LETTER TO THE EDITOR

The Zurich magnetic resonance imaging protocol for standardized staging and restaging of sinonasal tumours*

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Rhinology Online, Vol 4: 161 - 164, 2021
http://doi.org/10.4193/RHINOL/21.038

*Received for publication: August 8, 2021
Accepted: August 20, 2021
Published: August 28, 2021

To the Editor:

In combination with paranasal sinus computed tomography (CT), cross-sectional imaging with magnetic resonance imaging (MRI) is mandatory for staging and restaging of primary sinonasal malignancies (1-4). In the initial staging, MRI defines tumour size, provides information on extension into adjacent compartments of the sinonasal tract (in particular orbit, anterior or middle cranial fossa, leptomeningeal and brain parenchyma) and consecutively helps to determine the clinical T category. Furthermore, MRI delineates tumour from surrounding tissue (e.g. retention of mucus, reactive polyps) and may even identify perineural spread and bone marrow infiltration (3,4). The signal intensity of tumours varies depending on their cellularity, mucin content and presence of hemorrhage. However, even state-of-the-art cross-sectional imaging may fail to correctly identify orbital or skull base infiltration. Thus, both, false-positive and false-negative findings must be considered. Common pitfalls particularly include 1) the discrimination of bony pressure erosion and bony infiltration of the anterior skull base or the medial orbital wall and 2) the discrimination of reactive dural enhancement and dural infiltration by tumour (5,6). Based on these difficulties and in analogy to upper aero-digestive tract squamous cell carcinomas, we recently suggested an obligatory exploration of all sinonasal tumours under general anesthesia and targeted biopsy, if necessary (7). Besides its role in the initial staging (Figure 1), MRI is also important in the restaging setting, where tumour persistence or recurrence and treatment-associated alterations may be challenging.

Table 1. Standardized MRI protocol for staging and restaging of sinonasal tumours.

<table>
<thead>
<tr>
<th>MRI sequence</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>T1-weighted, native, coronar section</td>
<td>TR / TE 650/9.5ms, FOV 180, NEX 1, slice thickness 3.0mm, distance between slices 0.3mm</td>
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<tr>
<td>T1-weighted, native, transverse section</td>
<td>Fat: bright, due to its short relaxation time, high contrast towards other tissues</td>
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<tr>
<td>Tumour: longer relaxation time, poor contrast of tumour against muscle</td>
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<tr>
<td>Mucosa: similar to tumour</td>
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<tr>
<td>T2-weighted, native, fat-suppressed, coronar section</td>
<td>Fast Spin Echo-Sequence, 5100/89 ms, FOV 180, NEX 2, slice thickness 3.0mm, distance between slices 0.3 mm. Different techniques for fat suppression (e.g. IR or for less metallic artefacts DIXON).</td>
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<tr>
<td>Fluid: bright</td>
<td></td>
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<tr>
<td>Tumour: high contrast of tumour towards muscle, poor contrast of tumour towards fat</td>
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<tr>
<td>Fat: dark in fat-suppressed sequences, which allows a good contrast between tumour and suppressed fat</td>
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<tr>
<td>Diffusion-weighted, native axial section</td>
<td>Diffusion weighted images are helpful in differentiating malignant tumours from benign based on ADC values</td>
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<tr>
<td>T1-weighted, contrast-enhanced, fat-suppressed (FS), transverse section</td>
<td>Gadolinium chelate contrast agents</td>
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<td>Sagittal plane best for assessment of potential bony or dural infiltration of the skull base</td>
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<tr>
<td>Assessment of bone (anterior skull base) with dark signal adjacent to bright signal of nasal mucosa</td>
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<tr>
<td>T1-weighted, contrast-enhanced, fat-suppressed (FS), coronar section</td>
<td></td>
</tr>
<tr>
<td>T1-weighted, contrast-enhanced, fat-suppressed (FS), sagittal section</td>
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MRI, magnetic resonance imaging; FOV, field-of-view; NEX, number of excitations; TE, echo time; TR, repetition time.
to distinguish (Figure 2). Thus, a standardized way to compare MRI images at different time points is of utmost importance. In an effort to increase this comparability and in analogy to previous published protocols for paranasal sinus CT, we aimed to establish a standardized MRI protocol for sinonasal malignancies at our institution, which allows to reliably compare imaging sessions, even on different scanners and at different sites. Aiming to achieve a high inter-patient and intra-patient comparability, this protocol should remain unchanged, regardless (A) the tumour entity, (B) the tumour origin (nasal cavity / ethmoid sinus vs maxillary sinus), (C) the treatment algorithms or (D) the timing of the examination (pretherapeutic vs. posttherapeutic). Table 1 provides details on the proposed MR sequences.

