High-Resolution Isotropic Three-Dimensional MR Imaging of the Extraforaminal Segments of the Cranial Nerves

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KEYWORDS

• High-resolution MR imaging • Cranial nerves • Segmental classification
• Extraforaminal cranial nerves

KEY POINTS

- High-resolution isotropic 3-dimensional (D) MR imaging with and without contrast is now routinely used for imaging evaluation of cranial nerve anatomy and pathologic abnormality.
- Previous work has highlighted the utility of sequences, including constructive interference in steady-state without and with intravenous contrast, in such cases.
- The extraforaminal segments are well-visualized on these techniques, especially in the setting of contrast against varying tissue types.
- The extraforaminal segments are affected by a wide range of pathologic entities, which may cause enhancement or displacement of the nerve; in such pathologic conditions, the relevant findings are also visible to an extent not available on standard 2D imaging.

INTRODUCTION

For the purposes of imaging, the cranial nerves (CNs) may be divided into 7 segments based on anatomic context (**Fig. 1**),[1] designated as segments a through g. Each of the CNs, with the exception of the vestibulocochlear nerve (CN VIII), is partly found outside of the head, passing beyond a line drawn between the margins of the outer table of the skull at each side of the skull base foramina; that is, in the extraforaminal segment, which may be designated as CN #.g for rapid reference. More specifically, segments a and b remain within the central nervous system and are designated the nuclear and parenchymal fascicular segments, respectively. The cisternal segment, c, is that portion that lies within the cistern having exited the brainstem until it reaches the entrance of the dural cave segment, d. More distally, the CN courses beyond the inner dural layer, is no longer surrounded by cerebrospinal fluid (CSF), becomes associated with a venous plexus, and is considered as the interdural segment, e. After piercing the outer layer of dura, the CN is foraminal, f. The final extraforaminal segment, g, is reached when the nerve exits the skull base.

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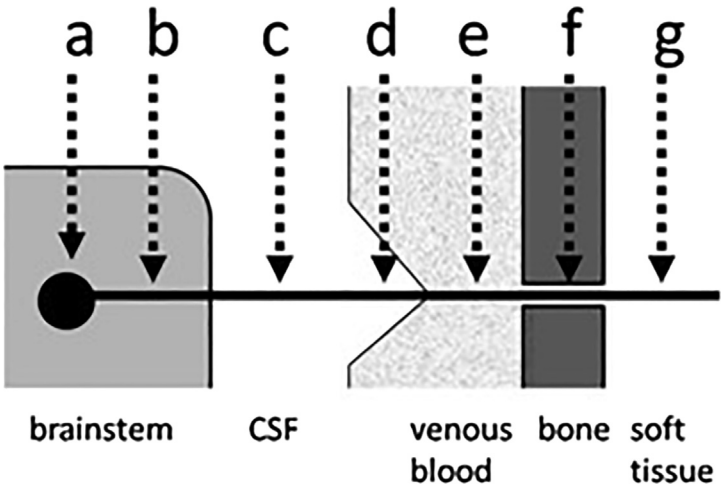

Fig. 1. The different anatomic segments of the cranial nerves. CSF, cerebrospinal fluid. (*From* Blitz AM, Aygun N, Herzka DA, et al. "High resolution three-dimensional MR imaging of the skull base: compartments, boundaries, and critical structures." Radiol Clin North Am 2017;55(1):21; with permission.)

CNs serve various functions, including but not limited to vision, movements of extraocular and facial muscles, and hearing. It is in the extraforaminal segments that the CNs may be seen extending through surrounding soft tissue to (in the case of motor innervation) or from (in the case of sensory innervation) the organs they innervate. Clinical suspicion of an extraforaminal location of disease affecting the CNs is sometimes possible due to the branching pattern of the CNs, proximity with other CNs with interrupted function, and/or a known abnormality such as dermatologic malignancy in the region of suspected CN dysfunction. Currently, MR imaging is the gold standard for visualization of various pathologic abnormalities associated with CNs. However, imaging of the extraforaminal segments of the CNs presents a particular challenge due to their small size, complex course, and varying anatomic context as they course adjacent to a variety of soft tissue structures. High-resolution 3-dimensional (D) MR imaging allows for visualization of a greater extent of the normal and abnormal extraforaminal segments of the CNs than was previously possible, although substantial challenges remain. Differential diagnosis of lesions is based on the location and gross anatomic features evident on imaging.

Cranial neuropathy may arise from disease affecting fiber bundles at any anatomic segment, from the nuclear segment (CN #.a) to the innervated end organs in the extraforaminal segments (CN #.g). Segmental classification of the CNs has been described elsewhere and is summarized in **Fig. 1**.[1] Readers interested in imaging of the CNs from their nuclear to the foraminal segments with their associated pathologic conditions can refer to review articles written elsewhere.[1–3] The extraforaminal segment, g, begins at the level of the outer cortex of the appropriate foramen. This article focuses on the normal high-resolution anatomy and appearance of several featured CNs, with specific emphasis on the extraforaminal segment, along with selected pathologic conditions affecting those segments.

IMAGING APPROACHES

At the authors' institution, high-resolution isotropic 3D MR imaging protocol consists of the following sequences: precontrast and postcontrast 3D constructive interference in steady-state (CISS), 3D T2-weighted short-tau inversion recovery (STIR) SPACE (Sampling Perfection with Application optimized Contrasts using different flip angle Evolution), precontrast volumetric interpolated breath-hold examination (VIBE), and postcontrast VIBE with fat saturation (**Table 1**).[4] In addition, standard precontrast imaging through the head is typically performed before the high-resolution imaging and standard postcontrast imaging is generally performed following the high-resolution sequences listed.

CISS sequences acquire high-signal, high-resolution isotropic 3D images, which can be reconstructed in multiple planes to visualize complex skull base and CN anatomy. The use of CISS imaging with and without contrast has been described for evaluation of the course of the CNs from the cisternal through extraforaminal segments.[1] Even though it is a gradient echo technique, CISS sequence includes both T1-weighting and T2-weighting, which enables postcontrast evaluation of structures, such as small regions of pathologic enhancement encountered in perineural spread of malignancies.[5] Additionally, nonpathologic postcontrast enhancement enables exquisite