The Skull Base in the Evaluation of Sinonasal Disease

Role of Computed Tomography and MR Imaging

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KEYWORDS

• Imaging • Computed tomography • MR imaging • Skull base pathology • Sinonasal pathology • Anatomy

KEY POINTS

- Computed tomography (CT) helps assess the cortical bone changes of the anterior skull base (ASB) whereas MR imaging is superior for evaluating the bone marrow and foramina of the central skull base (CSB).
- The paranasal sinuses contribute to the median ASB and CSB, and important variant anatomy should be recorded to help prevent surgical complications.
- MR imaging is useful in delineating sinonasal malignancy by demonstrating direct extension through the ASB, perineural extension through the CSB and involvement of intracranial structures.
- Intrinsic bone lesions are most frequently benign in the ASB whereas primary or secondary malignant intrinsic bone lesions may also feature in the CSB.
- Endocranial tumors and contents may traverse the skull base into the sinonasal region. Cephalocele is an important consideration when imaging demonstrates a sinonasal mass with a skull base defect.

INTRODUCTION

The median ASB and CSB form an interface between the sinonasal and intracranial compartments. Because clinical and endoscopic assessment is limited, the cross-sectional imaging modalities of CT and MR imaging play a key role in addressing the origin, nature, and extent of disease within the ASB and CSB. Advances in endoscopic surgical approaches, image-guided surgery, and targeted radiotherapy have expanded therapeutic possibilities, and the radiologist is central within the multidisciplinary team when deciding on treatment planning.

This review briefly describes the appropriate CT and MR imaging techniques, and the pertinent anatomy of the median ASB and CSB relevant to the spread of disease and surgical planning. It then focuses on the imaging appearances of pathologic processes that involve and traverse the skull base between the sinonasal and intracranial compartments.

TECHNIQUES

CT and MR imaging are frequently complementary in characterizing and demonstrating the extent of

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pathologic processes within the median ASB and CSB.

CT is excellent at detecting cortical bone erosion or deficiency and hence is particularly useful for assessing the thin bony structures of the ASB or the foramina of the CSB. CT is also used to provide a bony roadmap for surgery. It may help differentiate pathologies by demonstrating calcific or ossific elements (eg, fibrous dysplasia [FD] and osteoma), adjacent bony sclerotic reactions (eg, meningioma, olfactory neuroblastoma, inverted papilloma, and chronic inflammation), bony destruction (eg, high-grade carcinoma or neuroendocrine tumor) or bony remodeling (eg, low-grade tumors, including sarcoma, lymphoma, melanoma, and olfactory neuroblastoma).

Multidetector CT is performed with a single axial volume acquired at submillimetric slice collimation, with generation of multiplanar 1-mm reformats (including a bone algorithm). If concurrent MR imaging is not available, then increased milliampere-seconds (>50 mAs), intravenous contrast, and 3-mm thick reconstructions help optimize the soft tissue appearances. If only bone detail is required, then cone-beam CT may also be used to evaluate the skull base[1] at a lower radiation dose. CT angiography and CT cisternography are additional techniques that may be indicated for evaluation of skull base pathology.

MR imaging is superior for detecting infiltration of the bone marrow and perineural extension of disease, so it is valuable for imaging the CSB. MR imaging also provides superior mapping of the intrasinus extent of lesions (and hence contact with the skull base) while better delineating any intracranial extension.

MR imaging requires a combination of T1W, T2W, and gadolinium-enhanced T1W images. Sagittal sequences supplement routine coronal and axial planes for the assessment of midline pathology. Imaging is generally performed with 3- to 4-mm slice thickness and no gap, with an optimal field of view of 16 to 18 cm. Occasionally, volumetric sequences are used for image-guided surgery and radiotherapy planning and (with 3-D heavily T2W sequences) to demonstrate a cerebrospinal fluid (CSF) leak or cephalocele. T1W sequences are particularly useful for assessing bone marrow abnormality, whereas gadolinium enhancement delineates pathologic meningeal and perineural extension. Higher-resolution (eg, 512×512 matrix) sequences may be used to evaluate the integrity of bone and periosteum at the ASB or to assess for perineural spread (PNS). Fat-suppressed sequences are often included for imaging the CSB. Failure of fat suppression at the interface of the skull base and the paranasal sinuses is a problem with sequences based on frequency selective pulses, but this may be overcome by using short tau inversion recovery (STIR) or 3-point Dixon techniques.[2] Diffusion imaging of the paranasal sinuses and the skull base is feasible and can be optimized with parallel imaging, readout segmented techniques, multishot acquisition, and turbo spin-echo techniques; however, there is little data on the diagnostic impact of diffusion-weighted imaging (DWI) in the setting of skull base and sinonasal pathology.[3–5]

Intraoperative image guidance is frequently required to aid surgical approaches to the skull base. A tracking system (eg, optical or electromagnetic) simultaneously references a sensor on a surgical instrument with the patient and a preoperative or intraoperative imaging data set (using CT or MR imaging) (**Fig. 1**).[6]

ANATOMY

The paranasal sinuses contribute to the ASB and CSB in the midline and paramidline. Thus, the median ASB comprises the posterior wall of the frontal sinus, the roof of the nasoethmoid region, and the planum sphenoidale, whereas more posteriorly, the median CSB houses the sphenoid sinus. A coronal projection through the chiasmatic sulcus, tuberculum sella, and anterior clinoids separates the median ASB from the CSB (**Fig. 2**). The wide range of variant anatomy within this part of the skull base should be recognized to distinguish it from pathologic processes and to prevent complications of sinonasal surgical approaches (**Table 1**).[8,18,19]

Median Anterior Skull Base: Applied Anatomy

The median ASB is formed by the paired orbital plates of the frontal bone, the cribriform plate of ethmoid, and the lesser wing of sphenoid (see **Fig. 2**). Unlike the lateral ASB, which forms the roofs of the orbits, the median ASB it is directly related to the sinonasal region.

The orbital plate of frontal bone contributes to the ipsilateral posterior wall of frontal sinus and the fovea ethmoidalis (or roof of ethmoid). It generally consists of resistant compact bone, although there are multiple diploic valveless veins that traverse its walls with the potential to transmit infection. A large frontal sinus (pneumosinus) should be distinguished from abnormal expansion that encroaches on other structures, which is termed a pneumosinus dilatans (with a normal thickness wall) or a pneumocele (with thinned or deficient wall) (**Fig. 3**).[20] The fovea ethmoidalis slopes inferiorly at an angle of 15° as it extends posteriorly to the planum sphenoidale.