The role of preoperative computerized tomography in a safe posterior tympanotomy for cochlear implant surgery

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A posterior tympanotomy is a technique performed to access round window area to insert cochlear implant electrode into round window membrane or through cochleostomy. In this study, we aimed to classify and evaluate the anatomical relationships between the facial nerve (FN) (vertical segment), chorda tympani nerve, and facial recess (FR) pneumatization in an axial temporal bone computerized tomography (CT) to be safe when performing a posterior tympanotomy. We performed a retrospective analytic study of temporal bone CT scans. A cohort of 51 patients who underwent cochlear implantation with classical mastoidectomy with posterior tympanotomy were included. All patients had preoperative diagnostic CT of the temporal bone from January 2014 to November 2015. Anatomical correlations were classified according to several parameters including protrusion of the FN into the antrum, FR pneumatization, and status of the facial canal. Anatomical relationships between the vertical segment and posterior tympanotomy were classified into three types: type 1, the FN has no protrusion with a regular facial canal with pneumatized FR; type 2, the FN has protrusion into the antrum with a regular facial canal and/or poorly pneumatized FR; and type 3, the FN has sclerotic mastoid with no FR pneumatization. These results enable preoperative evaluation of the FN's status and difficulty while performing posterior tympanotomy, providing basic knowledge to prevent injury of the FN while performing a posterior tympanotomy.

Keywords:
cochlear implant, computed tomography, facial nerve, posterior tympanotomy

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Introduction

A posterior tympanotomy is a technique performed to access round window area to insert cochlear implant (CI) electrode into round window membrane or through cochleostomy, while preserving the posterior external auditory canal (EAC) wall. Its further clinical applications are exposure of the second genu, ventilation to the mastoid antrum, and exposure of the round window niche for CI. This technique was first described by Jansen in 1958 and is achieved by dissecting the bony triangle bordered medially by the fallopian canal, externally by the chorda tympani nerve, and superiorly by the fossa incudes [1]. CI is typically performed though mastoidectomy and posterior tympanotomy approach. The electrode array is inserted through the round window or a cochleostomy. The surgical procedure can be modified if necessary to obtain adequate surgical exposure. Preoperative high-resolution computerized tomography (CT) of the temporal bone demonstrates the anatomical features and can predict the difficulty of the surgical approach [2].

The facial recess (FR) is defined as the mastoid air cells between the chorda tympani nerve and the vertical segment of the facial nerve (FN). If the space between the EAC and the FN is more than 2–3 mm with adequate air cells, the width of the FR can be considered normal. If there is sufficient width and the round window is located normally, the FR typically provides adequate exposure to the round window niche. CI surgery is difficult to perform in patients with a narrow and a cellular FR. [3].

FN injury while performing mastoidectomy, especially a posterior tympanotomy, may happen and may be the most stressful complication for the otological surgeons [4]. While performing a posterior tympanotomy, inspecting the vertical segment of the FN is very important to prevent FN injury. However, this requires surgical skill and experience and, moreover, the vertical segments may have an anomalous course or a variable situation within the mastoid antrum. Therefore, it is necessary to preoperatively estimate both the FN's status and the anatomical relationships between vertical segment of FN and the antrum. Several radiological studies are available to assess the

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FN's anatomic status, but they cannot reveal the anatomical relationships between the vertical segment and FR [5–7].

In this study, we aimed to classify the relationships between the vertical segment of the FN, the antrum, and FR in axial temporal bone (CT). We hope that this study will provide basic knowledge and will help perform a safe posterior tympanotomy for CI.

Materials and methods

Axial CT scans (high-resolution) of the temporal bones, taken from January 2014 to November 2015, were examined. CT scans of 51 patients who underwent mastoidectomy and posterior tympanotomy for CI were evaluated. Patients with revision operation or history of preoperative facial palsy or other approaches for CI were excluded because the anatomy of their FN and FR air cells may be distorted. The study included 21 male and 30 female patients. The patients' average age was 7.3 years (range: 2–52 years). In all, 11 patients showed radiological findings of bilateral otitis media with effusion (OME). CT scans of 40 individuals with normal temporal bone CT were obtained.

The temporal bone CT was taken with the parameters of 140 kV, 250 mAs, and a 0.75 mm section (MX 8000 IDT; Philips, The Netherlands). Each side of the CT scan was analyzed separately. All scans were done in El-Rhama Scan Centre. All study cases were prepared for CI in local insurance system. We compared radiological findings of OME with normal temporal bones, which were performed by an experienced specialist. The axial CT scan, which showed the most visible image of the short limb of posterior semicircular canal, was identified. With this axial cut, the next superior and inferior cuts were evaluated for the relationships between the vertical segment and the mastoid antrum.

