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Original Article

A novel technique to avoid cerebrospinal fluid leaks following middle fossa approaches: Identifying a new triangle in the middle fossa

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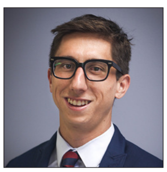

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ABSTRACT

Background: Skull-based approaches involving the middle fossa (MF) can be complicated by postoperative cerebrospinal fluid (CSF) leaks. Most of these CSF leaks are due to inadvertent entry into the eustachian tube (ET) or incomplete packing of surrounding air cells. Air cells are routinely plugged with bone wax during surgery; however, CSF leaks due to entry into the ET are often not recognized. Our objective was to define a safe zone for drilling that would avoid entry into the ET during MF approaches.

Methods: Ten cadaveric specimens were fixed in formalin and injected with latex. Twenty sides were dissected and examined under a microscope. We exposed and identified the petrous internal carotid artery (ICA), ET, and all surrounding anatomical landmarks.

Results: We identified a triangle bordered by the lateral aspect of the third division of the trigeminal nerve (V3), the lateral aspect of the petrous ICA, and an imaginary line through the middle meningeal artery connecting V3 to the petrous ICA. This triangle was then bisected at the base, creating a medial and lateral sub-triangle. In all 20 cadaveric exposures, the ET was in the lateral sub-triangle and did not extend into the medial sub-triangle.

Conclusion: Our findings demonstrate that entry into the ET while exposing the petrous ICA during MF approaches can be safely avoided by drilling in the medial sub-triangle. Drilling in the lateral sub-triangle will lead to entry into the ET, increasing the risk of a postoperative CSF leak.

Keywords: Cerebrospinal fluid leaks, Eustachian tube, Middle fossa, Skull base

INTRODUCTION

The middle fossa (MF) approach is a surgical technique that provides access to the internal auditory canal, petrous apex, internal carotid artery (ICA), cerebellopontine angle, and the trigeminal, facial, and vestibulocochlear nerves.[9,10] In some cases, the petrous ICA needs to be exposed, whether for proximal control, direct bypass, or tumor encasement. A major postoperative complication of elective neurosurgical cases is cerebrospinal fluid (CSF) leakage,

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with skull base surgeries having the highest rate at 6.2%.[4] The average rate of postoperative CSF leaks involving MF procedures ranges from 1.3% to 12.8%.[3,8,11-13]

Multiple studies have observed that CSF leaks through the eustachian tube (ET) and into the nasopharynx were more common than incisional leakage (60–96.2%).[3,4,11,12] Up to 72% of these CSF leaks were resolved with conservative treatment, while others needed 1–7 days of lumbar drainage for full resolution (20–40%).[3,4,11,12] However, 11–20% of patients with CSF rhinorrhea had to return to the operating room for surgical management.[3,11,12] CSF leaks increase the risk of secondary complications such as surgical wound infection, meningitis, delayed healing, and reoperations, which result in longer hospital stays.[3,4,7,8,13] The need to minimize postoperative CSF leaks is, therefore, crucial to improve patient outcomes.

This cadaveric study outlines a drilling technique through a safe triangle which leaves the ET intact and thus minimizes the likelihood of postoperative CSF leaks. This safe triangle is bordered by the ICA, the third branch of the trigeminal nerve (V3), and the line bisecting the middle meningeal artery (MMA) triangle at its base [Figure 1].

MATERIALS AND METHODS

Ten cadaveric specimens were fixed in formalin. Dissections were performed in adherence to regulations. Our institution does not require Institutional Review Board approval for deidentified cadaveric studies. The arterial system was injected with red latex through the cervical segment of the ICA. The venous system was injected with blue latex through the internal jugular vein at the C6 vertebral level. Twenty MF approaches were performed. Each side was dissected under a microscope to expose the petrous ICA. The ICA, V3, and MMA were identified as anatomical landmarks during dissection. Following exposure, the ET in relation to the petrous ICA, V3, and MMA was examined under a microscope.

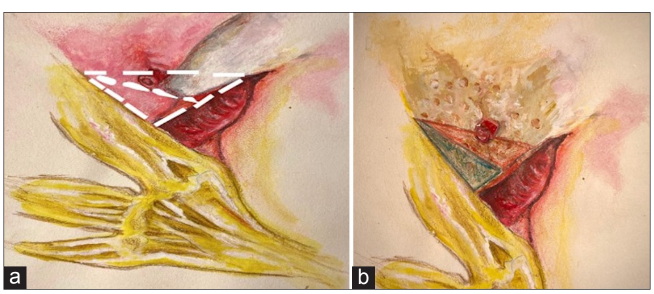

Figure 1: (a) An artist's depiction of the described triangle. The outline of the triangle after bisection (white dashed lines). (b) The triangle is divided into a lateral sub-triangle (red) and a medial sub triangle (green).

