Extracranial facial nerve imaging in parotid surgery candidates. Could 1.5 T MRI be beneficial?

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Received: March 29, 2023 • Revised manuscript received: May 4, 2023 • Accepted: May 16, 2023

ABSTRACT

Background and aim: Despite improvements in the imaging modalities, the optimal protocol for extracranial facial nerve imaging using 1.5 T MRI is still debatable. Pre-operative mapping of the facial nerve could provide valuable information for surgeons. The current study aimed to evaluate and choose proper 1.5 T MRI protocols for the extracranial segment of facial nerve pre-op imaging.

Patients and methods: Extracranial facial nerves on the tumoral and normal side of 19 patients (38 nerves) were imaged by 1.5 T MRI, using five sequences including T1-weighted, T2-weighted, T1-weighted-fat-saturated with contrast, Three-dimensional (3D) T1-weighted and 3D T2-weighted. The visibility of each of the three segments of the extracranial facial nerve (the main trunk, cervicofacial and temporofacial divisions and terminal branches) in each sequence was assessed.

Results: On the normal side, segments 1 and 2 of the nerve were identifiable in all patients and segment 3 was identifiable in 89.5% of patients in both 3D T1-weighted and 3D T2-weighted sequences. On the tumoral side, segments 1, 2 and 3 were identifiable in 89.5, 84.2 and 68.4% of patients, respectively, in 3D T1-weighted and T2-weighted sequences. 3D sequences showed significant improvement in visualizing extracranial facial nerve and its branches compared to routine T1-weighted and T2-weighted sequences.

Conclusions: Our protocol showed favourable results in visualizing the extracranial facial nerve and its branches. We believe the protocol used in this study could be used as a pre-operative facial nerve mapping method using 1.5 T MRI.

KEYWORDS

magnetic resonance imaging, facial nerve, facial nerve injuries, parotid cancer

Introduction

Facial nerve injuries are not uncommon during maxillofacial and facial surgeries [1]. Temporary and permanent facial nerve dysfunction has been reported in 20–65% and 0–7% of patients undergoing parotidectomy, respectively. Some studies have mentioned iatrogenic facial nerve injuries as the most severe side effect of parotid surgeries [2] since patients' quality of life could be adversely affected by functional and cosmetic complications of facial nerve injuries [3, 4].

Intracranial facial nerve segments (including cisternal, canalicular and some parts of the intra-temporal segment) are identifiable using magnetic resonance imaging (MRI) [5, 6].

After exiting stylo-mastoid foramen, the facial nerve courses ventrolaterally into retro-mandibular fossa, lateral to external carotid artery and retromandibular vein. The main trunk of the nerve divides into cervicofacial (CF) and temporofacial (TF) divisions. Then these two divisions branch off with different patterns to form five terminal branches [7]. Figure 1 shows...
The current study aimed to evaluate and choose proper 1.5 T cranial facial nerve imaging with more available 1.5 T MRI. There has been no consensus on optimal imaging methods for extracranial facial nerve segments, especially using MRI. As a result, the correlation of parotid lesions for extracranial segments of the facial nerve, especially using MRI, and Intra-operative facial nerve monitoring using MRI [11].

Patients and Methods

The study included 19 patients with parotid tumours, referred to our centre between March 2021 to December 2022 for pre-operative parotid imaging. The inclusion criterion was: All parotid surgery candidates referred to our centre for pre-operative imaging who did not meet the exclusion criteria. Exclusion criteria were: pregnant patients, patients under 18, patients with any contra-indication for MRI (including MRI incompatible implants, patients with impaired renal function (defined by glomerular filtration rate (GFR) below 60, and patients with claustrophobia). Written informed consent was obtained from all participants.

MRI using a head-neck coil was performed using Philips® Ingenia® (© Koninklijke Philips N.V, USA) 1.5 T. After testing several protocols (including gradient-echo and spin-echo sequences) in previous studies and imaging sessions, we finalized five pre-operative parotid and facial nerve imaging sequences in one session. These sequences included spin-echo three-dimensional T1-weighted and T2-weighted sequences, Two-dimensional T1-weighted, T2-weighted and contrast-enhanced fat-saturated T1-weighted (Parameters are summarized in Table 2).

