Imaging in Treatment Planning for Sinonasal Diseases
R. Maroldi · P. Nicolai (Eds.)

Imaging in Treatment Planning for Sinonasal Diseases

With Contributions by
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Series Editor’s Foreword by
A. L. Baert

Foreword by
W. Draf

With 268 Figures in 620 Separate Illustrations, 44 in Color and 14 Tables

Springer
To Elisabetta and Daniela,
for their support and patience

Roberto and Piero
This volume not only provides a modern multimodality imaging approach to the pathology of the sinonasal area, based on CT, MR imaging and endoscopy, but also focuses on the treatment strategy and the role of imaging in the decision-making process for each individual patient.

The combined interdisciplinary approach by a radiologist and an ENT surgeon gives this book unique clinical value.

The different chapters comprehensively cover imaging modalities, anatomy, physiology and the complete spectrum of sinonasal diseases. The volume as a whole is eminently readable and superbly illustrated.

The content represents mainly the approach of the editors’ institution, based on long clinical experience and innovative research, but also covers other modern views and concepts.

This outstanding volume will serve the needs not only of general radiologists dealing daily with the common sinonasal conditions but also of specialised head and neck radiologists. It can also be recommended highly as an invaluable reference not only to radiologists but also to ENT specialists.

I am confident that this excellent book will meet the same success as previous volumes published in this series.

Leuven

Albert L. Baert
The time should have passed when the radiologist produced the images he was asked for and the ENT surgeon took them and made his own interpretation as the basis for the decision on conservative or surgical treatment.

The optimal information from images is obtained from interdisciplinary discussion, sitting together as long as time allows. Without a doubt the neuroradiologist or the head and neck radiologist can describe the imaging findings in the most detailed way. On the other hand he or she depends to a high degree on the hopefully precisely formulated questions of the clinical partner. Sometimes the interdisciplinary discussion results in the recommendation of further imaging by the radiologist. This personal contact with the specialty clinician also ensures familiarity with the latest therapeutic options, which eases the interpretation of postoperative images.

This monograph combines in an ideal way the expertise of a superbly skilled head and neck radiologist and a rhinologist who is one of the pioneers of modern endonasal surgery, using endoscope and microscope as indispensable surgical tools. The book gives clear guidance on the necessary imaging and the findings, as well as interpretation of all types of nose and sinus pathology and general guidelines for treatment, particularly surgery, resulting from interdisciplinary discussion. It deals with anatomy, CT and MR techniques of study, inflammatory diseases, tumors, and post-treatment imaging. This is a particularly effective way forward in one of the most fascinating fields of modern otorhinolaryngology.

I wish this book a wide readership among neuroradiologists and head and neck radiologists, as well as ENT, head and neck, and maxillo-facial surgeons.

Fulda

Wolfgang Draf
As there are already many books on imaging of sinonasal tract diseases, one might wonder, “Why bother to compile another one?”. In responding to this question, it must be emphasized that cross-sectional imaging (i.e., computed tomography and magnetic resonance) has clearly been one of the backbones which has made possible, in the last decade, the remarkable evolution of treatment strategies for sinonasal tract diseases, in particular microendoscopic sinus surgery.

The purpose of this volume is to provide the knowledge required to properly solve the challenging issues raised by current treatment planning. Accordingly, this book is intended not only for the head and neck expert, or the general radiologist, but for the entire team of physicians (otorhinolaryngologist, maxillo-facial surgeon, radiotherapist, and oncologist) that participate in the decision-making process and who need to be confident with the indications, limitations, and advantages of state-of-the-art imaging techniques.

The book is organized into three main sections. In the first, general aspects such as CT and MR techniques, as well as anatomy and physiology, are thoroughly discussed. In addition, we decided to include a detailed guide to imaging assessment of critical issues, such as bone, orbit, and skull base invasion, in this section. The section is completed by an indispensable overview of a wide spectrum of surgical approaches for the sinonasal tract.

