The Anatomical Relationship Between the Eustachian Tube and Petrous Internal Carotid Artery

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**Objectives/Hypothesis:** The aim of the present study was to investigate the relationship between the eustachian tube (ET) and petrous internal carotid artery (ICA) in whole-mount human temporal bone specimens.

**Study Design:** Descriptive study.

**Methods:** Histologically prepared serial sections of 10 adult temporal bones were included in the study. Five specific landmarks were selected to evaluate relationships between the petrous segment of the ICA and the ET. The selected distances were measured using computer software (Metamorph 7.5.2.0; Molecular Devices, LLC, Sunnyvale, CA).

**Results:** The ET and the ICA get close posteriorly, and the bony part of the ET and the ICA generally share the same wall.

**Conclusions:** The junctional part of the ET may be a safe landmark to identify and protect the ICA during endoscopic endonasal surgery of the cranial base. Knowledge of the anatomical relationships of the ET and petrous part of the ICA, as well as their relationship with other surgical and radiological landmarks, would be useful to surgeons.

**Key Words:** Eustachian tube, foramen ovale, foramen spinosum, internal carotid artery.

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**INTRODUCTION**

Endoscopic endonasal surgery (EES) of the cranial base is made possible by technological advances in surgical endoscopy, instrumentation, and intraoperative navigational systems in combination with a new understanding of skull base anatomy from an endoscopic perspective. For coronal plane procedures that provide access to the middle cranial fossa and petrous apex, the anatomical relationships of the ET and petrous part of the ICA are important step. Surgical approaches are classified according to their relationship to the petrous segment of the ICA: suprapetrous and infrapetrous. The pterygoid canal with the vidian nerve and artery runs from the pterygopalatine fossa to the foramen lacerum and traverses the floor of the sphenoid sinus. This relationship between the vidian nerve and the petrous ICA is exploited during surgery to identify the genu of the ICA at the junction of the petrous and paraclival segments of the ICA. The vidian artery is not consistently present but is also a useful landmark. EES of the nasopharynx and infrapetrous approaches to the skull base often result in transgression or resection of the medial aspect of the eustachian tube (ET) in the current literature, there is limited knowledge that evaluates the relationship between the ET and petrous segment of the ICA. The aim of the present study was to investigate the relationship between the ET and petrous ICA in whole-mount human temporal bone specimens.

**MATERIALS AND METHODS**

Histologically prepared serial sections of 10 temporal bones were selected from the Sando temporal bone collection in the Department of Otolaryngology at the University of Pittsburgh School of Medicine. All specimens were obtained from normal individuals without a history of congenital disease. Ages ranged from 18 to 88 years old (mean age, 54.5 ± 25.1 years). All specimens were obtained, prepared, and stained according to the technique described by Sando et al. Serial 20 to 30 μm-thick sections were cut from the nasopharyngeal orifice to the middle ear perpendicular to the long axis of the ET. In these sections, five specific landmarks were selected to evaluate relationships between the petrous segment of the ICA and the ET: 1) foramen ovale level, 2) foramen spinosum level, 3) cartilaginous and bony ET junctional point level, 4) bone part level of the ET, and 5) parapharyngeal part level of the ICA. When both the foramen ovale and V3 of the trigeminal nerve (mandibular nerve) were identified clearly on the histological section, this histopathological section was accepted as a foramen ovale level (Fig. 1). When both foramen spinosum and arteria meningea media were identified clearly, this section was accepted as foramen spinosum level (Fig. 2). When both cartilaginous and bony parts of the ET were identified on the section, it was accepted as the junctional point level (Fig. 3). The first identified bony
part section of the ET when following from nasopharyngeal orifice to the middle ear was accepted as the bone part level (Fig. 4), and finally, when the first whole parapharyngeal part of the ICA on the histopathological section was identified, it is accepted as the parapharyngeal part level (Fig. 5).
All selected specimens were scanned at high resolution (1,200 dpi) with a flatbed scanner with transparency adapter. Calibration references were included in the initial scans. On each of five selected sections for each case, the vertical lumen length of the ET (VL), the distance between the upper part of the ET lumen and the carotid canal (UC), the bottom level of the ET lumen and the carotid canal (BC), the distance between the foramen ovale and the carotid canal (FOC), the distance between the foramen spinosum and the carotid canal (FSC), and the bone thickness between the ET and the carotid canal (BT) were measured using Metamorph 7.5.2.0 software (Molecular Devices, LLC, Sunnyvale, CA). Mean values were given as mean ± standard deviation.

RESULTS

The results of the UC, BC, FOC or FSC, BT, and VL measurements for specimens are given in Table I and Figure 6. For the foramen ovale level, the UC, BC, and FOC were 5.8 ± 1.41 mm (range, 3.65–8.57 mm), 10.15 ± 2.05 mm (range, 6.2–13.64 mm), and 5.24 ± 1.16 mm (range, 3.48–7.17 mm), respectively. For foramen spinosum level, the mean UC, BC, and FSC were measured as 3.53 ± 1.08 mm (range, 2.22–5.56 mm), 6.31 ± 2.09 mm (range, 3.39–10.9 mm), and 5.34 ± 1.44 mm (range, 2.97–8.13 mm). For junctional point level, the mean UC and BC were 1.91 ± 0.7 mm (range, 0.59–2.95 mm), and 3.18 ± 1.3 mm (range, 1.36–5.06 mm). The mean BT of specimens between the ET and the ICA at the foramen ovale level and foramen spinosum level were 2.7 ± 1.2 mm (range, 1.34–3.42 mm) and 1.72 ± 0.7 mm (range, 0.95–2.77 mm), respectively.