Image analysis was performed using MARCO® Picture Archiving and Communicating System (PACS) diVision® and Radiant® DICOM® viewer by three independent radiologists with at least five years of practice in head and neck imaging. The extracranial facial nerve was divided into three segments: 1- Main trunk. 2-Primary branches including Cervicofacial (CF) and Temporofacial (TF) divisions. 3-Secondary or terminal branches. The visibility of each segment was assessed on both normal and tumoral sides. Each segment was recorded as visible only if the entire length of that segment was identifiable in sequential images. Otherwise, it was recorded as non-visible. If a segment was not recognizable due to a tumoral lesion, it was recorded as non-visible. Data were analyzed using IBM® SPSS® statistics (version 26.0).

Results

Results of the visibility of each segment of the extracranial facial nerve using each sequence are summarized in Table 1. It is important to note that the tumoral lesions were extended to the stylomastoid foramen in two patients. Therefore, the main trunk of the facial nerve on the tumoral side was not identifiable in any of the sequences.

Figures 2–8 and videos 1 to 3 show visualization of the extracranial facial nerve and its branches in different sequences of our protocol.

We used a paired-sample t-test with a 95% confidence interval to determine the significance of differences between each sequence. In summary, there was no significant difference between 3D T1-weighted and 3D T2-weighted sequences in visualizing all three segments of the nerves, either on normal or tumoral sides. For segment 1 of the nerve on the tumoral side, 3D sequences were significantly more reliable in facial nerve identification than normal T1-weighted and T2-weighted sequences (P-value = 0.005), while this difference was not significant on the normal side (P-value = 0.163). 3D sequences were significantly more reliable in identifying facial nerve segments in all other segments (P-value <0.05).
Inter-observer agreement between reporters was 97%, and the differences were exclusively in identifying the terminal branches, especially on the tumoral side.

Discussion

Some studies have focused on imaging extracranial segments of the facial nerve using different MRI protocols, some of which are summarized and discussed below.

Dailiana et al. studied 3D Fourier transform (3D-FT), gradient-recalled acquisition in steady state (GRASS) and spoiled GRASS sequences with 1.5 T MRI in the extracranial segment of facial nerve imaging in 18 healthy subjects. They reported that the facial nerve was visible as a low-signal structure, emerging from stylomastoid foramen and coursing in a curvilinear path which was not a continuation of vascular structures. The authors reported that the most proximal segment of the extracranial facial nerve (to the level of the retromandibular vein) was visible in 72% of the cases. At the same time, terminal branches were visible in some cases [12]. We briefly evaluated GRASS sequence before finalization of our protocol and found that despite the visibility of proximal branches, this sequence was not ideal for identifying terminal branches. In 3D T1-weighted and 3D T2-weighted sequences, the extracranial facial nerve was identifiable as a low-signal structure exiting from stylomastoid foramen, branching into two main divisions (CF and TF) and then forming terminal branches. However, not only the main trunk and proximal divisions (higher visibility rate compared to the study mentioned above) but also the terminal branches were identifiable in the majority of the cases in sequential images. Facial nerve branches were identifiable from vascular structures and the parotid duct based on different courses and branching patterns.

In another study on nine healthy individuals and one patient, McGhee et al. tested T1-weighted gradient echo (GRE) in 1.5 T for facial nerve imaging and found that Gadolinium contrast does not benefit visualization of extracranial facial [10]. Our study showed similar results in T1-weighted spin echo images. Having said that, since baseline post-contrast studies were necessary to define the entity of parotid lesions, we included post-contrast images in our protocol. However, this protocol is time-consuming (30 min for five sequences in optimal situations). Therefore, we recommend performing routine pre-op MRI (including post-contrast images) and facial nerve imaging in two separate sessions to reduce imaging time and patients’ discomfort.

