 weeks of adequate antibiotics (IV or oral) with treatment of concomitant disease.

Surgery for chronic rhinosinusitis with frequent exacerbation is mostly limited to a partial ethmoidectomy: removal of the uncinate process, with or without a maxillary antrostomy in the middle meatus, and opening of the bulla is often sufficient. In other cases such as in cystic fibrosis with massive polyposis, extensive ethmosphenoidectomy may be necessary.

Most results are judged on symptomatic relief and do not include endoscopic examination or CT scan.

A meta-analysis performed by Hebert et al. (1037) showed in 8 published articles (832 patients) positive outcome rates going from 88 to 92%. The average combined follow-up was 3.7 years. They concluded that FESS is a safe and effective treatment for chronic rhinosinusitis that is refractory to medical treatment. Further, similar results have been published (1038-1040). Lieu and Piccirrillo (1041) retrospectively analysed the results of ESS in 133 children unresponsive to medical therapy using a 4 stage classification and suggested that operation was particularly effective for those in the intermediate stages.

Chan (1999) reported on 14 children with post FESS refractory rhinosinusitis and noted that 10 of them who were operated when under 4.8 years needed a disproportionately higher rate of further surgical intervention compared to the remaining clinical population. Ostitmeatal scarring was the most difficult complication (1042). They recommended judicious use of FESS in the very young. ESS is unlikely to be successful in under three year olds (1043) and its efficacy is reduced if the child is exposed to tobacco smoke. (1044). Disease duration prior to surgery does not affect outcome (1045). Intravenous dexamethasone per-operatively reduced swelling and scarring and was particularly useful in children with asthma, lower CT grades, no tobacco smoke exposure and in those over 6 years (1046).

Similar results were published by Jiang et al. (1046) and Fakhri et al. (1047) showing a postoperative improvement in 84% of the FESS patients (n=121). For this indication Bothwell et al. (1050) showed a postoperative improvement in 84% of the FESS patients. asian et al. (1051) found no statistically significant difference in the outcome of facial growth between a retrospective age-matched cohort out-

Duplechain (1049) reported for the first time the results of this kind of surgery in cystic fibrosis children followed by many other authors (1040, 1048, 1049, 1047). Co-ordinated care by paediatricians, pulmonologists anaesthetists, surgeons and physiotherapists is required, complication rates are around 11% in a recent study (1048). The results are less good than in non-CF children with around 50% of children reporting improvement at 2 years. However, sinus surgery post-lung transplantation is associated with a lower incidence of tracheobronchitis and pneumonia (1050).

The effectiveness of adenoidectomy in the management of paediatric rhinosinusitis is still a controversial issue. It is difficult to differentiate between the symptoms typical for chronic rhinosinusitis and those of adenoid hypertrophy. Hibert (1054) showed that nasal obstruction, snoring and speech defects occur more frequently in children with adenoid hypertrophy while symptoms of rhinorhoea, cough, headache, signs of mouth breathing, and abnormalities on anterior rhinoscopy occur as frequently in children with chronic rhinosinusitis as in children with adenoid hypertrophy.

Antibiotic-resistant bacteria were found on adenoid tissue culture in 56% of children undergoing adenoidectomy for hyper-trophy plus OME and CRS compared to 22% undergoing ade-noidecromy for hypertrophy without those complications (1049). Wang et al. e.g. found no significant correlation between the size of the adenoid and the presence of purulent secretions in the middle meatus on fibreoptic examination in 420 children between the age of 1 and 7 years, while there was a very significant correlation between the size of the adenoid and the complaints of mouth breathing (p<0.001) and snoring (p<0.001) (1052). The size of the adenoid and associated diseases seem to be factors for consideration.

Adenoidectomy was included in the stepwise protocol for the treatment of paediatric rhinosinusitis proposed by Don et al. (1057). Recently Ungkanont et al. proved adenoidectomy to be effective in the management of paediatric rhinosinusitis. They suggest performing an adenoidectomy as a surgical option before endoscopic sinus surgery (ESS), especially in younger children with obstructive symptoms (1052).

Ramadan (1999) has undertaken a prospective non-randomized study comparing ESS to adenoidectomy in the treatment of rhinosinusitis in 66 children with improvement in 77% of 31 children in the ESS group compared to 47% of 30 in the adenoidectomy group., (OR 3.9, p=0.01) (1055). Multivariate analysis demonstrated that ESS was significantly better after age, sex, allergy, asthma, day care and CT stage were adjusted for (OR 5.2,p=0.03). Asthma was an independent predictor of success (OR 4.3, p=0.03).
10. Chronic rhinosinusitis with or without nasal polyps in relation to the lower airways

10-1 Introduction

Due to its strategic position at the entry of the airway, the nose plays a crucial role in airway homeostasis. By warming up, humidifying and filtering incoming air, the nose is essential in the protection and homeostasis of lower airways \(^{(1056)}\). The nose and bronchi are linked anatomically, are both lined with a pseudo-stratified respiratory epithelium and equipped with an arsenal of innate and acquired immune defense mechanisms. It is not hard to imagine that nasal conditions causing nasal obstruction may become a trigger for lower airway pathology in susceptible individuals. In chronic sinus disease with nasal polyps \(^{(1055)}\) total blockage of nasal breathing may occur, hence bypassing nasal functions that may be relevant in preventing lower airway disease. It is, however, evident that the naso-bronchial interaction is not restricted to bronchial repercussions of hampered nasal air conditioning. Nose and bronchi seem to communicate via mechanisms such as neural reflexes and systemic pathways. Bronchoconstriction following exposure of the nose to cold air suggests that neural reflexes connect nose and lung \(^{(1056)}\). Recently, the systemic nature of the interaction between nose and bronchi has been proposed. Indeed, many inflammatory diseases of the upper airways show a systemic immunologic component involving the blood stream and bone marrow \(^{(1057)}\). In addition, genetic factors may also play a role in the manifestation of nasal and/or bronchial disease \(^{(1058)}\). In spite of the fact that aspiration of nasal contents may take place in neurologically impaired individuals, it is not clear whether micro-aspiration of nasal contents plays a role in the development or severity of bronchial disease \(^{(1059)}\).