DISCUSSION

The anatomy of the skull base in the coronal plane of the ICA is very complex, with close proximity of
important structures such as the ICA, sixth cranial nerve, trigeminal nerve, vidian nerve, middle meningeal artery, and greater petrosal nerve.\textsuperscript{10,12} Numerous anatomical studies employing cadaveric dissections and radiological examinations of the petrous bone have described the relationship between these critical structures. Endoscopic endonasal approaches to the petrous apex and middle cranial fossa require recognition of these anatomical relationships, especially the relationships of the ICA.\textsuperscript{1} The most important landmarks for localization of the petrous ICA are the vidian nerve, V2, V3, foramen spinosum, and the ET.\textsuperscript{1–3,12–15}

The Sando temporal bone collection is a unique resource that offers an opportunity to explore these anatomical relationships further. In the present study, normal whole-mount temporal bone specimens were used to evaluate anatomical relationships between the ICA and the ET, foramen ovale, and foramen spinosum. Therefore, all structures with surrounding soft tissues and bone can be examined in the same histological specimens without removal of tissue. In cadaveric specimens, exploration of these relationships requires extensive dissection of soft tissue and bone with the loss of anatomical information. Also, it can be difficult to obtain exact measurements of distances. In the present study, the objective analysis software was used to measure distances and minimize measurement errors. On the other hand, the process of preparing the temporal bone specimens for histopathology may introduce measurement artifact.\textsuperscript{9} In the present study, we found that the average distances between the carotid canal and foramen ovale and foramen spinosum in the adult specimens were $5.24 \pm 1.16$ mm and $5.34 \pm 1.44$ mm, respectively. Our results are in good agreement with the results of radiological and cadaveric studies (Table II). On adult three-dimensional computed tomography images, Villavicencio et al.\textsuperscript{13} reported that the average distance from the carotid artery to the foramen ovale was 3.8 mm, and the average distance from the carotid artery to the foramen ovale was 5.2 mm. Leonetti et al.\textsuperscript{16} showed that the average distance between foramen ovale and

![Fig. 6. The mean measurements in millimeters of the distance between the upper part of the eustachian tube lumen and the carotid canal (UC), the bottom level of the eustachian tube lumen and the carotid canal (BC), the distance between the foramen ovale and the carotid canal (FOC), the distance between the foramen spinosum and the carotid canal (FSC), and the bone thickness between the eustachian tube and the carotid canal (BT) at the foramen ovale level (FOI), foramen spinosum level (FSL), junctional point level (JPL), bone part level (BPL), and parapharyngeal part level (PPL). VL = vertical lumen length of the eustachian tube. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

![Fig. 7. Coronal magnetic resonance imaging sections of a 30-year-old female. One black arrow (A) shows the eustachian tube and the double black arrows (B) show foramen ovale and trigeminal nerve.]

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<th>Authors</th>
<th>ICA and Foramen Ovale, mm</th>
<th>ICA and Foramen Spinosum, mm</th>
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<tr>
<td>Villavicencio et al.\textsuperscript{13}</td>
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<td>Leonetti et al.\textsuperscript{16}</td>
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ICA = internal carotid artery.
the carotid artery was 4.6 mm, and the average distance between foramen spinosum and lateral wall of the carotid artery was 5.3 mm. Similarly, Aslan et al.\textsuperscript{14} reported that the average distances between foramen ovale and internal carotid artery, and foramen spinosum and internal carotid artery were $4.3 \pm 1.3$ mm and $5.7 \pm 1.5$, respectively, in the cadaveric dissection.

We selected foramen ovale level, foramen spinosum level, junctional point level, bone part level, and parapharyngeal part level sections to analyze the relationship of the ET and the carotid artery for each subject because these structures can be identified during preoperative radiological examination or surgery (Figs. 1–5 and Fig. 7). The BT of specimens between the ET and the carotid artery was $2.21 \pm 0.83$ mm at the foramen ovale level. It is necessary to drill almost 2.2 mm of bone thickness to reach the carotid artery at the foramen ovale level. When following the ET from the nasopharyngeal orifice to its bony part, the ET and the carotid artery get closer posteriorly and the bony part of the ET and the carotid artery generally share the same wall (Figs. 1–5). The distance between the junctional part of the ET and the carotid artery was approximately 2 mm from the upper lumen and 3 mm from the bottom lumen. To prevent injury to the carotid artery during ET dissection, the surgeon should try to identify the junction of the cartilaginous and bony ET as a landmark (Fig. 3) by following the ET lumen from the nasopharyngeal orifice to the junctional part. Beyond this point, the surgeon should be careful, because the ICA and the ET get very close and generally share the same thin bony wall.

CONCLUSION

In the adult population, the junctional part of the ET may be selected as a safe landmark to identify and protect the petrous segment of the ICA, because there is adequate bone between the ET and the petrous carotid artery for each specimen. Anatomical knowledge of the relationships of the ET and ICA, as well as their relationships with other surgical and radiological landmarks, will be useful to surgeons performing EES in the coronal plane.

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BIBLIOGRAPHY