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original article

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

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SUMMARY: **High resolution 3-T MR imaging in the evaluation of the facial nerve course.**

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Objectives. *To assess the value of 3-Tesla (3-T) MR imaging (MRI) in the evaluation of the course of the intracranial and extra-cranial tracts of the facial nerve.*

Patients and methods. *83 patients were studied by MRI in order to detect the course of facial nerve; a total of 166 facial nerves were examined. T2-weighted 3D Fast imaging employing steady-state acquisition (FIESTA) and T1-weighted Fast spoiled gradient recalled echo (fast SPRG) sequences were used. Two radiologists (reader A and B), independently, evaluated the course of the tracts of the facial nerve according to a qualitative scale (excellent, good, fair, poor). The Intraclass Correlation Coefficient (ICC) and Pearson correlation coefficient were used to assess the intra-observer and interobserver variability in the nerve course evaluation.*

Results. *Reader A evaluated 35 facial nerves as excellent, 94 as good, 33 as fair and 4 as poor. Reader B rated 31 facial nerves excellent, 89 good, 43 fair and 3 poor.*

The intraobserver variability was ICC = 0.919 in reader A and ICC = 0.842 in reader B. The interobserver variability (Pearson correlation coefficient) was 0.713 ($p \leq 0.01$).

Conclusions. *According to the preliminary results of our study the use of 3-T MRI with FIESTA and fast SPGR sequences may allow the study of the course of the facial 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, provide useful informations for a prompt neurosurgery and maxillofacial surgical planning.*

KEY WORDS: 3-T MR - Imaging - Facial - Nerve - Course.

Introduction

The facial nerve (seventh cranial nerve) is a complex nerve with motor, sensory, and parasympathetic fibers. The motor division is dominant, accounting for approximately 70% of the total axons, with the remainder composed by the sensory division and the nervus intermedius (nerve of Wrisberg). The motor division supplies somatic motor fibers to the muscles of the face, scalp, and auricle, the buccinator and platysma, the stapedius, the stylohyoideus, and the posterior belly of the digastric; it also contains some sympathetic motor fibers, which constitute the vasodilator nerves of the submandibular and sublingual glands and are conveyed through the chorda tympani nerve (1, 2).

Imaging plays an important role in the evaluation of the complex anatomy of the facial nerve because the nerve may be affected by a wide variety of primary pathologic processes and may also be secondarily involved in several congenital, inflammatory, traumatic and neoplastic disorders of the temporal bone and parotid gland.

Moreover the evaluation of the facial nerve course and his anatomical relationships with surrounding structures is very important for prevent possible injuries which may occur during surgery.

Magnetic resonance imaging (MRI) can provide highly detailed anatomical information with excellent discrimination of the soft tissues, avoiding patient's exposure to X-rays (3). In the previous studies the limited use of MRI was due to the longer examination time and the lower resolution compared with computed tomography. In fact the insufficient spatial resolution of the widespread

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magnetic field of 1.5-Tesla cannot display small lesion and detail small anatomical structures properly. Some researchers have demonstrated that the introduction of high resolution 3-Tesla MR systems and optimized sequences can significantly improve the signal-to-noise ratio (SNR) and increase the spatial resolution (4-6).

The aim of this retrospective study was to assess the use of 3-Tesla MR imaging in the evaluation of the course of the intracranial and extra-cranial segments of the facial nerve.

Patients and methods

Patient population

Eighty-three patients (52 males and 31 females; mean age: 58 years; range: 19 to 74 years) who underwent both MRI scan and CT examination of head and neck were retrospectively evaluated in the Department of Radiological Sciences of "Sapienza" University of Rome.

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

Imaging acquisition protocol

MRI

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 facial nerve course.

Imaging parameters of 3D FIESTA sequences 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 x20 cm; number of excitations (NEX)= 1; matrix = 512 x 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 x21 cm; number of excitations (NEX)= 2; matrix = 512 x 512.

Axial acquisitions were obtained for both sequences.

CT

A 64-section scanner (Sensation Cardiac 64; Siemens, Forchheim, Germany) was used with the following protocol: section thickness, 0.6 mm; reconstruction interval, 0.5 mm; 0.5-second gantry rotation time; pitch, 0.9; 120 kV; reference tube current, 200 mAs; mean tube current, 190 mAs; tube current range,170–230 mAs with tube current modulation (CareDose; Siemens); table feed, 40 mm/sec. The scanning begin at the skull base and continued toward the thoracic inlet level.

