High resolution 3-T MR imaging in the evaluation of the trigeminal nerve course

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Abstract. – BACKGROUND: The evaluation of the trigeminal course and his anatomical relationships with surrounding structures, is important for the assessment of the injury that may occur in tumors and several orofacial trauma and for avoiding the damage during surgeries.

AIM: The aim of this retrospective study was to assess the use of 3-T MRI in the evaluation of the course of the four segments of the trigeminal nerve: cisternal and Meckels’s cave, cavernous sinus, skull base and mandibular extracranial segments.

PATIENTS AND METHODS: 78 patients were studied, for a total of 156 trigeminal nerves examined. T2-weighted 3D Fast imaging employing steady-state acquisition and T1-weighted Fast spoiled gradient recalled echo sequences were used. Two radiologists (reader A and B), independently, evaluated the course of the four segments of the trigeminal nerve according to a qualitative scale. The Intraclass correlation coefficient (ICC) and Pearson correlation coefficient were used to assess the intraobserver and interobserver variability in the nerve course evaluation.

RESULTS: Reader A evaluated 47 trigeminal nerves excellent, 94 good, 12 fair and 3 poor. Reader B rated 43 trigeminal nerves excellent, 92 good, 16 fair and 5 poor. The intraobserver variability was ICC = 0.937 in reader A and ICC = 0.894 in reader B. The interobserver variability was 0.734 (p ≤ 0.01).

CONCLUSIONS: High resolution 3-T MRI imaging allows an accurate study of the trigeminal nerve and especially of its mandibular branch. The knowledge of the course and of the anatomic relationships of these nerve bundles with surrounding structures, as well as of the anatomical variants, allow oral and maxillofacial surgical plannings thus reducing the risk of nerve damage.

Key Words:
- Magnetic resonance imaging, Trigeminal nerve, Trigeminal nerve injuries, Mandibular nerve, Tomography, X-Ray computed.

Introduction

The trigeminal nerve is the largest cranial nerve and the most widely distributed in the supra-hyoid neck1. It is a mixed sensory-motor nerve, receiving sensory input from the face and providing motor innervation to the muscles of mastication.

The evaluation of the trigeminal course and his anatomical relationships with surrounding structures is important for the assessment of the injury that may occur in tumors and several orofacial trauma and for avoiding damage during surgeries.

A clinical examination using different tests has thus far been the only established method of diagnosing nerve lesions. The using of infrared equipment and magnetoencephalography are described in some publications to differ between interrupted and intact nerves but these methods, like other available tests, allow nerve lesions to be detected only indirectly2,3

In patients with mandible fracture accompanied by dysesthesia of the lower lip, panoramic radiographs, and CT show the severe dislocation of the mandible fracture, but it is impossible to know whether the nerve is interrupted, which is very important in designing corrective surgical procedures4-7.

Magnetic resonance imaging (MRI) can provide highly detailed anatomical information with excellent discrimination of the soft tissues, avoiding patient’s exposure to X-rays8. In the previous studies the limited use of MRI is due to the longer examination time and the lower resolution that this method has in comparison with computed tomography. Indeed, the insufficient spatial resolution 1.5T MRI cannot display small lesion and detail small anatomical structures properly.

Some researchers have demonstrated that the introduction of high resolution 3-T MR and opti-
mized sequences can significantly improve the spatial resolution and the signal-noise ratio (SNR)\(^9\)-\(^11\).

The aim of this retrospective study was to assess the use of 3 T MR imaging in the evaluation of the course of the trigeminal nerve and especially of its third mandibular branch.

**Patients and Methods**

**Patient Population**

The head and neck MRI scans of 78 patients (42 males and 36 females; mean age: 57 years; range: 17 to 71 years) were retrospectively evaluated in the Department of Radiological Science of “Sapienza” University of Rome, Italy.

The study was approved by the local Ethical Committee and conducted in accordance with the Helsinki Declaration of 1975 as revised in 2000.

**MR Imaging Acquisition Protocol**

All patients underwent an MRI examination performed using a superconducting magnet of 3 Tesla (Discovery MR750, GE Healthcare, Milwaukee, USA) equipped with an 8-channel neurovascular phased-array coil (GE Medical System). The standardized imaging protocol included: axial T1-weighted TSE sequence; axial T2-weighted TSE sequence; axial STIR sequence; axial, coronal and sagittal T1-weighted fat-saturated sequences after gadolinium injection; T2-weighted 3D-Fast imaging employing steady-state acquisition (3D FIESTA) and T1-weighted Fast spoiled gradient recalled echo (fast SPGR) sequences. 3D FIESTA and fast SPGR sequences were used to depict the trigeminal nerve course.

Imaging parameters of 3D FIESTA sequence were as follows: repetition time (TR) = 4.6 ms; echo time (TE) = 2.2 ms; slice thickness = 0.6 mm; field of view (FOV) = 20 × 20 cm; number of excitations (NEX) = 1; matrix = 512 × 512.