The second part of the book provides step-by-step information on the basic and advanced aspects of clinical presentation, imaging findings, and treatment of sinonasal diseases. For each specific disease, the rationale underlying the treatment strategy is discussed and the imaging findings critical to the decision-making process are identified and discussed. This approach reflects the constant team effort of our two departments, radiology and otorhinolaryngology, over the past 15 years towards integration of clinical and radiological information with the aim of establishing the most appropriate treatment. Special emphasis is placed on the identification of clinical and imaging data that allow selection of a microendoscopic or an external approach in candidates for surgery.

In the third part, the challenging issue of imaging acute or late complications and recurrent lesions is discussed in detail. Moreover, the integration of endoscopic and radiological follow-up in different diseases is thoroughly reviewed. As the book reflects the radiological and clinical experience of a single institution, two topics, namely traumatic lesions and congenital malformations, were not covered as we do not have the required expertise in these fields. We believe that through the correlation of imaging with endoscopic or clinical findings, this book will enable radiologists to familiarize themselves with a more “otorhinolaryngological” point of view and will help clinicians
to understand more fully the significance of specific radiological findings. It will also serve as a guide for the selection of imaging techniques.

Finally, we would like to acknowledge Prof. Chiesa (Head of the Department of Radiology) and Prof. Antonelli (Head of the Department of Otorhinolaryngology) who promoted the active cooperation between these two specialties at our university. Without their invaluable support, as well as that of younger colleagues, the writing of this book would have been an impossible challenge.

Brescia

Roberto Maroldi
Piero Nicolai
Contents

1 Techniques of Radiological Examination
D. Farina and A. Borghesi ......................................................... 1

2 CT and MR Anatomy of Paranasal Sinuses: Key Elements
R. Maroldi, A. Borghesi, and P. Maculotti ............................... 9

3 Physiology of the Nose and Paranasal Sinuses
D. Tomenzoli ............................................................................. 29

4 Neoplastic Invasion of Bone, the Orbit and Dural Layers: Basic and Advanced CT and MR Findings
R. Maroldi, D. Farina, and G. Battaglia .................................... 35

5 Endonasal and Open Surgery: Key Concepts
P. Nicolai, A. Bolzoni, C. Piazza, and A. R. Antonelli .................. 47

6 Inflammatory Lesions
D. Farina, D. Tomenzoli, A. Borghesi, and D. Lombardi .......... 59

7 Cerebrospinal Fluid Leak, Meningocele and Meningoencephalocele
L. Pianta, L. Pinelli, P. Nicolai, and R. Maroldi ......................... 93

8 Benign Neoplasms and Tumor-Like Lesions
R. Maroldi, M. Berlucchi, D. Farina, D. Tomenzoli, A. Borghesi, and L. Pianta ...................................................... 107

9 Malignant Neoplasms
R. Maroldi, D. Lombardi, D. Farina, P. Nicolai, and I. Moraschi .... 159

10 Expansile Lesions Arising from Structures and Spaces Adjacent to the Paranasal Sinuses
L. O. Redaelli de Zinis, P. Mortini, D. Farina, and F. Mossi ........... 221

11 Normal and Abnormal Appearance of Nose and Paranasal Sinuses
After Microendoscopic Surgery, Open Surgery, and Radiation Therapy
R. Maroldi, P. Nicolai, L. Palvarini, V. Portugalli, and A. Borghesi .... 255

Legends of Anatomic Structures ............................................. 295

Subject Index ........................................................................ 297

List of Contributors ............................................................... 303
1 Techniques of Radiological Examination