The reconstruction field of view was 34 cm, and the matrix size was 512 x 512, resulting in a voxel size of 0.6 x 0.6 x 0.6 mm. Image reconstruction was routinely performed with a medium soft-tissue deconvolution algorithm (B20 kernel. CT data sets were transferred to a dedicated workstation (Aquarius; TeraRecon, San Matteo, Calif) for post-processing.

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 facial nerves. The images were evaluated on an off-line dedicated workstation (AW VolumeShare2, GE Healthcare, Milwaukee, USA). Optimal planes were determined by means of multiplanar reformation (MPR) using the imager's standard reformation software.

The radiologists, to simplify the facial nerve evaluation, divided the anatomical course into intracranial and extra-cranial segments. The intracranial tract is divided into 5 segments: cisternal, intracanalicular, labyrinthine, tympanic, and mastoid. The greater petrosal nerve, a branch of intracanalicular segment, and the corda tympani, a branch of the mastoid segment, were also assessed. The branches of the extra-cranial tract evaluated have been: the posterior auricular nerve, the branch to the posterior belly of digastric muscle and to the stylohyoid muscle, the temporal branch and the cervical branch of the facial nerve.

The study of trans-temporal bone portions of facial nerve on MR images has been compared to CT images to allow a better identification and localization.

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 segment determines, according to the following conversion scale, the accuracy degree to depict the full facial nerve course:

- score from 19 to 21: excellent;
- score from 15 to 18: good;
- score from 11 to 14: fair;
- score < 10: poor.

After 1 week, the specialists reassessed the course of the facial segments in order to calculate the intraobserver variability.

Statistical analysis

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

Qualitative data of accuracy degree in the depiction of the facial nerve course (excellent, good, fair and poor) were described with frequency distribution. To evaluate reproducibility, the two experts repeated the evaluation of the facial nerves twice at intervals of one week. Intraclass correlation coefficient (ICC) was used to evaluate intraobserver variability. Pearson correlation coefficient was used to evaluate the interobserver variability. The significance was set at $p \leq 0.01$.

Results

The frequency distribution of accuracy degree in the depiction of the facial nerve course, according to reader A and reader B, is summarized in Table 1.

The cisternal segment was identified across the cerebello-pontine angle (CPA) cistern where leaved the brainstem at the ponto-medullary junction. It ran an-

TABLE 1 - QUALITATIVE ASSESSMENT OF FULL FACIAL COURSE.

Qualitative assessment	Reader A, n	Reader B, n
Excellent	35 = 21.2%	31 = 18.6%
Good	94 = 56.8%	89 = 53.9%
Fair	33 = 19.8%	43 = 25.8%
Poor	4 = 2.2%	3 = 1.7%

teriorly to the vestibule-cochlear nerve (cranial nerve VIII) within the CPA cistern and entered into the porus acusticus of the internal auditory canal (IAC), being approximately 24 mm in length (7-9) (10 di 3 e 1,5,6 di 2).

The intracanalicular segment was displayed in the porus acusticus at the medial aspect of the IAC and was about 8 mm in length. In the IAC the vestibule-cochlear nerve travelled laterally and slightly inferiorly to the facial nerve. Oblique sagittal FIESTA images could demonstrate the facial and superior vestibular nerves as separate structures located up from the cochlear nerve and down from the inferior vestibular branch (7-9).

The labyrinthine segment of the facial nerve was the narrowest (less than 0.7 mm) and shortest (about 5 mm) and extended from the anterosuperior region of the fundus to the geniculate ganglion. It passed between the ampulla of the superior semicircular canal and the cochlea to travel forward and downward and terminated in the geniculate fossa, a bulbous enlargement of the canal containing the geniculate ganglion. At the geniculate ganglion, the nerve made an abrupt sharp turn posteriorly, referred to as the anterior genu, to become the tympanic segment. Exiting anteriorly from the geniculate ganglion was the first branch of the facial nerve, the greater superficial petrosal nerve (GSPN) (7-11).