10-2 Asthma and Chronic Rhinosinusitis without NP

Bronchial asthma is considered a comorbid condition of CRS. In some centres, around 50% of patients with CRS have clinical asthma \(^{(1060, 1061)}\). Interestingly, most patients with CRS who do not report having asthma show bronchial hyperreactivity when given a metacholine challenge test \(^{(1061)}\). Others report that 60% of patients with CRS have lower airway involvement, assessed by history, pulmonary function and histamine provocation tests \(^{(865)}\). Alternatively, sinonasal symptoms are frequently reported in asthmatic patients, ranging up to 80% in some studies. Radiologic imaging of the sinuses has demonstrated mucosal thickening of the sinus mucosa in up to 84% of patients with severe asthma \(^{(1062)}\). However, these epidemiologic and radiologic data should be interpreted with caution as they may reflect a large referral bias.

CRS is currently thought to have a multifactorial etiology, in which host factors like anatomical, local defense and immunologic factors, act in synergy with microbial and environmental factors in the development and chronicity of the disorder. Histopathologic features of CRS and asthma largely overlap. Heterogeneous eosinophilic inflammation and features of airway remodeling like epithelial shedding and basement membrane thickening, are found in the mucosa of CRS and asthma patients \(^{(1063)}\). Cytokine patterns in sinus tissue of CRS highly resemble those of bronchial tissue in asthma \(^{(1064)}\), explaining the presence of eosinophils in both conditions. Therefore, eosinophil degranulation proteins may cause damage to the surrounding structures and induce symptoms at their location in the airway. Finally, lavages from CRS patients show that eosinophils were the dominant cell type in both nasal and broncho-alveolar lavages in the subgroup of patients with CRS with asthma \(^{(1065)}\). Beside the similarities in pathophysiology, sinusitis has been aetiologically linked to bronchial asthma, and vice versa. As is the case in allergic airway inflammation, sinusitis and asthma can affect and amplify each other via the systemic route, involving interleukin (IL)-5 and the bone marrow. In both CRS and allergic asthma, similar pro-inflammatory markers are found in the blood. Recently, nasal application of *Staphylococcus aureus* enterotoxin B has been shown to aggravate the allergen-induced bronchial eosinophilia in a mouse model \(^{(1066)}\). Here, mucosal contact with enterotoxin B induced the systemic release of the typical T helper 2 cytokines IL-4, IL-5 and IL-13, leading to aggravation of experimental asthma. However, the interaction between both rhinosinusitis and asthma in not always clinically present, as Ragab et al. \(^{(1067)}\) found no correlation between rhinosinusitis and asthma severity. However, patients with asthma showed more CT scan abnormalities than non-asthmatic patients \(^{(1068)}\), and CT scan abnormalities in severe asthmatic patients correlated with sputum eosinophilia and pulmonary function \(^{(1069)}\).

Endoscopic sinus surgery (ESS) for CRS aims at alleviating sinonasal symptoms but also improves bronchial symptoms and reduces medication use for bronchial asthma \(^{(862, 863, 1064, 1065)}\). After a mean follow-up period of 6.5 years, 90% of asthmatic patients reported their asthma was better than it had been before the ESS, with a reduction of the number of asthma attacks and medication use for asthma \(^{(1069)}\). Also in children with chronic rhinosinusitis and asthma, sinus surgery improves the clinical course of asthma, reflected by a reduced number of asthma hospitalizations and school days missed \(^{(1066)}\). Lung function in asthma patients with CRS was reported to benefit from ESS by some authors \(^{(1068, 1069)}\), but denied by others \(^{(863, 1064, 1066)}\). Of note, not all studies show beneficial effects of ESS on asthma \(^{(1062)}\). The reason for the inconsistency in study results between
studies relates to the heterogeneity and small number of patients included in these studies, and difference in outcome parameters studied. Interestingly, the presence of lower airway disease may have a negative impact on the outcome after ESS. Outcomes after ESS were significantly worse in the asthma compared to the non-asthma group (853, 1065). On the other hand, other authors report that asthma does not represent a predictor of poor symptomatic outcome after primary or revision ESS (1063). In a series of 120 patients undergoing ESS, Kennedy (514) reports that asthma did not affect the outcome after ESS when comparing patients with equally severe sinus disease, except for the worst patients, in which asthma did adversely affect the outcome.

Until recently, no well-conducted clinical trials have been performed showing beneficial effects of medical therapy for CRS on bronchial asthma. Ragab et al. (864) published the first randomized prospective study of surgical compared to medical therapy of 43 patients with CRS with/without NP and asthma. Medical therapy consisted of a 12 weeks course of erythromycin, alkaline nasal douches and intranasal corticosteroid preparation, followed by intranasal corticosteroid preparation tailored to the patients’ clinical course. The surgical treatment group underwent ESS followed by a 2 week course of erythromycin, alkaline nasal douches and intranasal corticosteroid preparation, 3 months of alkaline nasal douches and intranasal corticosteroid, followed by intranasal corticosteroid preparation tailored to the patients’ clinical course. Both medical as well as surgical treatment regimens for CRS were associated with subjective and objective improvements in asthma state. Interestingly, improvement in upper airway symptoms correlated with improvement in asthma symptoms and control.

10-3 Asthma and Chronic Rhinosinusitis with NP

Seven percent of asthma patients have nasal polyp (176) and in non-atopic asthma and late onset asthma, polyps are diagnosed more frequently (10-15%). Aspirin-induced asthma is a distinct clinical syndrome characterized by the triad aspirin sensitivity, asthma and nasal polyposis and has an estimated prevalence of 1% in the general population and 10% among asthmatics (176).

Increased nasal colonization by Staphylococcus aureus and presence of specific IgE directed against Staphylococcus aureus enterotoxins was found in NP patients (820). Interestingly, rates of colonization and IgE presence in NP tissue were increased in subjects with NP and co-morbid asthma or aspirin sensitivity. By their superantigenic activity, enterotoxins may activate inflammatory cells in an antigen-non-specific way. Indeed, nasal application of Staphylococcus aureus enterotoxin B is capable of aggravating experimental allergic asthma (422). Besides bacterial enterotoxins, Ponikau et al. report on the potentially important role of fungi, especially Alternaria, in the generation of chronic sinus disease with NP (1070). By their capacity to induce eosinophil degranulation (1071), Alternaria may contribute to the inflammatory spectrum of CRS with/without NP and asthma.

No well-conducted trials on the effects of medical therapy for NP on asthma have been conducted so far. Therefore, well-designed trials on nasal corticosteroids, oral antibiotics, vaccination therapy or anti-leukotriene treatment in patients with NP and asthma are warranted. After ESS for NP in patients with concomitant asthma, a significant improvement in lung function and a reduction of systemic steroid use was noted, whereas this was not the case in aspirin intolerant asthma patients (1068). In a small series of patients with NP, endoscopic sinus surgery did not affect the asthma state (180). However, nasal breathing and quality of life improved in most patients.

