
Preface

The skull base is a complex anatomical region that has a set of unique features, complex inner and outer surface and internal structure through which pass both the vascular and the nervous structures. All of this creates difficulties first in adequate visualization of pathological lesions located in this area and even more so in delineating them from the healthy anatomical tissue. Moreover, the skull base, being the most complicated part of modern neurosurgery, maxillofacial surgery, surgical otorhinolaryngology and ophthalmology, differs from other areas of the intracranial space with its histobiological variety of neoplasms, among which malignant forms are frequently encountered. Poor clinical symptoms and rapid aggressive growth of most tumours often lead to late diagnostics and unsatisfactory results of surgical or combined treatment.

Another feature of the skull base is that quite often there could be found structural changes that do not require any surgical treatment. The recognition and correct interpretation of those changes avoid misdiagnosis and unjustified surgical intervention or radiation therapy.

When examining the skull base, the presence of boundaries of tissues with different density, physical properties, chemical structure and magnetic characteristics leads to numerous artefacts on the diagnostic images. On CT, there are artefacts from the petrous bone (Hounsfield's artefact) which complicate the visualization of the posterior cranial fossa and artefacts from metal dental implants that sometimes make the examination completely noninformative. MRI is not devoid of artefacts either. The massive bone structure of the skull base does not fully use the unique capabilities of the modern MRI sequences such as diffusion-weighted imaging, MR spectroscopy, etc. Spatial distortion, caused by the proximity of the skull base bones, significantly reduces the quality of MR perfusion protocols based on intravenous administration of MR contrast medium. All of these factors reduce the diagnostic quality of the images of the skull base, making it difficult to identify tumours on an early stage.

It is important to emphasize that in the diagnosis of tumours in both the skull base and the brain, CT and MRI are used as complementary methods. That is the reason why we recommend a complex approach in the assessment of lesions of this region using the advantages of each method.

Modern neurosurgical approaches impose high requirements on neuroradiologist in the assessment of the location, extension and differential diagnosis of lesions in the region of the skull base. In order to plan surgical or radiation treatment, it has become essential to apply navigation technology with ultra-thin slices, which provides a high quality of 2D reformation and 3D reconstruction. Among the main issues concerning the diagnosis of skull base tumours, neuroradiologists pay special attention to the accurate topical diagnosis of lesions, their attitude towards meninges, the extension into bony and soft tissues, assessment of vessels and nerves of the skull base, the degree of tumour blood supply and, of course, the presumable pathological nature of tumours. The latter is particularly important, but as practice shows, it is the most difficult part in forming the final diagnosis. The solutions to all these difficulties could be found in a complex clinical-diagnostic approach in determining pathology, which may include direct angiography, CT, MRI, SPECT and PET.

New possibilities in the evaluation of vascular lesions of the skull base emerged with the introduction of dynamic CT angiography in the clinical setting. It is now possible to study

tumour blood flow, without a highly invasive direct angiography. The combination of high spatial and time resolution, and various tools for the skull base bones' removal from the image, has led to a very good visualization of all blood flow stages in the tumour tissue.

CT perfusion plays a special role in the diagnosis of skull base tumours. The lack of spatial distortion (common in MR perfusion of this region), high spatial resolution, automatic removal of bone structures on perfusion maps and the ability to monitor dynamics of contrast agent bolus passage through different tissues and lesions – all of these ensured the leading position of the CT perfusion method among all other methods of perfusion in evaluation of haemodynamic characteristics of benign and malignant tumours of the skull base. Today, we consider CT perfusion to be the method of “non-invasive biopsy” of some vascular tumours of the petrous bone (e.g. paraganglioma) and craniofacial regions (e.g. juvenile angiofibroma of nasopharynx).

The algorithms of MR diagnosis of the skull base tumours are slightly different from those used in imaging of tumours of other regions of the brain. First of all, it should be noted that MRI can better evaluate and distinguish soft-tissue structures located under the skull base in comparison with CT scanning. The use of different pulse sequences and scan modes opens up new opportunities in the non-invasive diagnosis of lesions in this area. And despite the rather long total scanning time compared to CT, we consider MRI an integral part of the diagnostic protocol. In the evaluation of skull base tumours, MR technology to suppress MR signal from fat, so-called Fat-Sat modes, acts as the key element in the examination of this anatomical region. Here, we use suppression of the signal from fat on T2-weighted images, T2-FLAIR and, of course, on T1-weighted images (spin echo, SPGR, etc.).

We consider it is obligatory to use intravenous contrast enhancement for all MRI studies of skull base tumours. So the pulse sequences with T1-weighted images + Fat-Sat technology + contrast enhancement should present the final step in any MRI study of skull base lesions.

