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Pre-operative assessment of facial recess width in paediatric cochlear implant recipients: a radiological study

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Main Article

Dr L Wang takes responsibility for the integrity of the content of the paper

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Abstract

Background. The location of the vertical segment of the facial nerve varies greatly among patients undergoing otological surgery. Its position relative to the incus determines facial recess width, which has implications for ease of cochlear implantation.
Objective. To investigate the variation in facial nerve depth, relative to the incus, on pre-operative computed tomography in patients undergoing cochlear implantation.
Methods. A retrospective cohort study was conducted of paediatric patients undergoing cochlear implantation at a tertiary referral centre. Distance between the incus short process and facial nerve, in the transverse (medial-lateral) dimension, was measured at six imaging slices, ranging from 1.25 to 7.25 mm below the tip of the incus short process.
Results. Facial nerve depth relative to the incus short process demonstrated significant variability. Among all subjects and at all measurements taken inferior to the incus, the mean dimension between the facial nerve and the incus short process was 1.71 mm.
Conclusion. This paper presents a rapid, repeatable technique to assess the depth of the facial nerve vertical segment on pre-operative computed tomography, as measured relative to the tip of the incus short process. This allows the surgeon to anticipate facial recess width and round window access during cochlear implantation.

Introduction

The facial nerve is of utmost concern in otological surgery. Its relatively deep anatomical position, and the inherent variability in its course and adjacent mastoid pneumatisation, predispose it to iatrogenic injury. Intra-operative injury can result from a combination of abnormal facial nerve anatomy combined with a lack of awareness of the facial nerve's relation to adjacent structures.[1]

Previous work has suggested that the facial nerve is most vulnerable during mastoidectomy, but any ear surgery, including tympanoplasty and canalplasty, can place the facial nerve at risk for iatrogenic injury.[1] In mastoidectomy, one of the factors determining the risk of facial nerve injury is the degree of temporal bone pneumatisation, for which various grading schemes have been proposed.[2] More pneumatised temporal bones generally demonstrate greater distances between the facial nerve and other temporal bone structures, including the sigmoid sinus and the spine of Henle.[3]

The facial recess is defined as the triangular area bounded by the facial nerve, the chorda tympani and the fossa incudis, and allows posterior access to the middle ear. The facial recess approach, or posterior tympanotomy, is the approach of choice for standard cochlear implantation.[4] The short process of the incus is an invaluable landmark for intra-operative identification of the facial nerve, and 'points' to the facial recess and the vertical segment of the facial nerve.[5] However, the depth of the facial nerve relative to the fossa incudis remains variable. This variability carries implications for the width of the facial recess and, accordingly, ease of access to the round window during cochlear implantation.

Previous work has analysed the width of the facial recess on computed tomography (CT) imaging by measuring the direct distance from the vertical segment of the facial nerve to the chorda tympani. In one such study, the mean width of the facial recess at the round window was noted to be 2.65 mm.[6] One limitation to this approach is that the chorda tympani nerve can be indistinct on CT imaging, particularly in the middle ear, and even in the bony segment between the facial nerve canal and the iter chordae posterius. In our investigation, we chose the tip of the short process of the incus, which is reliably present in a vast majority of cochlear implantation recipients, as a landmark for measurement.

This study characterised the transverse (i.e. medial-lateral) dimension of the vertical segment of the facial nerve relative to the tip of the short process of the incus in paediatric patients undergoing cochlear implantation, as a pre-operative estimate of facial recess width.