Evaluation of the anatomical relationships was performed according to several parameters: protrusion of the FN into the mastoid antrum, status of the facial canal, new bone formation over the facial canal, and the presence air cells in FR. Protrusion of the FN was defined as a projection of the facial canal based on the bottom of the mastoid antrum from the surgeon's view (patient's head rotated 30° away from the observer). The status of the facial canal was evaluated by surrounding thickness of the cortical bone of the vertical segment. Ossification of FR air cells around the vertical canal in FR was defined as a new bone formation over the facial canal. All cases was done with collaboraton with insurance medical institute with approval of local ethical committe. A written consent from the patients, in keeping with the Declaration of Helsinki's mandate.

A χ^2-test was used to statistically analyze the results using SPSS 10.0 (SPSS Inc., Chicago, Illinois, USA). P less than 0.05 was considered statistically significant.

Results

Anatomical relationships between the vertical segment and the mastoid antrum were classified into three types (Table 1): type 1, no protrusion of the FN with a regular facial canal with pneumatized FR (Fig. 1a and b); type 2, has protrusion into the antrum with a regular facial canal and little FR air cells (Fig. 2a and b); and type 3, has protrusion into the antrum with sclerotic mastoid with no FR pneumatization (Fig. 3a and b). There was no side difference in either normal or OME temporal bones. Type 1 was most common in both normal and OME temporal bones, and significantly more common in normal mastoids ($P<0.05$). In OME cases, type 1 was observed in 21 of 33 temporal bone scans (63.6%), and types 2 and 3 appeared in eight and four temporal bones scans, respectively. In normal cases, type 1 was observed in 101 of 120 temporal bone scans (84.2%), and types 2 and 3 were seen in 15 and four temporal bone scans, respectively. Temporal bones that might have a FN vulnerable to accidental injury (types 2 and 3) were seen in 12 (36.5%) sides in OME and 19 (15.8%) sides in normal temporal bones. Type 3 was significantly more common in OME (Table 2).

Discussion

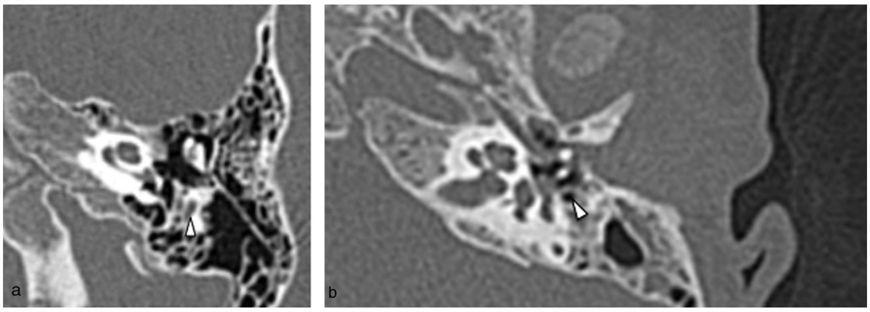
The posterior tympanotomy originated from the removal of the diseased mucosa of the posterior mesotympanum, while preserving the posterior EAC wall and extended later on to be stander for CI surgery. To safely perform a posterior tympanotomy,

Table 1 Classification of posterior tympanotomy structure as regards facial nerve protrusion, new bone formation around the canal, and cellularity of facial recess

Types	CT finding
Type 1	No protrusion of the facial nerve with a regular facial canal with pneumatized facial recess
Type 2	FN protrusion into the antrum with a regular facial canal and/or poorly pneumatized facial recess
Type 3	FN protrusion with sclerotic mastoid with no facial recess pneumatization

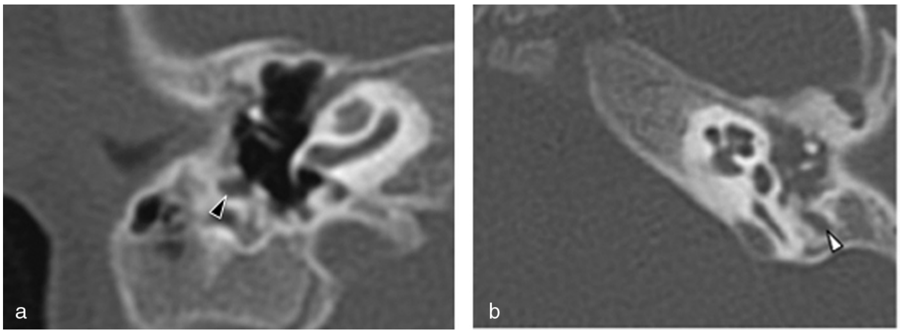
CT, computed tomography; FN, facial nerve.