10-4 COPD and rhinosinusitis

Up to 88 % of patients with COPD presenting at an academic unit of respiratory disease may experience nasal symptoms, most commonly rhinorrhea (1072). Nasal symptoms in COPD patients correspond well with an overall impairment of the quality of life (1072). So far, no further information is available on the nasobronchial interaction in COPD patients.
11. Socio-economic cost of chronic rhinosinusitis and nasal polyps

11-1 Direct Costs

Chronic rhinosinusitis, can be debilitating for patients and imposes a major economic cost on society in terms of both direct costs as well as decreased productivity. To better evaluate the socioeconomic impact of chronic rhinosinusitis, the current English literature has been reviewed. Data from outside the USA are very limited. In a 1999 publication, Ray et al estimated the total direct (medical and surgical) costs of sinusitis to be $5.78 billion in the US. This figure was extrapolated from governmental surveys such as the national health care survey and medical expenditure data. The cost of physician visits resulting in a primary diagnosis of sinusitis was $3.39 billion, which does not reflect the complete cost of radiographic studies, medication, or productivity losses.

Acknowledging that other airway disorders are closely tied to rhinosinusitis, Ray et al used the Delphi method to quantify how often rhinosinusitis is a secondary diagnosis contributing to the primary diagnosis assigned by physicians. An expert panel examined the co-incidence of rhinosinusitis in diseases such as asthma, otitis media, and allergic rhinitis, and determined that 10-15% of the cost of these other diseases was attributable to rhinosinusitis, increasing the economic burden of rhinosinusitis to the often quoted $5.78 billion sum. Ray’s paper relied on data collected by the National Centre for Health Statistics and did not attempt to distinguish ARS from the chronic form of this disease. Addressing the cost analysis in the diagnosis of chronic rhinosinusitis, Stankiewicz and Chow concluded that, at the present moment, subjective diagnostic paradigm for chronic rhinosinusitis is most cost-effective, although less accurate.

Franzese and Stringer made an economic analysis comparing a normal CT scan to limited coronal CT scan. In this study limited CT scan was found to be less cost-effective than the full CT scan, costing $217,13 more per correct diagnosis.

In 2002, Murphy et al examined a single health maintenance organization to evaluate the cost of CRS. The authors compared the costs of healthcare for members with a diagnosis of CRS to the cost of those without the diagnosis during 1994 and were able to determine the direct medical costs of the disease based on reimbursements paid rather than charges submitted. According to Murphy’s study, patients with a diagnosis of CRS made 43% more outpatient and 25% more urgent care visits than the general population (p=0.001). CRS patients filed 43% more prescriptions, yet had fewer hospital stays than the general HMO adult population. In total, the cost of treating patients with CRS was $2,609 per year, 6% more than the average adult in the HMO. Because patients received all healthcare services in one integrated system, this figure includes the costs of radiography, hospitalization, and medication. CRS care specifically cost $206 per patient per year, thus contributing to a calculated nationwide direct cost of $4.3 billion annually based on the 1994 statistic of 20.9 million individuals seeking care for CRS. Using the more recent value of 32 million affected, the overall cost would increase to $6.39 billion annually.

Addressing the cost of pharmacologic management of CRS, Giilkich and Metson’s 1998 study reported an annual expenditure of $1220. This figure is the sum of OTC medications ($198), nasal sprays ($250), and antibiotics ($772). In an ARS pharmacecoeconomic review article on antibacterial use, Wasserfallen et al suggest that, of the different treatment strategies, symptomatic treatment (patients being treated with antibiotics only if they fail to improve after 7 days) was the most cost-effective approach, compared with treating patients on the basis of specific clinical criteria, empirical treatment with antibiotics, or radiology-guided treatment.

Only one study in Europe has been found which considers the costs of CRS. This study was done in patients with severe chronic rhinosinusitis visiting a university hospital in the Netherlands. The direct cost of the CRS of these severe patients was $1861/year.

No data are available distinguishing costs of nasal polyps from CRS.

In conclusion we can deduce from these limited data that the average direct costs of CRS per patient per year is between $200,- and $2000,- depending on the severity of the disease.

11-2 Indirect Costs

The studies of direct medical costs demonstrate the social economic burden of the disorder. However, the total costs of CRS are greater. With 85% of patients with CRS of working age (between 18-65 years old) indirect costs such as missed workdays and decreased productivity at work significantly add to the economic burden of disease.

Goetz et al attempted to quantify the indirect costs of rhinosinusitis. Their 2003 study resulted in rhinosinusitis being named one of the top ten most costly health conditions to US employers. A large multi-employer database was used to track insurance claims through employee health insurance, absentee days, and short-term disability claims. Episodes of illness were linked to missed workdays and disability claims, accurately correlating absenteeism to a given disease.

In a large sample size (375,000), total healthcare payments per
employee per year for rhinosinusitis (acute and chronic) were found to be $60.17, 46% of which came from the cost of absenteeism and disability. These figures approximate the cost to employers, disregarding the cost incurred by other parties, and therefore tremendously underestimate the entire economic burden of the disease. In his 2003 study, Bhattacharyya (722) used patient-completed surveys to determine the direct and indirect costs of CRS. Patients completed a survey assessing symptoms of disease, detailing medication use, and quantifying missed worked days attributable to CRS. According to Bhattacharyya, the cost of treating CRS per patient totalled $1,539 per year. Forty percent of these costs were due to the indirect costs of missed work; the mean number of missed workdays in this sample of 322 patients was 4.8 days (95% CI, 3.4-6.1). Bhattacharyya’s study attempts to analyze both the direct and indirect costs of CRS and the final figures are enormous. Assuming a cost of $1500 per patient per year, and assuming CRS affects 32 million Americans, the overall cost of the disease would be $47 billion if the severity of disease was similar to that assessed in the study for all patients with the disorder. However, this would appear to be an unlikely assumption.

It should be noted that in this last study, the patient population evaluated were generated through visits to an otolaryngologist. Therefore, this patient population had already failed initial therapy by primary care givers and possibly by other otolaryngologists. The therapeutic interventions by the specialist are therefore likely to be biased toward more aggressive and thus more expensive therapy.