The tympanic segment of the facial nerve was usually and measured about 10 mm in length from its emergence at the geniculate fossa anteriorly to the posterior genu posteriorly (12). It continued along the medial wall of the tympanic cavity, medial to the incus, it coursed superior and posterior to the cochleariform process, along the upper edge of the oval window, and inferior to the lateral semicircular canal. At the origin of the stapedius tendon from the pyramidal process, the nerve turned inferiorly to become the mastoid segment.

The mastoid segment of the facial nerve extended approximately 13 mm from the posterior genu to the stylomastoid foramen, and it was related medially to the jugular bulb. The mastoid segment has two branches: the nerve to the stapedius and the chorda tympani (7-11).

The extracranial tract of the facial nerve exited the temporal bone by way of the stylomastoid foramen, deep in the posterior belly of the digastric, and immediately entered the parotid gland. Shortly afterward the stylomastoid foramen, it branched into the posterior auricular nerve and the branch to the posterior belly of digastric muscle and to the stylohyoid muscle. In the parotid gland the nerve divided into its two terminal branches: the upper temporofacial nerve and a lower cervicofacial nerve at the posterior border of the ramus of the mandible.

In the parotid gland, these nerves further divide to form the parotid plexus, which has five major branches: the temporal, zygomatic, buccal, marginal mandibular, and cervical (7-11), however both readers were not able to identify the parotid plexus in any patient.

The intraobserver variability in the evaluation of the facial nerve course was ICC = 0.919 in reader A and ICC = 0.842 in reader B.

The interobserver variability in the assessment of the facial segments (Pearson correlation coefficient) was 0.713 ($p \leq 0.01$).

Discussion

Knowing 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 achieve 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 enable 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 steady-state free precession sequences (SSFP), has brought clear advantages. The main advantage of a 3.0 Tesla magnet is the increasing in the SNR, which leads to a gain of the spatial resolution with improving the quality of images (13). SSFP 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 SSFP sequence is any gradient-echo sequence in which a nonzero steady state develops between pulse repetitions for both the longitudinal 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 SSFP 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 (14).

The use of 3-Tesla MR imaging with SSFP sequen-

ce 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 SSFP imaging is a reduced contrast resolution between hard and soft tissues that does not allow the visualization of peripheral branches inside bone structures. 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. For example in our study the depiction of the trans-temporal bone segments of the facial nerve has not been feasible with SSFP sequences, whereas Fast SPGR sequences allowed a good evaluation of the facial nerve portions inside the temporal bone. Moreover CT scans have been used to support the interpretation of Fast SPGR images to allow a better identification and localization of the trans-temporal bone portions of the facial nerve.

This retrospective study aimed to detect the course of facial nerve by means of SSFP and fast SPGR sequences.

To date there are few papers about MR imaging in depicting the intra-temporal parts of the facial nerve and its extra-cranial and intra-parotid path (2, 15, 16). Detailed MRI anatomical studies, however, would provide the surgeon with the exact knowledge of the course of these nerves and the relationships with local anatomical landmarks and any existing variants allowing surgical planning to be designed safely and thus avoiding possible nerve injuries.

The high intraobserver ICCs and high interobserver Pearson correlation coefficient found in this study indicate high degree of reliability and a high level of reproducibility in the evaluation of facial nerve course.

Our results suggest that the MRI study of the facial nerve course could get into the routine surgical planning with all the important advantages that can result in clinical practice.

A variety of congenital, traumatic, vascular, inflammatory, and neoplastic processes may affect the facial nerve. MR imaging combined with a complete understanding of facial nerve anatomy helps in narrowing the differential diagnosis. The precise anatomic course of the facial nerve must be charted in patients who undergo middle ear surgery. Also of great importance is the recognition of the fact that the facial nerve may be affected by large nerve perineural spread in patients who have cancers of the head and neck. Moreover another important use of MR imaging could be the importance of studying the relationship between a benign mass of the parotid gland and the intraparotid portions of the facial nerve because it is crucial to perform a nerve-sparing or a not nerve-sparing surgical approach. Furthermore SSFP sequences could be used as a valid tool in patients with abrupt unilateral neuro-sensorial hearing loss to discriminate surgical versus non-surgical diseases.

Conclusion

The use of 3-T MRI with FIESTA and fast SPGR sequences allowed the study of the course of the facial 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 neurosurgery and maxillofacial surgical planning thus reducing the risk of nerve damage. The reduced incidence of this complication provides advantages both for the patient, in terms of safety, and for the physician, in terms of medico-legal consequences.

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