Assessment of the bony and dural anterior skull base
In combination with CT imaging, an adequate assessment of the bony and dural skull base is pivotal. Eisen et al. stated, that the presence of pial enhancement, focal dural nodules or dural thickening of more than 5 mm is highly accurate in predicting dural invasion, while linear dural enhancement may also be reactive (5). McIntyre et al., however, found that the presence of “≥ 2 mm of dural thickening”, “loss of hypointense zone on T1-weighted images”, and “nodular dural contrast enhancement” were highly predictive for dural invasion (8). As Schuknecht et al. stated, the bony skull base is best seen on T1-weighted, contrast enhanced, fat-suppressed series with a dark signal of the bone and an adjacent, bright signal of the nasal mucosa (1). Fat suppression is needed to eliminate any high signal intensity from adjacent fat.

Figure 1. Magnetic resonance imaging for initial staging of a 55-year old male patient with a biopsy-proven sinonasal undifferentiated carcinoma (SNUC). On T1-weighted, non-enhanced coronal (A) and transverse (B) sections, we see a heterogeneous, mostly hypointense, obstructing and poorly demarcated tumour in the nasal cavity and in the adjacent ethmoidal cells (black rhomb), with secondary opacification of the MS (black asterix) and the SS (white asterix) due to mucus retention. On T2-weighted, non-enhanced transverse sections (C), the tumour (black rhomb) displays an inhomogeneous, intermediate signal (white asterix, SS). On T2-weighted, FS coronal images (D), the tumour (black rhomb) is easy to differentiate from mucus retention in the MS (black asterix). As best seen on T1-weighted, CE FS coronal (E) sections in combination with T1-weighted non-enhanced coronal sections (A), a clear distinction between erosion and infiltration of the bony orbit and periorbita in its supero-medial quadrant in proximity to suprerior oblique muscle is challenging (white arrowheads, (E)). However, no affection of the extraconal adipose tissue or extraocular eye muscles was suspected. On T1-weighted CE FS axial (F) sections, we can confirm an inhomogeneous tumour (black rhomb) in the nasal cavity and ethmoidal cells, with secondary opacification of the SS (white asterix). On T1-weighted CE FS sagittal sections (G), we see a linear and thin dural enhancement (black arrows), which is most likely reactive. Intraoperative exploration of the tumour revealed an infiltration of the periorbita in its supero-medial quadrant, without affection of the extraconal fat tissue or the extraconal eye muscles. However, no evidence of infiltration of the bony or dural skull base was found. CE, contrast-enhanced; FS, fat-suppressed; MS, maxillary sinus; SS, sphenoid sinus.
Assessment of the orbit

Radiological criteria for determining orbital infiltration in MRI include (a) bony orbit and periorbita, (b) extraconal adipose tissue, (c) extraocular eye muscles and (d) intracanal structures (2,7). However, as previously shown, one has to account for false-positive findings and an overestimation of the true extent of infiltration (7). The most important plane for extra- and intracanal structures is the coronal plane. As the lamina papyracea is thinnest directly posterior to the nasolacrimal duct, a careful attention in the coronal section must be paid in this distinct area. The coronal plane also allows detection of eye muscle infiltrations, extracanal extension, and infiltration of the optic nerve (7). Healthy muscles have a low signal intensity in T1-weighted images, in comparison to the high signal intensity of the adipose tissue (9). Intracanal masses can be visualized on unenhanced T1-weighted sequences, because nearly all intracanal pathologies are hypointense in comparison to hyperintense surrounding adipose tissue (9).

Conclusion

We here present a standardized and easy to reproduce MRI protocol for staging and restaging of sinonasal tumours, which allows a thorough assessment of the orbit and the anterior skull base. In order to achieve a high inter-patient and intra-patient comparability, this protocol should remain unchanged, regardless the timing of examination, tumour entity, treatment algorithms or tumour origin.

Authorship contribution

CMM: designed the study, collected data, designed the figures,
wrote the manuscript; AP: neuroradiological expertise, wrote the manuscript, developed the concept; SP: neuroradiological expertise, wrote the manuscript, designed the figures; LE: edited the manuscript; MBS: edited the manuscript; DH: designed the study, edited the manuscript, developed the concept.

Acknowledgments
Not applicable.

Funding
None.

References

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Availability of data and materials
Not applicable.

Conflict of interest
None.