The cost burden of absenteeism is enormous, and yet it is only the beginning. The general health status of patients with CRS is poor relative to the normal US population (588). This decreased quality of life not only leads to absenteeism, but also contributes to the idea of “presenteeism” or decreased productivity when at work. Ray et al estimated by the 1994 National Health Interview Survey, that missed worked days due to rhinosinusitis was 12.5 million and restricted activity days was 58.7 million days (3). Economic loss due to presenteeism cannot be easily quantified, but surely increases the cost burden of the disease.
12. Outcomes measurements in research

Trial design has largely focussed on medical therapy. The FDA recommends three components (1079)

1. the objective of the study must be clearly stated, coupled with a summary of the methods used for analysis of the results

2. the design must permit quantitative assessment of drug (ie therapeutic) effectiveness by a valid comparison with a control group

3. the study protocol should accurately define the design and duration of the study, sample size issues and whether treatments are parallel or sequential.

A single primary outcome measure is preferred to minimise the possibility of a Type I error (incorrectly assuming that a drug is effective). However, the FDA recognises that 2 may be appropriate.

Trials may be conducted in acute and chronic rhinosinusitis with or without polyps and may consider single, short-term or longer term interventions. Studies may be conducted in primary or secondary care and the criteria for diagnosis, inclusion and exclusion together with outcome measures will depend upon the setting.

Table 12-1 Criteria for studies conducted in primary and secondary care

<table>
<thead>
<tr>
<th>criteria</th>
<th>primary care</th>
<th>secondary care</th>
</tr>
</thead>
<tbody>
<tr>
<td>symptom profile &amp; severity using VAS</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>endoscopy (scoring eg 0-3)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>imaging</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>CT (scoring eg Lund-Mackay 0-24)</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>medication use</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>co-morbidity (eg allergy, asthma, aspirin sensitivity)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>smoking history</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>additional tests (eg microbiology, smell, mediators, cytology, mucociliary function, haematology, airway)</td>
<td>±</td>
<td>±</td>
</tr>
</tbody>
</table>

Table 12-2. Data for all studies to include:

- Title
- rationale for study
- objectives
- design
- study population: inclusion & exclusion criteria
- outcomes:
- primary & secondary
- subjective & objective
- safety assessments
- statistical methodology/power analysis
- ethics approval
- drop-out analysis
13. Evidence based schemes for diagnostic and treatment

13-1 Introduction

The following schemes for diagnosis and treatment are the result of a critical evaluation of the available evidence. The tables give the level of evidence for studies with a positive outcome and well powered studies with negative outcome. Ib (-) in this tables means a well designed (Ib) study with a negative outcome. The grade of recommendation for the available therapy is given. Under relevance it is indicated whether the group of authors think this treatment to be of relevance in the indicated disease.

Table 13-1. Treatment evidence and recommendations for adults with acute rhinosinusitis

<table>
<thead>
<tr>
<th>therapy</th>
<th>level</th>
<th>grade of recommendation</th>
<th>relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral antibiotic</td>
<td>Ia</td>
<td>A</td>
<td>yes: after 5 days, or in severe cases</td>
</tr>
<tr>
<td>topical corticosteroid</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>topical steroid and oral antibiotic combined</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>oral corticosteroid</td>
<td>Ib</td>
<td>A</td>
<td>yes reduces pain in severe disease</td>
</tr>
<tr>
<td>oral antihistamine</td>
<td>Ib</td>
<td>B</td>
<td>yes, only in allergic patients</td>
</tr>
<tr>
<td>nasal douche</td>
<td>Ib (-)#</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>decongestant</td>
<td>Ib (-)#</td>
<td>D</td>
<td>yes, as symptomatic relief</td>
</tr>
<tr>
<td>mucolytics</td>
<td>none</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>phytotherapy</td>
<td>Ib</td>
<td>D</td>
<td>no</td>
</tr>
</tbody>
</table>

# : Ib (-) study with a negative outcome

Table 13-2. Treatment evidence and recommendations for children with acute rhinosinusitis

<table>
<thead>
<tr>
<th>therapy</th>
<th>level</th>
<th>grade of recommendation</th>
<th>relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral antibiotic</td>
<td>Ia</td>
<td>A</td>
<td>yes: after 5 days, or in severe cases</td>
</tr>
<tr>
<td>topical corticosteroid</td>
<td>IV</td>
<td>D</td>
<td>yes</td>
</tr>
<tr>
<td>topical steroid on top of oral antibiotic</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>topical decongestant</td>
<td>III (-)</td>
<td>C</td>
<td>no</td>
</tr>
<tr>
<td>saline douching</td>
<td>IV</td>
<td>D</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 13-3 Treatment evidence and recommendations for adults with chronic rhinosinusitis without nasal polyps *

<table>
<thead>
<tr>
<th>therapy</th>
<th>level</th>
<th>grade of recommendation</th>
<th>relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral antibiotic therapy short term &lt; 2 weeks</td>
<td>Ib (-)</td>
<td>C</td>
<td>no</td>
</tr>
<tr>
<td>oral antibiotic therapy long term &gt; 12 weeks</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>Antibiotics – topical</td>
<td>III</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>steroid – topical</td>
<td>Ib (-)</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>steroid – oral</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>nasal saline douche</td>
<td>Ib (-)</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>decongestant oral / topical</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>mucolytics</td>
<td>III</td>
<td>C</td>
<td>no</td>
</tr>
<tr>
<td>antimycotics – systemic</td>
<td>Ib (-)#</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>antimycotics – topical</td>
<td>Ib (-)#</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>oral antihistamine in allergic patients</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>proton pump inhibitors</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>bacterial lysates</td>
<td>Ib (-)</td>
<td>A</td>
<td>no</td>
</tr>
<tr>
<td>immunomodulators</td>
<td>Ib (-)#</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>phytotherapy</td>
<td>Ib (-)#</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>anti-leukotrienes</td>
<td>III</td>
<td>C</td>
<td>no</td>
</tr>
</tbody>
</table>

* Some of these studies also included patients with CRS with nasal polyps
* Acute exacerbations of CRS should be treated like acute rhinosinusitis
# : Ib (-) study with a negative outcome
**Table 13-4** Treatment evidence and recommendations postoperative care in adults with chronic rhinosinusitis without NP*

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Level</th>
<th>Grade of recommendation</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral antibiotic short term &lt; 2 weeks</td>
<td>no data</td>
<td>D</td>
<td>yes, immediately postoperative, if pus was seen during operation</td>
</tr>
<tr>
<td>Oral antibiotic long term ~ 12 weeks</td>
<td>no data</td>
<td>D</td>
<td>yes</td>
</tr>
<tr>
<td>Topical antibiotics</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Oral steroid</td>
<td>Ib (one +, one -)</td>
<td>B</td>
<td>yes</td>
</tr>
<tr>
<td>Nasal douche</td>
<td>no data available</td>
<td>D</td>
<td>yes</td>
</tr>
</tbody>
</table>