Another distinctive feature of MRI in comparison with CT scan is the ability of blood vessels imaging (arteries and veins) without contrast enhancement. Among the non-contrast angiographic MR techniques, 3D TOF technology is the best in the imaging of arteries. With the use of 3T MRI has significantly expanded its capacity in the assessment of microvascular pattern of the tumours' blood supply of the anterior, middle and posterior cranial fossae. Nowadays, we rarely use direct angiography in our clinical practice, replacing it with MR angiography with high spatial resolution on 3T MR scanners.

2D TOF angiography method in the skull base and upper cervical spine imaging is being gradually replaced by the new technology of imaging of mixed vascular picture (arteries and veins displaying on the same MR image) – a variation of phase contrast angiography – INHANCE (GE). The main advantages of the latter are a high spatial resolution and the possibility of manipulating the velocity encoding parameters (VENC) at rather short scanning time (about 5–6 min). This method is more sensitive in the diagnosis of complete or partial thrombosis of the skull base sinuses.

Enhanced techniques of MR angiography, bolus MRA and dynamic MRA (TRICKS, GE), have opened a new direction in the study of tumour blood supply, previously available only with direct angiography. Ultrashort scanning time ($\frac{1}{2}$ – $1\frac{1}{2}$ min) allows visualizing the vascular architectonics of the skull base tumours with the arterial and venous components separately from each other.

Among the MR perfusion methods, the arterial spin labelling (ASL) technique should be emphasized as the most promising in the assessment of haemodynamics of intra- and extracranial lesions, including tumours in the skull base region. This method does not require intravenous contrast enhancement, can be easily repeated in the clinic and is especially applicable in paediatric practice. Unlike the widely used T2* MR perfusion, in ASL there are no artefacts from the skull base bones, and the blood flow parameters are characterized by absolute values.

Unfortunately, new pulse sequences based on magnetic susceptibility (SWI, SWAN, etc.) that in recent years are often applied in the diagnosis of various intracranial pathologies are

still used to a limited extent in the assessment of skull base lesions. The main problem is the spatial distortion and artefacts caused by massive bone structures of the skull base. Furthermore, the bones themselves initially have low MR signal in these modes.

The unique diagnostic ability of modern 3.0 T MR scanners, specifically the combination of high resolution rates and signal-to-noise ratio that obtains ultra-thin slices (up to 0.6 mm) and 3D reconstructions, is reflected in the diagnosis of skull base pathology. With MRI, it has become possible to scan with isotropic voxel, which greatly reduced the total scanning time. It is sufficient to obtain images only in one plane, and the subsequent reformates are reconstructed separately without any loss of quality. In our everyday practice in the study of skull base anatomy, we prefer the following programmes: BRAVO (T1 MRI), CUBE (T2 MRI) and FIESTA (T2 MRI). A main and important feature of FIESTA (GE) sequence is the combination of the thin “hard” T2-weighted slices with “artefact suppression” technology from the pulsation of the cerebrospinal fluid. One of the important indications for the use of this programme was to study the location of cranial nerves in the skull base cisterns and their relationship with the surrounding vessels at suspicion of neurovascular conflict.

Due to the large amount of fat tissue not only in the extracranial space under the skull base but also in the bony structures, the majority of patients with lesions in this region require the use of different methods of MR signal suppression of fat tissue. In MRI, fat has a high MR signal in both most frequently used T1- and T2-weighted sequences, which creates difficulties in the pathology assessment. Today, there are several ways to suppress the signal from fat. The most commonly used method is a technology based on the effect of chemical shift. The saturation signal from the fat tissue (Fat-Sat method) with the use of special RF pulse is commonly applied. Another widely used sequence is an inversion-recovery sequence, in which the MR signal from fat can be selectively saturated (STIR method). T1 and T2 MRI technologies with suppression of fat signal obtain a more accurate contrast enhancement in the anatomical areas surrounded by fat tissue or tissue with fat components and evaluate the changes in their signal characteristics. The suppression of MR signal from fat significantly distinguishes a subacute haemorrhage (with methaemoglobin) or cyst formations with high concentration of proteins from fat tissue. Fat-Sat mode is irreplaceable in the studies of the orbital and maxillofacial region. Diagnostic accuracy significantly increases with the combination of the Fat-Sat mode and intravenous contrast enhancement.

Recently, we have successfully tested a new method for MR signal suppression from fat based on the Dixon method. The new technology provides stronger suppression of high MR signal from fat tissue even in the presence of metal implants or metal fixation systems in the upper cervical spine after reconstructive surgery (IDEAL, GE). The second main task of the fat suppression technology is to improve the visualization of the lesions that accumulate contrast medium (tumours, lymph nodes, etc.).

The authors sincerely thank the staff of the *Burdenko Neurosurgery Institute*, especially L. V. Shishkina, S. V. Tanyashin, A. B. Kadasheva and A. I. Belov, who helped in selecting material for this book.

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CT and MRI of Skull Base Lesions

A Diagnostic Guide

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2018, XI, 826 p. 629 illus., 78 illus. in color., Hardcover

ISBN: 978-3-319-65956-5