Imaging of Diseases of the Cranial Nerves: Tips and Tricks

Bernd F. Tomandl¹; Norbert Sommer²; Patrick J. Egan¹; Tibor C. Mitrovics¹

¹Dpt. of Radiology and Neuroradiology, Christophshad Hospital, Göppingen, Germany
²Dpt. of Neurology, Christophshad Hospital, Göppingen, Germany

Introduction

The intention of this article is to alert readers to common problems and pitfalls concerning magnetic resonance imaging (MRI) for pathologies of cranial nerves. It also provides an introduction to helpful sequences and post processing techniques. There are numerous reports about imaging of the cranial nerves that show the capabilities of sub-millimeter heavily T2-weighted images, like the CISS or balanced FFE-sequences for the visualisation of the anatomy of the cranial nerves in the living body [1]. However, these sequences will only show the course of the cranial nerves within the basal cisterns, and whilst this is helpful in clinically-suspected cases of neurovascular compression symptoms [2, 3], in most other cases more information is needed to find the cause of cranial nerve palsy. To familiarise the reader with cranial nerve imaging, examples of the normal anatomy as well as typical pathological cases are shown in this article. Most images were acquired with a 1.5T MAGNETOM Avanto (Siemens Healthcare, Erlangen, Germany). All cited references are available online for free.

Anatomy and MR sequences

Imaging of diseases of the cranial nerves requires good knowledge of the course...
### Table 1: Course and function of the cranial nerves (CN).

<table>
<thead>
<tr>
<th>CN</th>
<th>Name</th>
<th>Course and Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Olfactory nerves</td>
<td>Part of the brain. Responsible for the sense of smell. They run in the anterior base of the skull; their fibres exit the skull through the cribriform plate. These nerves are frequently injured in skull-base fractures.</td>
</tr>
<tr>
<td>II</td>
<td>Optic nerves</td>
<td>Part of the brain; surrounded by CSF and the dura. Responsible for the sense of vision. Frequent diseases affecting the optic nerves include multiple sclerosis and pituitary adenomas, as well as meningiomas and gliomas of the optic nerves.</td>
</tr>
<tr>
<td>III</td>
<td>Oculomotor nerves</td>
<td>Responsible for eye movement. The relatively large oculomotor nerves also control pupillary constriction. While CN III and VI are easily identified on CISS images, the trochlear nerve – being the only one of the cranial nerves to leave the brain stem at its back below the quadrigeminal plate – is often difficult to find due to its tiny size [11]. The course of the abducens nerves is interesting. They leave the brain stem below the pons, enter a duplication of the dura at the clivus (Dorello’s canal), and finally enter the cavernous sinus after crossing the petrosphenoidal ligament (Gruber’s ligament). Imaging of an affliction of an abducens nerve should therefore include contrast-enhanced T1w images of the clivus with fat saturation. Acute palsy of the oculomotor nerve is frequently (15%) related to an intracranial aneurysm of the internal carotid artery at the origin of the Pcom.</td>
</tr>
<tr>
<td>IV</td>
<td>Trochlear nerves</td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>Abducens nerves</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Trigeminal nerves</td>
<td>They divide into three branches: the V1 (ophthalmic), V2 (maxillary) and V3 (mandibular) branch. They leave the skull through the superior orbital fissure (V1), the foramen rotundum (V2) and the foramen ovale (V3). They transmit sensations from the face, scalp and teeth, including chewing. Neurovascular compression of the nerve at the entrance zone to the brain stem may result in trigeminal neuralgia.</td>
</tr>
<tr>
<td>VII</td>
<td>Facial nerves</td>
<td>The facial and vestibulocochlear nerves both enter the internal auditory meatus. The facial nerves are responsible for the sensation of taste from the anterior 2/3 of the tongue as well as the motoric innervation of face muscles. Acoustic schwannomas and meningeomas are frequent pathologic findings affecting these nerves.</td>
</tr>
<tr>
<td>VIII</td>
<td>Vestibulocochlear nerves</td>
<td></td>
</tr>
<tr>
<td>IX</td>
<td>Glossopharyngeal nerves</td>
<td>The glossopharyngeal, vagus and accessory nerves leave the skull through the jugular foramen. CN IX is also responsible for involuntary blood-pressure reflexes, cardiac and respiratory sensing, contraction of the pharynx and the swallowing reflex. Some of these signals overlap with CN X, which is more involved in reflexes and vital functions. They can be involved in skull-base tumors or dissections of the carotid artery.</td>
</tr>
<tr>
<td>X</td>
<td>Vagus nerves</td>
<td></td>
</tr>
<tr>
<td>XI</td>
<td>Accessory nerves</td>
<td></td>
</tr>
<tr>
<td>XII</td>
<td>Hypoglossal nerves</td>
<td>The hypoglossal nerves exit the skull through the hypoglossal foramen. They control the movement of the tongue by innervating three of the four muscles. The fourth muscle is under the control of CN X.</td>
</tr>
</tbody>
</table>

Parts of table 1 are courtesy of Alicia Mae Prater, http://suite101.com/article/the-cranial-nerves-a105837.