* Some of these studies also included patients with CRS with nasal polyps

**Table 13-5.** Treatment evidence and recommendations for adults with chronic rhinosinusitis with nasal polyps *

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Level</th>
<th>Grade of recommendation</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral antibiotics short term &lt; 2 weeks</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Oral antibiotic long term &gt; 12 weeks</td>
<td>Ib</td>
<td>D</td>
<td>yes, for late relapse</td>
</tr>
<tr>
<td>Topical antibiotics</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Oral steroids</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>Nasal douche</td>
<td>Ib no data in single use</td>
<td>A</td>
<td>yes for symptomatic relief</td>
</tr>
<tr>
<td>Decongestant topical / oral</td>
<td>no data in single use</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Mucolytics</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Antimycotics – systemic</td>
<td>Ib (-)#</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Antimycotics – topical</td>
<td>Ib (-)#</td>
<td>A</td>
<td>no</td>
</tr>
<tr>
<td>Oral antihistamine in allergic patients</td>
<td>Ib (I)#</td>
<td>A</td>
<td>no, in allergy</td>
</tr>
<tr>
<td>Capsaicin</td>
<td>II</td>
<td>B</td>
<td>no</td>
</tr>
<tr>
<td>Proton pump inhibitors</td>
<td>II</td>
<td>C</td>
<td>no</td>
</tr>
<tr>
<td>Immunomodulators</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Phytotherapy</td>
<td>no data</td>
<td>D</td>
<td>no</td>
</tr>
<tr>
<td>Anti leukotrienes</td>
<td>III</td>
<td>C</td>
<td>no</td>
</tr>
</tbody>
</table>

* Some of these studies also included patients with CRS without nasal polyps

# : (Ib) study with a negative outcome

**Table 13-6.** Treatment evidence and recommendations postoperative treatment in adults with chronic rhinosinusitis with nasal polyps*

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Level</th>
<th>Grade of recommendation</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral antibiotics short term &lt; 2 weeks</td>
<td>no data</td>
<td>D</td>
<td>immediately post-operative, if pus was seen during operation</td>
</tr>
<tr>
<td>Oral antibiotics long term &gt; 12 weeks</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>Topical steroids after FESS</td>
<td>Ib (2 studies one + one -)</td>
<td>B</td>
<td>yes</td>
</tr>
<tr>
<td>Topical steroids after polypectomy</td>
<td>Ib</td>
<td>A</td>
<td>yes</td>
</tr>
<tr>
<td>Oral steroids</td>
<td>no data</td>
<td>D</td>
<td>yes</td>
</tr>
<tr>
<td>Nasal douche</td>
<td>no data</td>
<td>D</td>
<td>yes</td>
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</table>

* Some of these studies also included patients with CRS without nasal polyps

**Table 13-7** Treatment evidence and recommendations for children with chronic rhinosinusitis

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Level</th>
<th>Grade of recommendation</th>
<th>Relevance</th>
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<tbody>
<tr>
<td>Oral antibiotic</td>
<td>Ia</td>
<td>A</td>
<td>yes, small effect</td>
</tr>
<tr>
<td>Topical corticosteroid</td>
<td>IV</td>
<td>D</td>
<td>yes</td>
</tr>
<tr>
<td>Saline douching</td>
<td>III</td>
<td>C</td>
<td>yes</td>
</tr>
<tr>
<td>Therapy for gastro-oesophageal reflux</td>
<td>III</td>
<td>C</td>
<td>yes</td>
</tr>
</tbody>
</table>
13-2 Introduction

Since the preparation of the first EP3OS document an increasing amount of evidence on the pathophysiology, diagnosis and treatment has been published (figure1-1). However, in compiling the tables on the various forms of therapy, it may be that despite well powered level Ib trials, no significant benefit has been demonstrated. Equally results may be equivocal or apparently positive results are undermined by the small number of trials conducted and/or the small number of participants in the trial(s). In these cases, after detailed discussion, the EPOS group decided in most cases, that there was no evidence at present to recommend use of the treatment in question. Alternatively for some treatments no trials have been conducted, even though the treatment is commonly used in which case a pragmatic approach has been adopted in the recommendations.
13-3 Evidence based management scheme for adults with acute rhinosinusitis

13-3-1 Evidence based management scheme for adults with acute rhinosinusitis for primary care

**Diagnosis**
Symptom based, no need for radiology.

*Not recommended:* plain x-ray.

**Symptoms**
sudden onset of two or more symptoms one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):
± facial pain/pressure;
± reduction/loss of smell;

---

**Symptoms less than 5 days or improving thereafter**

- **Common cold**
- **Symptomatic relief**
- **No improvement after 14 days of treatment**
- **Consider referral to specialist**

**Symptoms persisting or increasing after 5 days**

- **Moderate**
  - **Topical steroids**
  - **Effect in 48 h**
  - **Continue treatment for 7 - 14 days**

- **Severe**
  - **Antibiotics**
  - **Topical steroids**
  - **No effect in 48 h**
  - **Refer to specialist**

---

**Treatment**
*Treatment evidence and recommendations for acute rhinosinusitis see Table 13-1.*
Initial treatment depending on the severity of the disease:
See figure 13-1.
- mild: start with symptomatic relief (decongestants, saline, analgesics);
- moderate: additional topical steroids
- severe: additional antibiotics and topical steroids

---

At any point immediate referral/hospitalisation
- Periorbital oedema
- Displaced globe
- Double vision
- Ophthalmoplegia
- Reduced visual acuity
- Severe unilateral or bilateral frontal headache
- Frontal swelling
- Signs of meningitis or focal neurologic signs

---

*Sudden onset of two or more symptoms, one of which should be either nasal blockage/obstruction/congestion or nasal discharge: anterior/posterior nasal drip:
± facial pain/pressure;
± reduction or loss of smell;
examination: anterior rhinoscopy
X-ray/CT not recommended

---

*fever > 38°C severe pain

---

Figure 13-1. Treatment scheme for primary care for adults with acute rhinosinusitis
13-3-2 Evidence based management scheme for adults with acute rhinosinusitis for ENT specialists

**Diagnosis**

**Symptoms**
- sudden onset of two or more symptoms one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):
  - ± facial pain/pressure;
  - ± reduction/loss of smell;

**Signs**
- nasal examination (swelling, redness, pus);
- oral examination: posterior discharge;
- exclude dental infection.

ENT-examination including nasal endoscopy.

*Not recommended:* plain x-ray.

CT-Scan is also **not** recommended **unless** additional problems such as:
- very severe diseases,
- immunocompromised patients;
- signs of complications.