Takahashi et al. studied high-resolution T1-weighted spin-echo, T2-weighted fast spin-echo and GRASS sequences of 1.5 T MRI with three circular surface coils for imaging extracranial facial nerve in 13 patients with benign parotid lesions. The authors found that the main trunk of the facial nerve was visible in all of their study subjects, while CF and TF branches were visible in 84.1% and 53.8% in GRASS sequence, respectively [8]. Our study included a
larger sample (19 patients on the tumoral and normal side, 38 facial nerves in total). There was no significant difference between the visibility of CF and TF divisions in any of the evaluated sequences. CF and TF branches were identifiable in 100% of studied subjects on the normal side. However, on the tumoral side, CF and TF branches were not visible in only two patients whose tumoral lesions had extended to the stylomastoid foramen. Terminal branches, both on the normal and tumoral side, were also visible in most patients.

Chu et al. report that using a surface coil in 3 T MRI with 3D PSIF-DWI (Time reversed FISP/Fast Imaging with Steady-state free Precession-Diffusion Weighted Imaging) sequences, they were able to identify CF and TF branches in all and secondary branches in 83.8% of their 21 patients. In comparison, with the head coil, only 51.4% of the secondary branches were identifiable [9]. In later studies, Guenette et al. could not reach similar findings using PSIF-DWI sequences [11]. Our study was performed with a head-neck coil in 1.5 T MRI, the more available MRI technology. We found that in both 3D T1-weighted and T2-weighted sequences, secondary branches of the facial nerve were identifiable in 89.5% on the normal side. On the tumoral side, respective numbers decreased to 63.2% in 3D T1-weighted and 68.4% in 3D-T2-weighted sequences. We believe that using 3 T MRI could improve the accuracy of our protocol. However, the preferability of surface coil should be assessed in further studies.

In another study of 18 healthy subjects, Qin et al. used 3D-DESS-WE (Double Echo Steady State with Water Excitation) in 1.5 T MRI to identify extracranial facial nerve. They found that, like the parotid duct and retromandibular vein, the facial nerve was visible as a high-signal structure in

Fig. 2. Axial 3D-T1 (A) and 3D-T2 (B) images at the level of the mastoid process show cervicofacial division (arrows) as a low signal structure anterior to a retromandibular vein

Fig. 3. Comparison between identification of facial nerve primary divisions in 3D-T1 (A) and 2-D T1 (B) sequences. Arrow in A shows the right facial nerve’s primary division (temporofacial). The mentioned division is not identifiable at the same level in the T1 sequence (B)
In our study, the facial nerve was visible as a low-signal structure in an intermediate to high-signal parotid background. The facial nerve and its branches were distinguishable from vascular structures and the parotid duct based on their different course and branching pattern in sequential images.

In a study on six healthy subjects by two observers, using 3 T MRI, Van der Cruyssen et al. introduced a novel black-blood 3D STIR TSE (Short Tau Inversion Recovery Turbo Spin Echo) sequence for extracranial nerve imaging (3D CRANI). The authors were able to assess facial nerve trajectory starting in the temporal bone and stopping at the anterior border of the parotid. Although the authors claim that interobserver agreement in the visualization of the facial nerve has been lower than other nerves (such as inferior alveolar and lingual branches of V3), they still consider it favourable [14]. In comparison, our study used a lower field unit (1.5 T) but included a larger sample. In addition, not only were we able to visualize intra-parotid branches of the facial nerve with a good inter-observer agreement, the definition of the facial nerve and its branches were more detailed in our study.

In another review article, Van der Cruyssen and colleagues reviewed different state-of-art MRN techniques for extracranial nerves, including facial nerves. The authors have mentioned using 3D CRANI, 3D PSIF and 3D-DESS-WE sequences in facial nerve mapping studied by their team and in the published literature [15]. As mentioned in this review article, MRN techniques mostly focus on 3-D visualization of the nerve and its branches in both normal

**Fig. 4.** Axial 3D-T1 (A) and 3D-T2 (B) sequences show the abutment of a terminal branch of the facial nerve (arrows) by a tumoral lesion in the left parotid gland

**Fig. 5.** Axial 3D-T1 (A) shows the proximity of the left parotid’s tumoral lesion to the facial nerve’s main trunk just proximal to its bifurcation (arrow). This correlation could not be appreciated in the T1 sequence in the same level (B)
conditions and nerve pathologies (which increase nerve calibre and signal intensities), and they do not necessarily address nerve relation to adjacent pathologies, such as tumours. Our study aimed to optimize a cost and time-efficient protocol in the pre-operative mapping of the facial nerve and its correlation to parotid tumours. State-of-art techniques and high-power-field MRI units are invaluable in MRN when available. However, in many cases, as in our country, these units are not widely available. There are only a few 3-T MRI units in the major cities in our country, and to the best of our knowledge, they are not referral centres.