Davide Farina and Andrea Borghesi

CONTENTS
1.1 Incremental and Single-Slice Spiral CT Technique 1
  1.1.1 CT Protocol Chronic Rhinosinusitis and Nasal Polyposis 1
  1.1.1.1 Patient Preparation 1
  1.1.1.2 Direct Coronal Plane Acquisition 1
  1.1.1.3 Axial Plane Acquisition 2
  1.1.2 CT Protocol in Neoplastic Lesions 3
  1.1.2.1 Axial Scanning 3
  1.1.2.2 Coronal Scanning 3
  1.2 Multislice CT of the Paranasal Sinuses 3
  1.3 MR Technique 4
  1.3.1 Designing an MR Protocol: Basic Concepts 4
  1.3.2.1 MR Protocol 4
  1.3.2.2 Additional MR Sequences 5
  1.3.2.3 Signal vs Time Curves in Follow-Up Studies 6
  References 7

1.1 Incremental and Single-Slice Spiral CT Technique

1.1.1 CT Protocol Chronic Rhinosinusitis and Nasal Polyposis

1.1.1.1 Patient Preparation

Patients affected by chronic rhinosinusitis must receive adequate medical treatment before CT examination of the paranasal sinuses, in order to treat acute infection and solve mucosal edema. Oral antibiotics, nasal steroids and antihistamines – prescribed at least 3 weeks before CT – decrease the risk of overestimating chronic inflammation and polypoid reaction of the mucosa. Additionally, according to the recommendations of several authors, patients should be asked to clear their nose before undergoing the examination (Oliverio et al. 1995; Phillips 1997; Zinreich 1998).

Radiation dose is a major concern, especially when CT examination is performed as a screening or presurgical test, in a population that includes a large number of young subjects. In this setting, the rationale of imaging studies is to obtain detailed information on patency/occlusion of mucous drainage pathways, on bone changes (particularly in critical areas such as the skull base and orbit), intrasinusal content (air, fluid, solid, calcifications), and on anatomic variants. As a consequence, conventional radiology should be discarded as an obsolete tool, even though the overall radiation dose delivered to the eye-lens with this technique is rather low (approximately 0.57 mGy) (Zammit-Maempel 1996; Phillips 1997; Zinreich 1998; Sievers et al. 2000).

Computed tomography is a relatively high-dose examination, nevertheless the high natural contrast between air, mucosa and bone enables optimization of low-dose protocols by decreasing tube current down to 30–50 mAs (MacLennan 1995; Hein et al. 2002; Hagtvedt et al. 2003). This results in a considerable decrease of the eye-lens dose (3.1 mGy when 50 mAs are applied) (Sohail et al. 2001) without significant loss of diagnostic information. With MSCT scanners, patient exposure is a primary issue. Recent data demonstrate eye-lens dose higher than single-slice (SS) scanners, even when low-dose protocols (40 mAs) are applied (9.2 mGy). Nevertheless, also with this new tool, exposure is far below the threshold for detectable lens opacities (0.5–2 Gy) (Zammit-Maempel et al. 2003).

1.1.1.2 Direct Coronal Plane Acquisition

Images are electively acquired on coronal plane, as perpendicular to the hard palate as permitted by gantry tilting and patient cooperation. This plane is able to demonstrate patency, width, and morphology of all those airspaces (middle and superior meatus, ethmoid infundibulum) hidden by turbinates and therefore difficult to access at clinical examination. Moreover, coronal imaging clearly depicts both superior and lateral insertion of the middle turbinate, and the cribiform
plate. The main weaknesses of this scanning orientation are the poor delineation of the frontal recess (coursing along an oblique-sagittal plane), as well as the impossibility to demonstrate sinusal walls lying in the coronal plane.

Two options are described for patient positioning: supine, with hyperextended head (hanging-head position) (PHILLIPS 1997), or prone. The latter is usually preferred because it is more easily tolerated by the patient and less susceptible to motion artifacts. Additionally, fluid material retained in a maxillary sinus, in the hanging-head position will freely flow towards the ostium, therefore impairing the evaluation of its patency.