Imaging parameters of fast SPGR sequence were as follows: repetition time (TR) = 8 ms; echo time (TE) = 3 ms; slice thickness = 0.6 mm; field of view (FOV) = 15 × 21 cm; number of excitations (NEX) = 2; matrix = 512 × 512.

Axial acquisition were obtained for both sequences.

**MRI Post-Processing and Image Interpretation**

Two experts in oral radiology (reader A with 25 years of experience and reader B with 5 years of experience) evaluated, independently, the images of the trigeminal nerve. The images were evaluated on an off-line dedicated workstation (AW Volume-Share2, GE Healthcare, Milwaukee, USA). Optimal planes, including the course of the inferior alveolar nerve (IAN), were determined by means of multiplanar reformation (MPR) using the imager’s standard reformation software (Figure 1).

The radiologists, to simplify the trigeminal nerve evaluation, divided the anatomical course into 4 segments: cisternal and Meckel’s cave, cavernous sinus, skull base and mandibular extracranial segments. The course of each segment was rating as described below:

- Unclear course: 1;
- Probable recognition of the course: 2;
- Definite recognition of the course: 3.

The presence of motion artifacts was rated in each segment as follows:

- Severe artifacts: 1;
- Mild artifacts: 2;
- None: 3.

The sum of the scores of each component determines, according to the following conversion scale, the accuracy degree to depict the full trigeminal nerve course:

- Score from 24 to 20: excellent;
- Score from 19 to 14: good;
- Score from 13 to 8: fair;
- Score < 8: poor.

After 2 months, the two specialists reassessed the course of the trigeminal segments in order to calculate the intraobserver variability.

**Statistical Analysis**

Data were evaluated using a statistical analysis software (SPSS\(^\text{®}\), Statistical Package for Social Science, IBM Corporation, Armonk, NY, USA).

Qualitative data of accuracy degree in the depiction of the trigeminal nerve course (excellent, good, fair and poor) were described with frequency distribution. To evaluate reproducibility, the two experts repeated the evaluation of the trigeminal nerves on two occasions at intervals of 2 months. Intraclass correlation coefficient (ICC) were used to evaluate intraobserver variability. Pearson correlation coefficient was used to evaluate the interobserver variability. The significance was set at \(p \leq 0.01\).
Figure 1. 3D FIESTA (A-C) and 3D SPGR (D-F) images showing the procedure needed to obtain an optimal plane to display the IAN. In multiplanar reformation (MPR) technique the reference axis were centered in the proper axial images at the level of the mandibular third molar with an axis oriented parallel and the other perpendicular to alveolar bone in order to achieve a parasagittal plane to correctly depict the course of the IAN. C, F. The relationship with the IAN and third molar roots is well displayed (white arrows).

Results

The frequency distribution of accuracy degree in the depiction of the trigeminal nerve segments course, according to reader A and reader B, is summarized in Table I.

The cisternal segment was identified at the ventrolateral midpons where the trigeminal nerve emerges as two separate roots. The larger sensory root was located laterally and the smaller motor root medially (Figure 2A) and penetrated into Meckel’s cave containing the gasserian ganglion. The sensory root entered the ganglion and divided into 3 branches: ophthalmic, maxillary and mandibular (Figure 2B). The motor root went through under the ganglion, turned inferiorly to exit the skull base together with the mandibular division of the sensory root.

In the cavernous segment the ophthalmic and maxillary divisions continued within the lateral wall of the cavernous sinus (Figure 2C), below the cavernous part of internal carotid artery.

In the skull base segment the ophthalmic division leaved the anterior cavernous sinus and exited the intracranial compartment through the superior orbital fissure (Figure 2D), the maxillary division exited the central skull base through foramen rotundum and entered the pterygopalatine fossa (Figures 2E, F) and the mandibular division, the largest of the three, exited the skull base through foramen ovale, entering the nasopharyngeal masticator space (Figures 3A, B).

The mandibular peripheral segment gave off 4 sensory branches: buccal, auriculotemporal, lingual and inferior alveolar nerve (IAN). The divi-

<table>
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<tr>
<th>Qualitative assessment</th>
<th>Reader A</th>
<th>Reader B</th>
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<tbody>
<tr>
<td>Excellent</td>
<td>47 = 28.8%</td>
<td>43 = 27.6%</td>
</tr>
<tr>
<td>Good</td>
<td>94 = 61.6%</td>
<td>92 = 59.1%</td>
</tr>
<tr>
<td>Fair</td>
<td>12 = 7.7%</td>
<td>16 = 10.2%</td>
</tr>
<tr>
<td>Poor</td>
<td>3 = 1.9%</td>
<td>5 = 3.1%</td>
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sion of mandibular branch in IAN and lingual nerve was found 8 mm beneath the foramen ovale (Figure 3C).