RESULTS

We identified a triangle bordered by the lateral aspect of V3, the lateral aspect of the petrous ICA, and an imaginary line connecting V3 to the petrous ICA that goes through the MMA. This triangle was then bisected at the base, resulting in a medial and lateral sub-triangle. The safe triangle is the medial sub-triangle, which is V3, ICA, and the bisecting line border. The dangerous triangle is the lateral sub-triangle, which is the MMA, ICA, and the bisecting line border. In all 20 cadaveric exposures, the ET was located in the lateral sub-triangle and not in the medial sub-triangle [Figure 2].

DISCUSSION

The MF approach is used to access pathologies affecting the internal auditory canal, petrous apex, ICA, cerebellopontine angle, and the trigeminal, facial, and vestibulocochlear nerves.[1,8,13] High complication incidence of CSF leakage is reported with traditional operative approaches to the middle cranial fossa.[4] Secondary complications from postoperative CSF leakage result in longer hospital stays (1–3 extra days),[7,8] increased reoperation rates (5% for MF approaches),[4] and increased costs (66.2% additional costs for skull base procedures).[13] In cases where horizontal petrous ICA exposure is needed, ET preservation is paramount to prevent complications. Glasscock's posterolateral triangle and the posteromedial rhomboid have been described to guide exposure of the MF.[5,6] Banerjee *et al*. note through their morphometric study the lateral to medial trajectory leaves the ET at risk. In a study of 8 MF approaches they note a small range from 0.2 to 1.9 mm lateral to the lateral wall of the ICA before putting the ET at risk.[2] The proposed triangle is in line with their study, providing a practical intraoperative tool for localization. The novel surgical landmark identified in this study aims to be

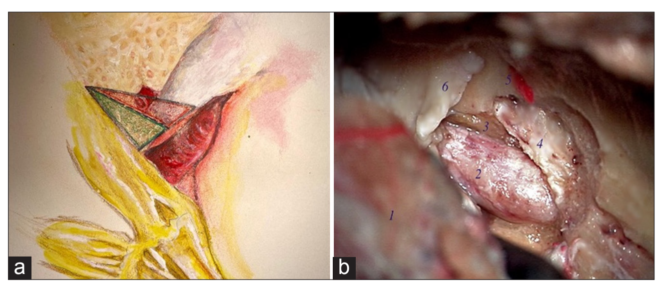

Figure 2: (a) The eustachian tube is depicted here as the white tubular structure entering the lateral sub-triangle. The medial sub-triangle is the safe zone for exposing the petrous internal carotid artery (ICA). (b) Sub-temporal-extradural view of a right-sided cadaveric specimen from the study: (1) Temporal dura, (2) petrous ICA, (3) medial sub-triangle (safe zone), (4) Eustachian tube, (5) middle meningeal artery, and (6) V3.

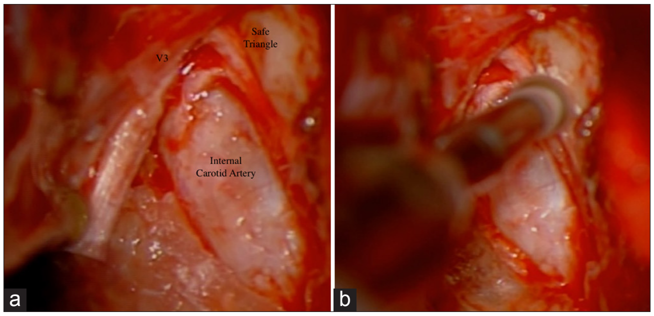

Figure 3: (a) Intraoperative view of the medial safe sub-triangle. (b) This facilitates safe drilling for exposure of the petrous internal carotid artery.

implemented to minimize postoperative CSF leakage and, therefore, improve patient outcomes.

A deep understanding of the anatomy of the MF floor is imperative for safe work in this region. Greater superficial petrosal nerve and the MMA are often the first landmarks that act as the compass to uncover the MF floor. The petrous ICA, V3, and MMA are important anatomical landmarks in the MF and can guide drilling in this area depending on the goal of the procedure [Figure 3]. We used these as major borders to help define a safe area for bony removal, which would decrease the risk of postoperative CSF leaks. We found that in all 20 sides of the specimen, the ET tube was in the defined risk triangle and did not extend into the safe triangle. Drilling in the medial sub-triangle safely avoids the ET, which consequently lowers the risk of a CSF leak.

One major limitation of this study is the sample size. There are likely anatomic variations not captured in this cohort. Further attention to this relationship can verify the safety of the medial sub-triangle.

CONCLUSION

Postoperative CSF leaks are one of the most common complications of MF approaches. Most of these CSF leaks are observed through the ET or surrounding air cells. Based on this cadaveric study, the ET can be safely avoided by drilling through our defined safe medial sub-triangle: lateral to the third branch of the trigeminal nerve (V3), ventral to the petrous segment of the ICA, and medial to our defined line bisecting the MMA triangle at its base. We anticipate that the details of the drilling technique outlined in this study will be helpful in reducing the incidence of postoperative CSF leaks following MF approaches.

Ethical approval: Our institution does not require IRB approval for deidentified cadaveric studies.

Declaration of patient consent: Patient's consent was not required as there are no patients in this study.

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