An overview of the cranial nerves is given in table 1 and figure 1. A more interactive and entertaining introduction to cranial nerve anatomy and function is given by Barbara Liang on the wisc-online site (http://www.wisc-online.com/Objects/ViewObject.aspx?ID=AP11504). Large cranial nerves are visible even on standard MR-images: The ophthalmic, optical, trigeminal, oculomotoric as well as the facial and vestibulocochlear nerves can be readily identified on 4 mm T2w images (Fig. 2). The smaller nerves are more difficult to see and thin section images are required. As an example how the anatomic course of a cranial nerve influences the choice of MR sequences, the course of the sixth cranial nerves (abducens nerves) is as follows: The nerves leave the brain stem below the pons, enter a duplication of the dura at the clivus (Dorello’s canal), and finally enter the cavernous sinus after crossing the petrosphenoidal ligament (Gruber’s ligament) [4]. While CISS-images will only show the intracisternal course of the nerve (Fig. 3), other sequences are needed to exclude an infarction in the pons or a tumor along the course of the nerve. Imaging of an acute affliction of an abducens nerve should therefore always include diffusion-weighted...
How-I-do-it

2 4 mm T2w TSE MRI. Some cranial nerves are always visible: (2A) T2w TSE with fat saturation in a patient with multiple sclerosis. Hyperintense right optic nerve indicating optic neuritis (white arrow). The left optic nerve is normal (arrowhead). In addition the olfactory nerves are visible (red arrows). (2B) The oculomotor nerves (arrows) crossing the space between the posterior cerebral artery and the superior cerebellar artery. (2C) The trigeminal nerves at their origin (red arrows) and the facial and vestibulocochlear nerves within the internal acoustic canal are clearly visible (white arrows).

3 Multiplanar reformations from 0.7 mm CISS images in oblique sagittal and coronal planes show the intracisternal course of the abducens nerves (yellow arrows) and the origin of Dorello’s canal (red arrows).

4 images (DWI) of the pons and (if no infarction is visible) contrast-enhanced T1w images of the clivus (sagittal plane) and cavernous sinus (coronal plane) with fat saturation [5]. Time-of-Flight (TOF) MR angiography (MRA) can be helpful to detect aneurysms in the cavernous sinus. Always remember that this technique is not sufficient to exclude intracranial aneurysms [6].

Often T1-weighted 3D-sequences after administration of gadolinium (e.g. Magnetization Prepared Rapid Gradient Echo (MPRAGE)) are very helpful as they allow for intensive post processing of the data (Fig. 4) [7].

Post processing

Usually the cranial nerves follow an oblique course through the basal cisterns. Therefore 3D post processing with multiplanar reconstructions (MPR) and/or volume rendering is often helpful to get a clearer delineation of the course of a specific cranial nerve and its vicinity.

The following case report will make that more clear: A 46-year-old woman attended her physician after she developed acute ptosis and double vision especially when looking to the left side (Fig. 5). Clinical examination revealed an oculomotor palsy. The normal anatomy of the third...
**How-I-do-it**

4 T1w MPRAGE after intravenous administration of Gadolinium-DTPA in a patient with multiple meningiomas and an assumed acoustic schwannoma. (4A) MPR in three orthogonal planes allows for optimal delineation of the tumor within the internal acoustic canal. In addition a volume rendered image shows the brain surface. (4B) Thin section MIP images (15 mm) and low opacity volume rendering allow good delineation of both the large intracranial arteries and veins.

5 Acute right oculomotor palsy in a 46-year-old woman.

6 Intracisternal course of the left oculomotor nerve (black arrow) demonstrated on a volume rendered image (6A) of the brainstem and an oblique sagittal view from 0.7 mm CISS data (6B). The nerve (black arrow) leaves the midbrain (*) between the posterior cerebral artery (white arrow) and the superior cerebellar artery (white arrowhead). After crossing the basal cisterns it enters the cavernous sinus.
How-I-do-it cranial nerve is shown in figure 6. MRI was performed including DWI and TOF-MRA without result. As the oculomotor palsy did not improve within 4 weeks the patient was sent to our hospital. She brought her images on a CD and we reviewed the images including post processing of the TOF-MRA that was done on a Siemens MultiModality workplace (Leonardo). While it was very difficult to see the lesion on the initially produced maximum intensity projection (MIP) reconstructions that included the whole volume data (Fig. 7) it was rather easy to detect the aneurysm on 15 mm thin MIP images in 3 planes and even easier on volume rendered images (Fig. 8). This is a good example why whole-volume MIP imaging is not very helpful if we want to see more than just the big arteries [8]. Of course it is mandatory to review the source images before any kind of 3D-imaging is done [9]. In our hospital we use routinely thin section MIPs of 15 mm section thickness in sagittal axial and oblique coronal planes where the coronal plane is reconstructed parallel to the basilar artery to get a clear visualization of the 2 vertebral arteries and the basilar artery and its branches (Fig. 9). Using this type of reconstruction makes it easy to delineate aneurysms in the vicinity of the cranial nerves. It is important to know that about 15% of acute oculomotor palsy cases are caused by intracranial aneurysms that are usually located at the distal intracranial internal carotid artery at the origin of the posterior communicating artery [10]. The course of the nerve roughly parallels the course of the posterior communicating artery (Fig. 6). It is very important to perform the MRA with high quality in these patients. We must be aware that TOF-MRA cannot exclude an aneurysm because slow flow within the aneurysm may lead to non-visualisation within the flow sensitive sequences so that other imaging modalities like contrast-enhanced MRA, CTA or even DSA are sometimes necessary.
Summary

Before performing MRI of a patient with cranial nerve palsy make sure that you know the course of the particular cranial nerves. Use thin section CISS-sequences to see the intracisternal course of the nerves. Use fat suppressed T1w images after contrast administration to visualize pathology within the skull base. Use 3D MPRAGE for a variety of reconstructions. Don’t rely on whole-volume MIP images from TOF-MRA. Routinely use the excellent post-processing tools that come with all Siemens scanners, such as MPR, thin section MIPs and volume rendering. This will ensure that you will not miss important findings.

References