The IAN entered the mandibular canal through the mandibular foramen (Figure 4A) at the lingual surface of the mandibular ramus and travelled along the body of the mandible (Figures 1C, F, 4B). It divided at the first and second premolars teeth into terminal incisive and mental branches. The mental nerve emerged at the mental foramen and innervated the skin of the chin and the mucous membrane of the lower lip (Figure 4C). The incisive nerve ran from the mental foramen usually to the region of the ipsilateral incisor teeth (Figure 4D)\textsuperscript{11}. The lingual nerve lied at first beneath the lateral pterygoid muscle medial to and in front of IAN. The nerve then passed between the medial pterygoid muscle and the ramus of the mandible, and crossed obliquely to the side of the tongue over the costrictor pharyngis superior and styloglossus. From there, it passed between the mylohyoid muscle and the mucous membrane of the floor of the mouth along the side of the tongue (Figure 4B).

Both readers were not able to identify the buccal and auriculotemporal branches in all patient.

The intraobserver variability in the evaluation of the trigeminal nerve course was ICC = 0.937 in reader A and ICC = 0.894 in reader B.

The interobserver variability in the assessment of the trigeminal segments (Pearson correlation coefficient) was 0.734 ($p \leq 0.01$).
Discussion

To know the course of the cranial nerves before the surgical planning is of primary importance to avoid the risk of nerve bundles injury. In the previous studies, MRI with conventional field strength did not allow the evaluation of the course of the cranial nerves (although it has always been considered the gold standard for the study of the nervous system), because the conventional 1.5 Tesla magnet is not able to reach high spatial resolution so as to acquire images suitable for the study of the cranial nerves which have small diameter and tortuous course. Another drawback is a high incidence of motion artifacts related to the high interval of time necessary for the acquisition of the images. Recently, the introduction into clinical practice of high-field strength MR systems (3.0 Tesla) and the use of fast sequences such as 3D FIESTA, has brought clear advantages. The main advantage of a 3.0 Tesla magnet is the increasing in the signal-to-noise ratio, which leads to a gain of the spatial resolution with improving the quality of images. 3D FIESTA allows the acquisition of images with a submillimetric section thicknesses in a very short time, with a consequent reduction of the motion artifacts allowing the study of smaller structures such as nerve bundles.

An 3D FIESTA sequence is any gradient-echo sequence in which a nonzero steady state develops between pulse repetitions for both the longi-
tudinal and transverse relaxation values of the interrogated tissues. A small flip angle and short relaxation time are required for this to occur. The clinical utility of an 3D FIESTA sequence lies in its ability to generate a strong signal in tissues that have a high T2/T1 ratio, such as cerebrospinal fluid (CSF) and fat. The use of 3.0 Tesla MR imaging with 3D FIESTA sequence allows to reach a higher spatial resolution and a decrease of motion artifacts, with a consequent clearer depiction of tiny cranial nerve bundles, showed as low signal intensity structures.

The main disadvantage of 3D FIESTA imaging is a reduced contrast resolution between hard and soft tissues that does not allow the visualization of peripheral branches inside mandibular bone. This drawback can be overcome by the use of T1-weighted fast spoiled gradient recalled echo (fast SPGR). Fast SPGR is a 3D fast fat saturated T1-weighted sequence which provides a high contrast between nerve bundles, displayed as a high signal intensity structure, and bone tissue, depicted as a very low signal intensity structure (Figures 1F, D).

This study has been focused on the trigeminal nerve and especially on the mandibular branch. Indeed the knowledge of the IAN and the lingual nerve course (the two main branches of the mandibular nerve) is of a great importance in oral

**Figure 4.** A, Axial 3D FIESTA image shows the IAN (white arrow) entering the mandibular canal through the mandibular foramen at the lingual surface of the mandibular ramus. B, Axial 3D FIESTA image displays the IAN (white arrow) travelling along the body of the mandible and the lingual nerve (black arrow) running between the mylohyoid muscle and the mucous membrane of the floor of the mouth along the side of the tongue. C, Coronal 3D FIESTA image shows the mental nerve (white arrowheads) emerging at the mental foramen and entering into the soft-tissues of the chin and the lower lip. D, Axial fast SPGR image shows the IAN (white arrowheads) travelling along the body of the mandible, the mental foramen (white arrow) and the incisive nerve (black arrowheads) running from the mental nerve to the region of the ipsilateral incisor teeth.
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Conclusions

The use of 3.0 T MRI with 3D FIESTA and fast SPGR sequences allowed the study of the course of the trigeminal nerve and its branches. The knowledge of the course and of the anatomic relationships of these nerve bundles with surrounding structures, as well as of the anatomical variants, allow oral and maxillofacial surgical plannings thus reducing the risk of nerve damage. The reduced appearance of this complication provides advantages both for the patient, in terms of safety, and for the physician, in terms of medico-legal consequences.

Conflict of Interest

The Authors declare that there are no conflicts of interest.

References