---

**Figure 13-2. Treatment scheme for ENT specialists for adults with acute rhinosinusitis**
13-4 Evidence based management scheme for adults with chronic rhinosinusitis without nasal polyps

13-4-1 Evidence based management scheme for adults with CRS with or without NP for primary care and non-ENT specialists

**Diagnosis**

Symptoms present longer than 12 weeks  
two or more symptoms one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):  
± facial pain/pressure,  
± reduction or loss of smell;

Additional diagnostic information
- questions on allergy should be added and, if positive, allergy testing should be performed.

Not recommended: plain x-ray or CT-scan

Acute exacerbations of CRS should be treated like acute rhinosinusitis (108).

- Examination: anterior rhinoscopy
- X-ray/CT not recommended

Endoscopy available

- Polyps
  - Follow ENT specialist  
  - NP scheme
  - Refer to ENT specialist if operation is considered
- No polyps
  - Follow ENT
  - CRS scheme

Endoscopy not available

- Examination: anterior rhinoscopy
- X-ray/CT not recommended

Topical steroids
  - Nasal douching/lavage  
  + antihistamines if allergic

Re-evaluation after 4 weeks

- Improvement
  - Continue therapy
- No improvement
  - Refer to ENT specialist

Consider other diagnosis
- Unilateral symptoms  
- Bleeding  
- Crusting  
- Cacosmia

Orbital symptoms:
- Periorbital oedema  
- Displaced globe  
- Double or reduced vision  
- Ophthalmoplegia

Severe frontal headache  
Frontal swelling  
Signs of meningitis or focal neurological signs

Systemic symptoms

Urgent investigation and intervention

Figure 13-3 Chronic Rhinosinusitis with or without nasal polyps management scheme for primary care and non-ENT specialists (CRS/NP)
13-4-2 Scheme for adults with CRS without NP for ENT-Specialists

Diagnosis

Symptoms present longer than 12 weeks
Two or more symptoms one of which should be either nasal blockage/blockage/congestion or nasal discharge (anterior/posterior nasal drip):
± facial pain/pressure,
± reduction or loss of smell;

Signs
• ENT examination, endoscopy;
• review primary care physician’s diagnosis and treatment;
• questionnaire for allergy and if positive, allergy testing if it has not already been done.

Treatment should be based on severity of symptoms
• Decide on severity of symptomatology using VAS

Improvement

Failure after 3 months

Failure after 3 months

Topical steroids
Nasal douching/lavage

Topical steroids
Nasal douching
culture
Long-term macrolides

Topical steroids
Nasal douching/lavage

CT scan

Surgery

Follow-up + nasal douching
Topical steroids ± long-term macrolides

Figure 13-4. Treatment scheme for ENT-Specialists for adults with CRS without nasal polyps
13-4-3 Scheme for adults with NP for ENT-Specialists

**Diagnosis**

**Symptoms present longer than 12 weeks**
Two or more symptoms one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):
- ± facial pain/pressure,
- ± reduction or loss of smell;

**Signs**
- ENT examination, endoscopy;
- review primary care physician’s diagnosis and treatment;
- questionnaire for allergy and if positive, allergy testing if not already done.

**Severity of the symptoms**
- (following the VAS score for the total severity) mild/moderate/severe.

---

**Figure 13-5. Treatment scheme for ENT-Specialists for adults with CRS with nasal polyps**
13-5 Evidence based schemes for therapy in children

The following scheme should help different disciplines in the treatment of rhinosinusitis in children. The recommendations are based on the available evidence, but the choices need to be made depending on the circumstances of the individual case.

13-5-1 Evidence based management scheme for children with acute rhinosinusitis

**Diagnosis**

**Symptoms**

sudden onset of two or more symptoms one of which should be either nasal blockage obstruction congestion or nasal discharge (anterior/posterior nasal drip):

± facial pain pressure;
± reduction loss of smell;

**Signs (if applicable)**

- nasal examination (swelling, redness, pus);
- oral examination: posterior discharge;
- exclude dental infection.

ENT-examination including nasal endoscopy.

**Not recommended**: plain x-ray.

CT-Scan is also **not** recommended unless additional problems such as:

- very severe diseases,
- immunocompromised patients;
- signs of complications.

**Treatment**

Treatment evidence and recommendations for acute rhinosinusitis see Table 13-2.

Initial treatment depending on the severity of the disease: See figure 13-6.

---

![Figure 13-6. Treatment scheme for children with acute rhinosinusitis](image-url)
13-5-2 Evidence based management scheme for children with chronic rhinosinusitis

Diagnosis

Symptoms present longer than 12 weeks
two or more symptoms one of which should be either nasal blockage/obstruction/congestion or nasal discharge (anterior/posterior nasal drip):
± facial pain/pressure,
± reduction or loss of smell;

Additional diagnostic information
• questions on allergy should be added and, if positive, allergy testing should be performed.
• other predisposing factors should be considered: immune deficiency (innate, acquired, GERD)

Signs (if applicable)
• nasal examination (swelling, redness, pus);
• oral examination: posterior discharge;
• exclude dental infection.
ENT-examination including nasal endoscopy.

Not recommended: plain x-ray.
CT-Scan is also not recommended unless additional problems such as:
• very severe diseases;
• immunocompromised patients;
• signs of complications.
• ENT examination, endoscopy if available.

Treatment should be based on severity of symptoms

Figure 13-7 Chronic Rhinosinusitis in children management scheme
14. Research needs and priorities

While our understanding of CRS has increased considerably, this only serves to outline areas that will require further exploration and clinical trials for validation of observations and hypotheses.

14-1 Epidemiology: Identifying the risk factors for development of CRS and NP
Our understanding of factors predisposing to CRS and NP remain embryonic with few studies to date. Epidemiologic studies aimed at identification of personal risk factors and environmental modifiers are required to increase our understanding of the disease process, select appropriate populations for clinical trials and interpret information from genetic studies.

Addressing this need will require detailed assessment and long-term follow up of a well-characterised patient populations to identify risk factors associated with development of CRS. A prospective population study of age- and sex-matched controlled atopic and non-atopic individuals might allow better characterisation of the incidence of all upper respiratory tract symptoms including acute and chronic rhinosinusitis over a 5-year period. Similarly, a long-term follow-up of a cohort of patients with nasal polyposis would allow study of the natural history of the condition.

Identification of environmental modifiers will require prospective assessment of a very large cohort of patients to monitor for development of disease. While probably impractical for CRS alone, the trend to development of databases of medical and genetic information on large populations such as the UK BioBank initiative may eventually offer populations for this research.