Figure 1



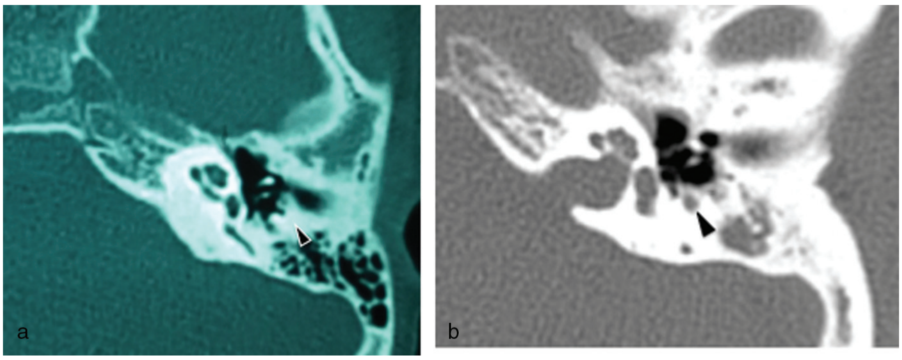
A: Indicate type 1 (no facial nerve protrusion, white arrow). B: Indicate type 1 (presence of sentinel cell, white arrow)

Figure 2



A: Indicate type 2 (normal mastoid with black arrow point to sentinel air cell). B: Indicate type 2 (mastoid with OME arrow point to sentinel air cell)

Figure 3



A: Indicate type 3 (absent of sentinel cell, black arrow). B: Indicate type 3 (sclerotic mastoid in OME with protrusion of facial nerve, black arrow)

Table 2 Anatomical classification between otitis media with effusion and normal temporal bone scans as regards facial nerve protrusion, new bone formation around the canal, and cellularity of facial recess

Diseases	OME	Normal
Type 1*	21	101
Type 2	8	15
Type 3*	4	4

OME, otitis media with effusion. *$P<0.005$.

appropriately thinning the posterior EAC wall and identifying the FN are important. The vertical segment is known as the most common site of iatrogenic injury during otological surgery, especially posterior tympanotomy, along with the tympanic segment [3]. Several surgical landmarks are used to identify the FN in the mastoid: the lateral semicircular canal, the digastric ridge, the hypotympanic air cells, and the posterior semicircular canal [8]. An imaginary line between the lateral semicircular canal and the digastric ridge may indicate the approximate course of the FN's vertical segment. However, the facial canal may display congenital bony dehiscence, variations, and anomalies in its usual course [9]. The most frequent anomaly of the facial canal's vertical segment is known as dorsal hump, which is when the vertical segment is in a more lateral position than usual [10]. In such a situation, the FN may protrude to the operator, and might be vulnerable to accidental injury if the operator neglects it. It is important to assess the FN's status preoperatively, to prevent iatrogenic FN injury. Therefore, an imaging study is indispensable. Many studies have reported the FN's radiological anatomy. These are performed mostly in the form of measuring the distances between the FN and neighboring structures, and the FN's course in the normal or pathological temporal bone [4–7].

When performing a mastoidectomy, the mastoid antrum is generally exposed first, and widens in the direction of the epitympanum and the mastoid tip. Therefore, it is necessary to survey the anatomical relationships between the vertical segment and the mastoid antrum, and it is helpful to prevent iatrogenic FN injury. The FN's vertical segment can be easily identified in an axial temporal bone CT. It is observed as a structure embedded in a compact bone different from the surrounding bone.

In this study, we intended to demonstrate the FN's status by analyzing axial temporal bone CT scans. We evaluated the anatomical relationships between the FN's vertical segment, the mastoid antrum and FR, and classified those relationships into three types. Type 1 was the most commonly found relationship, and a posterior tympanotomy was performed on it with little difficulty. Type 2 was observed in 24.2 and 12.5% of OME and normal mastoids, respectively, and surgeons should pay attention to the facial canal's focal thin facial canal or abrupt bulging into the mastoid antrum. Compared with OME mastoids, type 2 was more frequently found in normal mastoids. This finding may be due to the well-developed pneumatization of a normal mastoid.

In type 2 OME mastoids, surgeons must keep in mind that they may encounter a lack of bony covering or facial canal dehiscence when performing a posterior tympanotomy. In an anatomic study of 535 temporal bones, Baxter [11] reported that 4% of dehiscence occurred through opening into the FR, and 1% opened into the tympanic sinus or the hypotympanic cells. Type 3 was observed in OME mastoids and normal mastoids in a ratio of 12.1 and 3.3%, respectively. In this situation, identification of the FN is not easy because surgeons have to remove the thick bone overlying it. Especially in a contracted mastoid and lack of cellularity of FR, identification of the FN's vertical segment should progress from the epitympanum. Sometimes removing the incus and drilling the incudal buttress are needed to safely perform a posterior tympanotomy.

Conclusion

Anatomical relationships between the FN's vertical segment, the mastoid antrum, and FR air cells can be classified into three types according to the FN's protrusion into the antrum, the facial canal, new bone formation over it, and cellular pneumatization of FR in the temporal bone CT. These results help preoperative evaluation of the FN status and provide basic knowledge to prevent FN injury when performing a safe posterior tympanotomy.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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