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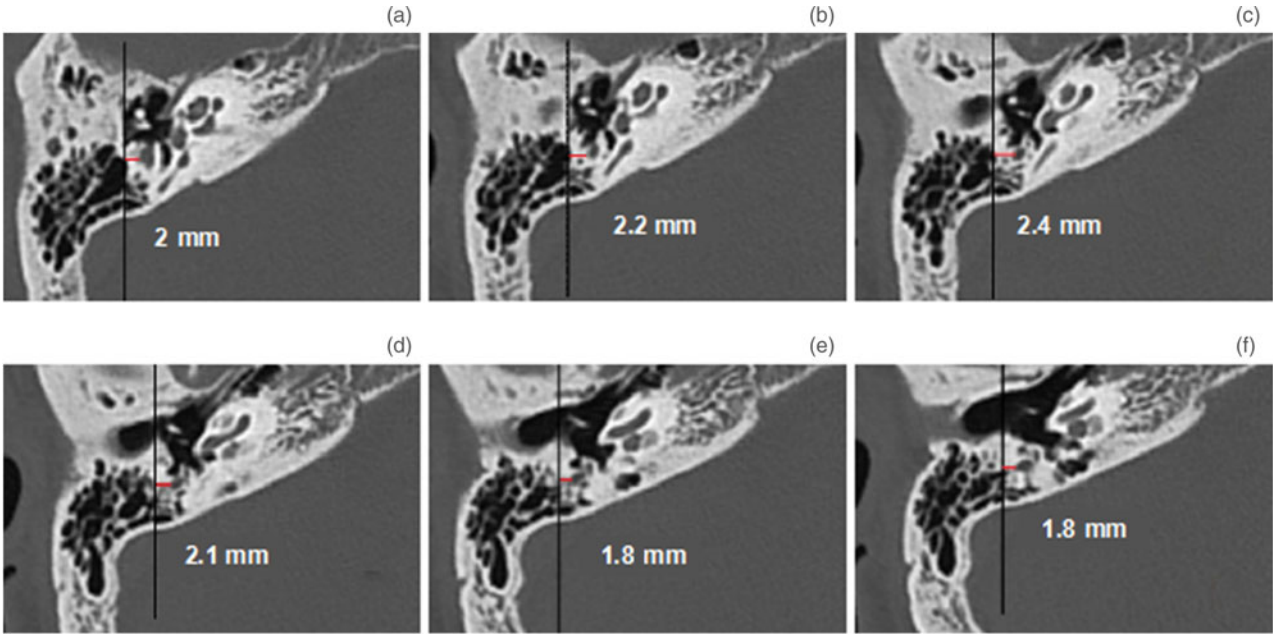

Fig. 1. Computed tomography slices, axial views, of a patient who underwent right-sided cochlear implantation. Parts (a)–(f) represent increasing distances inferior to the short process of the incus, ranging from 1.25 mm in (a) to 7.5 mm in (f). The vertical line in each slice marks the reference line through the sagittal plane of the tip of the short process of the incus. The distance from the facial nerve to this line was measured (red line).

Materials and methods

Ethical considerations

This study received institutional review board approval at the sponsoring institution (institutional review board number: L-2017-019).

Subjects

Thirty paediatric patients with bilateral profound hearing loss undergoing unilateral cochlear implantation between January and December 2014 were included in the study (18 male, 12 female). All patients underwent pre-operative CT imaging, and all patients were free of external-, middle- and inner-ear malformations. The mean age at the time of implantation was 2.5 years (range, 1.0–5.5 years). Right-sided implantation was performed in 21 cases and left-sided implantation was performed in 9 cases.

Surgical details

Cochlear implantation was performed by a single senior neurotological surgeon. A standard mastoid/facial recess approach was used. In all cases, a complete mastoidectomy was performed with a high-speed drill, and the incus was identified. The vertical segment of the facial nerve was then identified with high-speed drilling under continuous irrigation, leaving a thin shelf of bone over the identified facial nerve. If not previously identified, the chorda tympani nerve was then identified, and the facial recess opened. Cochlear implantation was then performed.

Radiological analysis

The pre-operative CT scans of the study patients were retrospectively reviewed. Axial sections of CT imaging with a slice thickness of 1.25 mm taken parallel to the orbitomeatal line were examined. The tip of the short process of the incus was identified, and a sagittal reference line was drawn through the tip of the short process of the incus. The distance between the lateral aspect of the vertical segment of the facial nerve and this reference line was then measured at 1, 2, 3, 4, 5 and 6 slices below the short tip of the incus, corresponding to 1.25, 2.5, 3.75, 5, 6.25 and 7.5 mm inferior to the tip of the short process of the incus (Figures 1 and 2).

Statistical analysis

Statistical analysis was performed with SPSS software (IBM, Armonk, New York, USA).

Results

Cochlear implantation was accomplished in all subjects via a facial recess approach. No immediate or late operative complications were noted in the study patients.

Pre-operative computed tomography scans were reviewed for all patients. The orthogonality of patient orientation, defined as the presence of an uninterrupted slice through the entirety of the horizontal semi-circular canal and vestibule on the operated side, was confirmed for each patient. The incus and its short process could be identified in all patients.