14-2 Beyond infection: New roles for bacteria
It is increasingly recognised that bacteria may play a role in the chronic inflammation of CRS. Among others, Staphylococcus aureus has been specifically implicated, with possible persistence favoured by bacterial biofilms. In the light of this evidence, the role of bacteria in CRS needs to further explored in at least three areas.
1. Host factors favouring persistence of bacterial colonisation need to be better characterised.
2. The relative importance of biofilms and intracellular S. aureus in the development and persistence of CRS must be assessed
3. The role of S. aureus in development or persistence of CRS via postulated staphylococcal enterotoxins stimulating T-cells directly via a superantigenic mechanism needs to be validated.

14-3 Host response
Further studies into the mechanisms leading to the development of CTRS need to be identified. Events occurring at the level of the epithelium including non-specific defences such as innate immunity need better description and offer potential targets for therapy.

14-4 Genetics
Finally, pathogenesis of CRS may be better explored with research techniques taken from the growing field of genetics. Population association studies may allow detection of polymorphisms in genes in individuals suffering from CRS. Studies of candidate genes in currently known pathways may allow identification of specific genetic polymorphisms in the different steps of the pathways, while whole genome scans probing the entire genome offer the hope of identification of novel genes not suspected of being implicated.

Studies of gene expression in biopsy samples will help identify differential gene activation in different disease states and following different courses of therapy. Both of these offer the hope for development of tests allowing better differentiation of disease states and targeted therapy, with the tantalizing promise of identification of new drug targets not presently exploited.

These studies will require a cohort of investigators trained in these new techniques and development of multidisciplinary groups to collect and exploit the large populations required for these studies. Multinational collaborative initiatives will have to be initiated to collect the large sample sizes of affected individuals required for this work.

14-5 Clinical trials
Although much work has been recently been done on chronic rhinosinusitis and nasal polyps this work needs to be validated in terms of its clinical impact. Our understanding needs to translate into therapy for disease and experimental hypotheses need to verify by appropriate clinical trials. The following suggestions should highlight some areas of interest for further investigation.
1. Areas that have been identified need to be targeted with specific therapies. In particular, means of targeting biofilms, reducing S. aureus colonisation and of modulating response to S. aureus enterotoxins need to be developed and assessed by means of well-designed clinical trials.
2. Emerging therapies need to be assessed critically in order to determine which ones are effective and in which settings. There is an urgent need for randomized placebo controlled trials to study the effect of antibiotics in acute rhinosinusitis, chronic rhinosinusitis and exacerbations of chronic rhinosinusitis. These
should be compared with nasal steroids as a single modality of treatment for these conditions.

3. A well-powered prospective study of the effectiveness of macrolides in CRS and NP would allow validation of the positive effects suggested by some studies. The role of topical antibiotic therapy in exacerbations of CRS needs to be performed with well-characterized patients to identify optimal situations for use.

4. In the same fashion, novel therapies introduced over the coming years should be scrutinised closely prior to widespread adoption. Specifically, it is hoped that in the future clinicians will remain vigilant to claims made without the support of prospective, adequately powered clinical trials.

5. Surgical management for CRS and NP will probably continue to play a role in the management of CRS. In the future, rather than attempting to demonstrate superiority of one therapy over another, studies should target selected patient populations or situations so as to guide the clinician to a rational use of medical and/or surgical therapy as part of a comprehensive treatment plan individualised to stage of disease and patient needs.

6. Most QoL and symptom-specific questionnaires have been designed for a North American population and need to be validated for European patients.

7. The relationship between the upper and lower respiratory tract needs further investigation and will offer further insight into pathophysiology of inflammation and therapeutic possibilities.
15. Glossary terms

**Acute non-viral rhinosinusitis (ARS):** an episode of sudden onset with an increase of symptoms after 5 days or persistent symptoms after 10 days with less than 12 weeks duration.

**Acute viral rhinosinusitis:** an episode of sudden onset with duration of symptoms for less than 10 days

**Common cold:** Acute viral rhinosinusitis

**Chronic rhinosinusitis (CRS):** a condition lasting for >12 weeks, comprising two or more symptoms one of which should be either nasal blockage/congestion/congestion or nasal discharge (anterior/posterior nasal drip):
- ± facial pain/pressure;
- ± reduction or loss of smell;
May occur with or without polyps

**Cacosmia:** awareness of an unpleasant smell, often rotten or faeculent

**Cobblestoned:** an irregular bumpy mucosal surface usually post-surgery for polyps

**Conventional surgery:** a range of operations which predated endoscopic sinus surgery eg polypectomy, inferior meatal antrostomy, Caldwell-Luc operation, Denker’s procedure, external fronto-ethmoidectomy

**Endonasal surgery:** any surgery performed through the nose

**Functional surgery:** an operation which aims to restore function eg restitution of mucociliary clearance, improvement in olfaction

**Iatrogenic:** a condition induced unintentionally by a physician, usually by a therapeutic action

**Local corticosteroid:** topical intranasal instillation of a corticosteroid preparation

**Middle meatus:** that area of the lateral wall of the nose lying lateral to the middle turbinate

**Middle meatal antrostomy:** an opening into the maxillary sinus though the lateral wall of the middle meatus

**Mucopurulent secretion:** a mixture of opaque and discoloured mucus which is not frank pus

**Orbital complications:**
- **Ecchymosis:** an area of discoloration beneath the skin secondary to bleeding
- **Enophthalmos:** abnormal retraction of the eyeball into the socket
- **Myospherulosis:** granulomatous foreign body reaction in soft tissues due to extravasation of paraffin or oil
- **Orbital emphysema:** the presence of air within the soft tissues of the eye
- **Periorbital cellulitis:** inflammation of the eyelid and conjunctiva

**Ostiomeatal complex:** that area of the middle meatus into which the maxillary, anterior ethmoid and frontal sinuses drain

**Pansinusitis:** involvement of all paranasal sinuses, usually demonstrated radiologically

**Pathogen:** any organism capable of producing disease

**Rhinitis medicamentosa:** a condition associated with use of intranasal decongestants in which the nasal mucosa undergoes atrophy

**Rhinorrhoea:** any discharge from the nose. May run from the front of the nose (anterior) or into the back (posterior or post-nasal discharge)

**Rhinosinusitis:** inflammation of the nose and paranasal sinuses

**Simple polypectomy:** surgical removal of polyps from the nasal cavity without additional surgery on the paranasal sinuses

**Treatment:**
- **short term treatment:** usually 2 weeks or less
- **long-term treatment:** usually 12 weeks or longer
16. Information on QOL instruments:

16-1 General health status instruments:
- SF-36: www.sf-36.org
- Euro-QOL: www.euroqol.org
- SF-12: derived from the SF-36: www.sf-36.org
- Quality of Well-Being Scale: jharvey@ucsd.edu
- Glasgow Benefit Inventory:
  www.ihr.mrc.ac.uk/scottish/products/ghsq.php
- Mc-Gill pain questionnaire: Ronald Melzack: Department of Psychology, McGill University, 1205 Dr. Penfield Avenue, Montreal, Que. H3A 1B1, , Canada

16-2 Disease specific health status instruments:
- RSOM-31: Jay Piccirillo: piccirij@msnotes.wustl.edu
- SNOT-20: derived from the RSOM-31: Jay Piccirillo: piccirij@msnotes.wustl.edu
- SNOT-16: derived from the SNOT-20: Eric Anderson, Department of Otolaryngology-Head and Neck Surgery, University of Washington School of Medicine, Box 356515, Seattle, WA 98195-6515, USA
- RSDI: Michael Benninger, Department of Otolaryngology-Head and Neck Surgery, Henry Ford Hospital, 2799 W Grand Blvd, Detroit, MI 48202, USA
- RQLQ: www.qoltech.co.uk
- RSUI: D.A. Revicki: revicki@medtap.com
- SN-5: David Kay: davidkay@pol.net
- RhinoQoL: Steven Atlas: satlas@partners.org
### 17. Survey of published olfactory tests

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Test name</th>
<th>Test-Time</th>
<th>Country</th>
<th>Sample size</th>
<th>Test retest</th>
<th>Subject differences</th>
<th>Method</th>
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<tr>
<td>Doty et al (1084)</td>
<td>1984 (a,b) 1985</td>
<td>UPSIT</td>
<td>15 min</td>
<td>USA</td>
<td>&gt;3000</td>
<td>r=0.981</td>
<td>Age, gender, culture, smoker, disease, olfactory disorder, malingering.</td>
<td>Identification of 40 encapsulated odours. 4AFC. Scratch-and-sniff technique.</td>
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<td>Wright</td>
<td>1987</td>
<td>Odourant Confusion</td>
<td>15 min</td>
<td>USA</td>
<td>480</td>
<td>Disease.</td>
<td>Identification of 10 odours each presented once (100 stimuli or 121 if a blank is added). Forced choice from list of 10 names. Pattern of odorant identification and misidentification.</td>
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<tr>
<td>Kurtz et al (1086)</td>
<td>2001</td>
<td>Matrix (OCM)</td>
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<td></td>
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<tr>
<td>Corwin (1088)</td>
<td>1989, 1992</td>
<td>YN-OIT</td>
<td>USA</td>
<td></td>
<td></td>
<td>Age, disease</td>
<td>Based on 20 UPSIT odours. Yes or no matching of a descriptor to a proposed odour.</td>
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<tr>
<td>Doty et al (1091, 1092)</td>
<td>1995, 1996</td>
<td>CC-SIT MOD-SIT</td>
<td>5 min</td>
<td>USA Europe Asia</td>
<td>&gt;3000</td>
<td>r=0.71</td>
<td>Age, gender, olfactory disorders.</td>
<td>Identification of 12 encapsulated odours. 4AFC. Scratch and sniff technique.</td>
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<td>1996</td>
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<td>Identification of 7 odours in pens. Forced choice from 4 alternatives.</td>
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<td>Davidson and Murphy</td>
<td>1997</td>
<td>AST</td>
<td>USA</td>
<td>100</td>
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<td>Olfactory disorder.</td>
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<td>Nordin</td>
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<td>SOIT</td>
<td>Sweden, Finland</td>
<td>&gt;600</td>
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<td>Identification of 16 odours in bottles. 4AFC</td>
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<td>Kremer et al.</td>
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<td>4 min</td>
<td>Germany, Netherlands</td>
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<td>Hyposmia.</td>
<td>6 aromas sprayed into open mouth. Odours in nasal sprays.</td>
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<td>McCaffrey et al.</td>
<td>2000</td>
<td>PST</td>
<td>USA</td>
<td>40</td>
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<td>Discrimination between Alzheimer’s dementia and major depression.</td>
<td>Identification of 3 encapsulated odours. 4AFC. Scratch-and-sniff technique.</td>
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<td>Kobal et al.</td>
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<td>Germany</td>
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<td>r=0.71</td>
<td>Gender, olfactory disorder.</td>
<td>Labelling of 16 concentrations of two odorants randomly presented.</td>
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<td>Hummel et al.</td>
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<td>“Four-minute odour identification test”</td>
<td>Germany</td>
<td>1,012</td>
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<td>Age, olfactory disorder.</td>
<td>Identification of 12 odours. 4AFC. Odours in pens.</td>
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<td>Cardesin et al.</td>
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<td>Barcelona Smell Test - 24 (BAST-24)</td>
<td>Spanish</td>
<td>120</td>
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<td>24 odours scoring smell detection, identification, and forced choice</td>
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402. Madden JF, Serhan CN. Lipoxin A4 and B4 are potent stimuli for human monocyte migration and adhesion: selective inactiva-
401. Xue L, Gyles SL, Wettey FR, Gazi L, Townsend E, Hunter MG, Ying S, Meng Q, Scadding G, Parikh A, Corrigan CJ, Lee TH. Aspirin-sensitive rhinosinusitis is associated with reduced E-
400. Ying S, Meng Q, Scadding G, Parikh A, Corrigan CJ, Lee TH. Aspirin-sensitive rhinosinusitis is associated with reduced E-
398. Ying S, Meng Q, Scadding G, Parikh A, Corrigan CJ, Lee TH. Aspirin-sensitive rhinosinusitis is associated with reduced E-
392. Madden JF, Serhan CN. Lipoxin A4 and B4 are potent stimuli for human monocyte migration and adhesion: selective inactiva-
391. Xue L, Gyles SL, Wettey FR, Gazi L, Townsend E, Hunter MG, Ying S, Meng Q, Scadding G, Parikh A, Corrigan CJ, Lee TH. Aspirin-sensitive rhinosinusitis is associated with reduced E-
390. Ying S, Meng Q, Scadding G, Parikh A, Corrigan CJ, Lee TH. Aspirin-sensitive rhinosinusitis is associated with reduced E-


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nation treatment for invasive fungal sinusitis in immunocompro-

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Acute and chronic sinusitis in children

Current concepts in the management of paediatric rhinosinusitis

Pediatric rhinosinusitis