Guenette et al. studied facial nerve imaging on 16 healthy individuals (32 facial nerves) and four patients (4 facial nerves), using a head and neck coil with Constructive Interference Steady State (CISS) sequence in 3 T MRI. Authors have identified CF and TF branches in all of their patients. In addition, the correlation of parotid tumours with facial nerve branches has been identifiable in all of their four patients. Guenette et al. report that using mere surface coil and manual post-processing is insufficient in mentioned imaging [11]. We tested Balanced Fast-Field Echo (BFFE), the equivalent of CISS sequence in Philips® Ingenia® 1.5 T MRI machine several times for facial nerve imaging before our current study. In our experience, unlike the cisternal segment of the facial nerve, extracranial segments (especially primary and terminal branches) could not be consistently identified in CISS (or BFFE) sequence in 1.5 T MRI, mainly due to decreased signal-to-noise ratio (Fig. 4).

In a recent article, Chhabra et al. discussed the different state-of-art neurography techniques in imaging craniospinal nerves below the skull base. The authors have stated that optimal MR neurography requires a multichannel head coil.
and could be performed within 6–7 min on 3 T units and almost double the time when using lower-field strength units (such as 1.5 T). In their paper, the authors have cited the works of Qin et al. and Chu et al. (discussed in previous paragraphs) in imaging techniques of extracranial facial nerve imaging [16]. Extracranial facial nerve and its branches were identifiable on both tumoral and normal sides in most of our patients using 3D T1-weighted and T2-weighted sequences with a head-neck coil in 1.5 T MRI. Therefore, our results are contradictory to Guenette’s report. This finding could be due to the use of 3 T MRI in their study. We tried to define the most efficient protocol with the most widely used technology (1.5 T and head-neck coil) and believe our final results were favourable. 3D T1-weighted or 3D T2-weighted sequences can be used as a mapping protocol with reasonable imaging time and cost in parotid surgery candidates. Although we did not introduce any new protocols in our study, we improved time, cost-efficiency, and availability by omitting unnecessary sequences and limiting the study to a handful of sequences with maximum relevant data.

One major limitation of our study was prolonged imaging time, sometimes leading to patients’ discomfort. Since the current study was a part of baseline pre-op workups, all five sequences were obtained in one imaging session. As a result, the imaging process was quite time-consuming (30 min in optimal situations). To solve this problem, we suggest obtaining routine MRI sequences (including T1-weighted, T2-weighted and with contrast images) in one session and in surgery candidates, MRI mapping using our protocol to be scheduled in a different session. Since there was no significant difference between 3D T1-weighted and T2-weighted images, only one of these sequences could be obtained based on radiologists’ and surgeons’ preferences. In this way, mapping time could be limited to approximately 7–10 min.

Conclusions

In conclusion, we believe that when 3 T MRI and state-of-art MRN techniques are not available (as in the case of the majority of imaging centres in our country), using the protocol for 1.5 T MRI explained in this study could provide surgeons with beneficial pre-op information regarding the location of the facial nerve and its correlation with tumoral...
lesions. This protocol could be further adjusted for different MRI manufacturers for improved results. In our future studies, we would evaluate the correlation of pre-op facial nerve mapping with intraoperative findings and post-op results and how this imaging method could benefit surgeons and patients.

Ethical statement: Our work was approved by the local Ethical Committee, approval number: IR.IUMS.FMD.REC.1400.185.


Funding sources: This study was partially funded by ENT Foundation of Iran University of Medical Sciences.

Conflict of interests: The authors have no conflict of interest to disclose.

Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1556/1647.2023.00121.

REFERENCES