The examination area extends from the anterior frontal sinus wall to the posterior border of the sphenoid sinus. Scanning parameters are highly variable according to the clinical issues to be addressed and to the available equipment (ZINREICH 1998). In our experience, optimal demonstration of the ostiomeatal unit and of natural drainage pathways is achieved with:

- Thin slice collimation (1–2 mm), to minimize partial volume artifacts that may mimic mucosal thickenings along small caliber drainage pathways.
- 3- to 4-mm increment/1.5 pitch (sequential or SS spiral equipment, respectively) as a trade-off between dose reduction and the necessity not to miss anatomical structures such as the uncinate process (Table 1.1).

For sinus screening purposes, sufficient information can be obtained with thicker collimation (3–5 mm) and an increment of up to 15 mm.

### Table 1.1. Chronic rhinosinusitis, nasal polyposis: scanning parameters, coronal plane

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sequential CT</th>
<th>SSCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slice thickness</td>
<td>1 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td>Increment/ pitch</td>
<td>3 mm</td>
<td>Pitch 1,5</td>
</tr>
<tr>
<td>mA/kV</td>
<td>70/133</td>
<td>60/120÷140</td>
</tr>
<tr>
<td>Reconstruction algorithm – <em>kernel</em></td>
<td>Ultrahigh</td>
<td>A 70÷90</td>
</tr>
</tbody>
</table>

SSCT, single-slice spiral technique. * Siemens equipment

#### 1.1.1.3 Axial Plane Acquisition

This scanning plane enables adequate demonstration of some anatomical structures difficult to assess on coronal plane due to their spatial orientation (such as posterior frontal sinus and sphenoid sinus wall, sphenethmoid recess). Nonetheless, axial acquisition is recommended only whenever the digital lateral view (topogram) shows excessive dental amalgam or metallic implants, or as a complement after coronal scanning whenever precise information on specific anatomic structures is required.

In the first condition, a data set of thin and contiguous (to avoid aliasing) slices may be acquired with the incremental technique (1–2 mm collimation) or the SS spiral technique (2 mm collimation; pitch 1–1.5; 1–2 mm reconstruction) (Table 1.2). The patient lies in supine position, both his/her sagittal plane and hard palate should be perpendicular to the gantry's scan line, in order to achieve, respectively, optimal symmetry of the anatomical structures on axial plane, and no/minimal gantry tilting. In fact, the quality of MPR is degraded by gantry inclination (stair-step artifacts). Direct scans should be oriented parallel to the hard palate and range from the upper border of frontal sinuses to the alveolar process of maxillary bones; nasal tip and petrous bone should be included in the field of view. Subsequent coronal MPR reformation is obtained for proper assessment of critical anatomical areas either at risk of iatrogenic damage (cribriform plate, fovea ethmoidalis) or playing a key role in mucous drainage (ostiomeatal unit).

When acquired as a complement to the coronal study, axial scans are basically focused on anatomical areas inadequately demonstrated in that orientation (i.e., anterior and posterior walls of maxillary, frontal, and sphenoid sinus, sphenethmoid recess). Additionally, this scan plane is valuable for the detection of Onodi cells. In this setting, contiguous slices and full coverage of the paranasal area are generally unnecessary, as a consequence, 4- to 5-mm increments can be applied, decreasing both patient exposure and examination time.

### Table 1.2. Chronic rhinosinusitis, nasal polyposis: scanning parameters, axial plane

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sequential CT</th>
<th>SSCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collimation</td>
<td>1÷2 mm</td>
<td>2 mm</td>
</tr>
<tr>
<td>Increment/ pitch</td>
<td>1÷5 mm</td>
<td>Pitch 1÷1,5</td>
</tr>
<tr>
<td>mA/kV</td>
<td>70/133</td>
<td>60/120÷140</td>
</tr>
<tr>
<td>Reconstruction algorithm – <em>kernel</em></td>
<td>Ultrahigh</td>
<td>A 70÷90</td>
</tr>
<tr>
<td>MPR</td>
<td>COR/SAG</td>
<td>Idem</td>
</tr>
</tbody>
</table>