A reference plane, or landmark, was drawn on the axial CT images, focusing on the implanted ear. This reference plane was a sagittal plane drawn through the tip of the short process of the incus, and this was propagated through all images in the same series. Measurements of the transverse (i.e. medial-lateral) dimension between the landmark and the lateral surface of the vertical segment of the facial nerve were taken at six slices, inferior to the tip of the short process of the incus – namely, at 1.25, 2.5, 3.75, 5, 6.25 and 7.5 mm.

Table 1 shows the distance between the tip of the short process of the incus and the lateral surface of the vertical segment of the facial nerve, as measured on pre-operative CT scans. Overall, the mean distance between the landmark and the facial nerve was 1.71 mm across all patients and all slices

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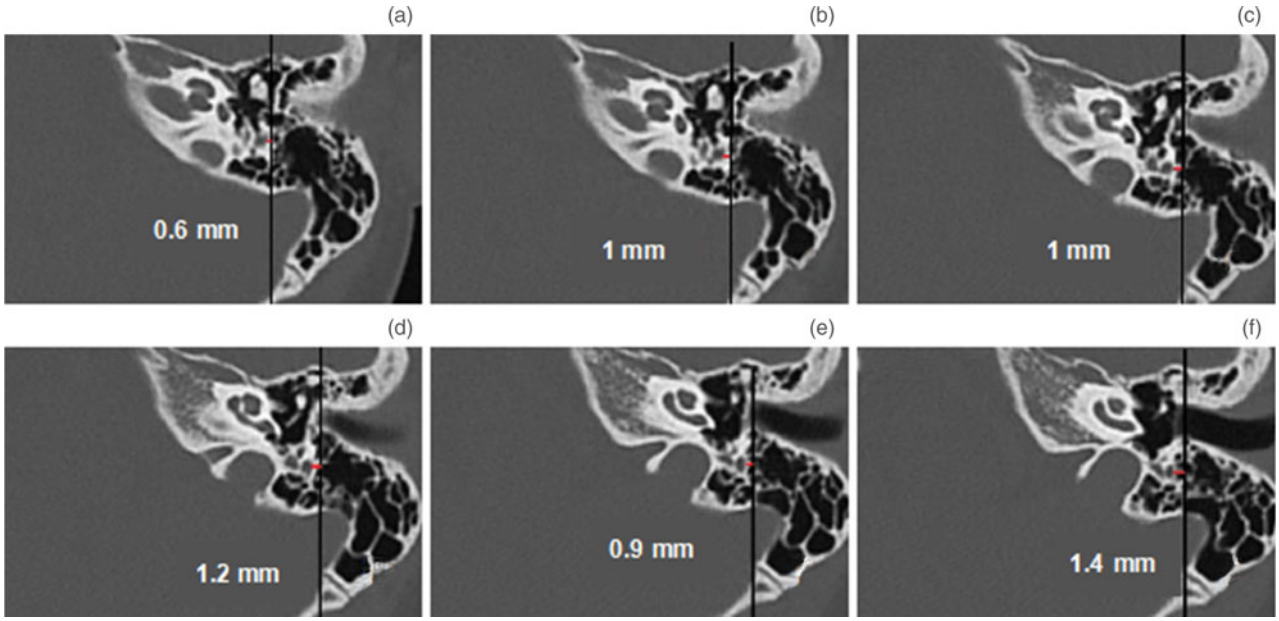

Fig. 2. Computed tomography slices, axial views, of a patient who underwent left-sided cochlear implantation. Parts (a)–(f) represent increasing distances inferior to the short process of the incus, ranging from 1.25 mm in (a) to 7.5 mm in (f). The vertical line in each slice marks the reference line through the sagittal plane of the tip of the short process of the incus. The distance from the facial nerve to this line was measured (red line).