SSCT, single-slice spiral technique; MPR, multiplanar reformation; COR, coronal; SAG, sagittal. * Siemens equipment
1.1.2
CT Protocol in Neoplastic Lesions

The first step in the diagnostic work-up of both benign and malignant sinus neoplasms consists of fiberoptic examination. Endoscopy allows adequate demonstration of the superficial spread of the lesion and may guide a biopsy. The discrimination between benign and malignant tumors and the precise characterization of the lesion are, in most cases, far beyond the capabilities of CT. The main goals of imaging are, therefore, to provide a precise map of deep tumor extension in all those areas blinded at fiberoptic examination, especially anterior cranial fossa, orbit, and pterygopalatine fossa.

In this setting, MR is the technique of choice for several reasons:
- It clearly differentiates tumor from retained secretions
- It allows early detection of perivascular/perineural spread
- It allows higher contrast resolution

On the other hand, the strengths of CT consist of:
- Superior definition of bone structures even in the case of subtle erosions
- Faster and easier performance
- Superior accessibility and lower cost.

As a consequence, in our experience CT indications are restricted to patients who have not undergone a preliminary examination by the otolaryngologist (to rule out non-neoplastic lesions) or to patients bearing contraindications to MR.

1.1.2.1
Axial Scanning

CT protocol consists of native and post-contrast scanning in both axial and coronal planes; it is preferable to start the examination on the axial plane and to complete it with coronal scans, usually limited to the area of the lesion. Both incremental and spiral techniques can be applied, though the latter is faster and requires lower doses of contrast agent.

On the axial plane, the gantry must be parallel to the hard palate. The examination area extends from the superior border of the frontal sinus to the alveolar process of the maxillary bone. Scans are acquired with 2- to 3-mm collimation, 2- to 3-mm increments (sequential CT), pitch 1–1.5 (SS spiral equipment) (Table 1.3). The fastest rotation time should be applied to decrease the risk of motion artifacts. A high contrast resolution is mandatory, therefore a higher radiation dose is required (200–240 mAs, 140 kV) and both soft tissue and bone algorithms are adopted for image reconstruction.

Contrast agent protocol consists of biphasic injection (80–90 ml at a rate of 2.5 ml/s plus 30–40 ml at a rate of 1–1.5 ml/s), and a scanning delay of approximately 80 s. This time interval enables an assessment of the lesion in its window of more intense enhancement, therefore maximizing the detection of lesion boundaries (Maroldi et al. 1998). Early acquisition in the arterial phase (30s delay) may be indicated when a highly vascular lesion is suspected or to precisely delineate the relationships between the neoplasm and the carotid arteries.

1.1.2.2
Coronal Scanning

Scanning parameters in the coronal plane are comparable to those used for the axial plane. Additional contrast agent administration (40–50 ml at a rate of 2 ml/s) may be suggested. Whenever prone positioning is impossible to obtain, the patient is scanned exclusively in the axial plane (contiguous 2-mm thick slices, no gantry tilting) and multiplanar reconstructions are subsequently obtained.

1.2
Multislice CT of the Paranasal Sinuses

Improvements in CT imaging of the paranasal sinuses provided by multislice technology include fast coverage of the volume of interest, thin collimation (up to 0.75 mm with 16-row MSCT), and acquisition of
nearly isotropic (i.e., cubic) voxels. The latter results in high quality multiplanar reformation of the data set, preferably acquired on the axial plane. According to the number of detectors of the equipment employed, the volume of interest is acquired from 4×1 mm up to 16×0.75 mm collimation and no gantry tilting. Data are then reconstructed as 1-mm thick slices with 50% slice overlap, on the axial plane. This set of images is suitable for excellent MPR post-processing (Table 1.4).

Table 1.4. MSCT scanning parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>MSCT (4 rows)</th>
<th>MSCT (16 rows)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>Axial, no gantry tilting</td>
<td></td>
</tr>
<tr>
<td>Collimation</td>
<td>4×1 mm</td>
<td>16×0.75 mm</td>
</tr>
<tr>
<td>Rotation time</td>
<td>0.75 s</td>
<td>0.75 s</td>
</tr>
<tr>
<td>mA/kV</td>
<td>70/133</td>
<td>60/120÷140</td>
</tr>
<tr>
<td>Reconstruction algorithm – kernel*</td>
<td>H70h</td>
<td>H70h</td>
</tr>
<tr>
<td>Volume reconstruction (axial plane)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>1.25 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td>Interslice gap</td>
<td>0.7 mm</td>
<td>0.5 mm</td>
</tr>
</tbody>
</table>

* Siemens equipment

1.3 MR Technique

MR plays a prominent role in imaging of the paranasal sinuses. Its high contrast resolution combined with multiplanar capability make it a valuable tool in the assessment not only of benign and malignant neoplasms, but also in the evaluation of aggressive inflammatory lesions (invasive mycoses, Wegener granulomatosis, sarcoidosis). In these settings, the high contrast resolution of this technique enables discrimination between the lesion and intrasinusal retained secretions, demonstrating its relationships with adjacent structures, and, in many cases, to providing clues for a differential diagnosis. In contrast, no major indication to MR is found for patients affected by chronic rhino sinusitis or nasal polyposis: scant detail relating to thin bone structures (which are numerous and critical in this area) and high costs are substantial drawbacks (ZINREICH 1998).

1.3.1 Designing an MR Protocol: Basic Concepts

Though modern equipment enables rapid acquisition of nearly all kind of sequences, a basic principle guides the design of an MR protocol: the faster the examination time, the lower the risk of motion artifacts. A second key point consists in spatial resolution: nasal cavity and paranasal sinuses are a complex framework of airspaces bordered by thin, bony boundaries. Moreover, a thin osteo-periosteal layer separates the sinonasal region from the anterior cranial fossa (cribriform plate and dura) and the orbit (lamina papyracea and periorbita). An adequate depiction of these structures mandates high field equipment (1.5 T) and a dedicated circular coil (head coil). In addition, a high-resolution matrix (512) should be applied along with the smallest FOV achievable (individually variable, but generally 180–200 mm). Smaller FOV may be obtained but this, of course, requires oversampling in the phase encoding direction to avoid aliasing artifacts, and therefore results in an overall increase of examination time. Acquiring images not exceeding 3–3.5 mm thickness, with an interslice gap ranging from 1.5 mm to 2.4 mm (50%–70%) is also recommended. The parameters listed above, applied to both TSE T2 and SE T1 sequences, are an acceptable compromise between the need to attain small pixel size and the risk of significantly decreasing signal-to-noise ratio.

1.3.2 MR Protocol

Symmetric representation of anatomic structures is of the utmost importance, as in many cases the diagnosis may be based on the observation of differences in size and signal intensity of a paired structure when matching the two sides. To achieve this, the internal auditory canals, imaged with a TSE T2 localizer sequence, are taken as a landmark to correctly orientate axial and coronal studies. As for CT protocols, the hard palate is a second point for reference for proper sequence orientation (parallel on axial plane, perpendicular on coronal plane); sagittal studies are aligned to the nasal septum and falx cerebri.

The sequences applied are, basically, TSE T2 and SE T1. The first one provides the best discrimination between solid tissue and fluids (retained secretions, cerebrospinal fluid, colliquated tissues). It is acquired in axial plane and in a second perpendicular plane chosen according to the priority dictated by the lesion site of origin and clinical signs (Table 1.5). SE T1 has the advantage of a superior anatomic resolution, valuable for the definition of the interface between lesion and adjacent structures. Moreover,