Table 1. Transverse (i.e. medial-lateral) distance between landmark (tip of incus short process) and facial nerve

Parameter	Vertical distance inferior to tip of incus short process (mm)					
	1.25	2.5	3.75	5.0	6.25	7.5
Minimum (mm)	0.5	0.6	0.7	1	1.1	1.3
Maximum	2.2	2.5	2.5	2.7	2.8	2.4
Mean	1.45	1.56	1.64	1.82	1.92	1.85
Standard deviation	0.57	0.64	0.67	0.67	0.67	0.42

Measurements were taken at six computed tomography slices, each 1.25 mm thick, inferior to the tip of the short process of the incus.

inferior to the incus short process. The mean distance between the landmark and the facial nerve ranged from 1.45 mm at the first slice inferior to the incus to 1.92 mm at the fifth slice inferior to the incus; the distance then decreased at the sixth slice. There was wide variation among subjects: the minimum distance between the landmark and the facial nerve was 0.5 mm, and the maximum distance observed was 2.8 mm.

Discussion

The position of the vertical segment of the facial nerve has significant implications for cochlear implantation, including issues relating to ease of access through the facial recess and avoidance of iatrogenic injury. Access to the round window via the facial recess is improved when the facial nerve has a relatively deeper course along its vertical segment, effectively widening the facial recess.

The vertical segment of the facial nerve is often identified intentionally in the intra-operative setting to delineate the facial recess anatomy. One of the markers for the vertical segment of the facial nerve and the facial recess is the short process of the incus, although other methods of facial nerve identification have been described and are commonly used.

Previous research has focused on measuring the width of the facial recess, defined as the distance from the chorda tympani to the vertical segment of the facial nerve, on CT imaging.[6] In our experience, this is an imperfect technique, largely because the chorda tympani is not well seen in many patients. Specifically, the chorda tympani can be extremely difficult to identify at its entry point into the middle ear (the iter chordae posterius); even in its bony segment between the facial nerve and the iter chordae posterius, its calibre is often too small to be identified positively. We instead chose a relatively reliable landmark, the tip of the short process of the incus, as a reference. We performed measurements of the transverse (medial-lateral) dimension between this landmark and the vertical segment of the facial nerve.

In our study, we chose to take this measurement up to six CT slices, or 7.5 mm, inferior to the short process of the incus, in a cohort of paediatric patients undergoing cochlear implantation. This range was chosen because the length, or craniocaudal dimension, of the facial recess in a related study was estimated at approximately 7.8 mm.[7] Measurements inferior to this are therefore of less clinical relevance for posterior tympanotomy.

We found significant variation in this measurement among subjects (range, 0.5–2.8 mm). The mean distance between the landmark and the facial nerve was 1.71 mm. As the incus short process nearly bisects the facial recess, this measurement can be loosely interpreted as half the width of the facial recess. This is in line with prior studies, which have variously reported a facial recess width of 2.7–4.0 mm in adult subjects.[6,8–10] In perhaps the most rigorous investigation of its type, facial recess dimensions were compared between paediatric and adult patients; no significant difference was encountered between the two populations.[11] Accordingly, it may be possible to generalise our results, obtained in children, to the adult population.

Study limitations and future directions

One limitation of this study is the CT slice thickness of 1.25 mm. At the time of subject recruitment, this slice thickness

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was the standard available for temporal bone CT imaging at our tertiary referral medical centre. In future investigations, measurements will also focus on the width of the facial recess adjacent to the round window, as this area is of greatest clinical relevance for cochlear implantation. Further research will also include adult cochlear implantation recipients. Correlation of these radiological findings with ease of implantation will allow us to extrapolate the observed measurements to the surgical setting, and this will be an area of further research. Finally, future investigations will focus on the degree of pneumatisation and its correlation with facial recess measurements.

- Estimation of facial recess width on pre-operative computed tomography (CT) allows anticipation of round window access from the facial recess during cochlear implantation
- Facial recess dimensions can only be directly measured in a subset of patients, as the chorda tympani is often indistinct on CT
- Utilising the tip of the incus short process as a landmark, the distance to the facial nerve vertical segment can be rapidly measured
- This measurement, which approximates half of the facial recess width, is reliable and repeatable

Conclusion

This paper presents a rapid, repeatable technique to assess the depth of the facial nerve vertical segment on pre-operative CT imaging, as measured relative to the tip of the incus short process. The average measurement was 1.71 mm; because the incus short process approximately bisects the facial recess, this can be viewed as approximating half the facial recess width. This measurement is arguably more reliable than attempting to locate the chorda tympani on CT imaging, and allows the surgeon to anticipate access to the round window via the facial recess during cochlear implantation.

Competing interests. None declared

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