TECHNICAL NOTE

Applications of Image-Guided Navigation in the Middle Cranial Fossa: An Anatomic Study

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Abstract—Determining the location of pertinent anatomic structures (ie, the internal auditory canal [IAC]) in middle cranial fossa surgery is commonly based on indirect inferences from bony landmarks. Several methods have been proposed for identification of the IAC, each using bony landmarks coupled with geometric formulation. Identification of the IAC based on bony architecture and geometry may be severely limited when a mass lesion is present. Image-guided surgery has the advantage of rapid localization and may be helpful in navigating a complex surgical field which has been distorted by tumor. This study evaluates the feasibility and accuracy of the ISG viewing wand in determining pertinent anatomic landmarks in the middle fossa of the human cadaver. High-resolution (1 mm) computed tomography was performed on a preserved human cadaver head in which fixed fiducial markers had been placed. Subsequently, the cadaver head was registered in a simulated operative field, and middle fossa craniotomy was performed. The foramen spinosum, foramen ovale, greater superficial petrosal nerve, internal carotid artery, arcuate eminence, and IAC were identified visually, and three independent localizations of each structure were performed with the viewing wand. Accurate localizations were consistently performed within 1 mm for each anatomic landmark. Image-guided navigation is both feasible and accurate in determining intraoperative landmarks in the middle fossa. Image-guidance may enhance surgical accuracy and efficiency. Further clinical studies evaluating image-guided techniques in the middle fossa are warranted. (*Skull Base Surgery*, 6(3):187–190, 1996)

Middle fossa craniotomy is often performed as a primary or adjunctive procedure in the removal of cranial base tumors. For example, middle fossa craniotomy is a well-established approach for IAC acoustic neuromas and is also an integral part of total temporal bone resections for temporal bone malignancy. The normal anatomic landmarks used to identify the IAC, such as the arcuate eminence and the greater superficial petrosal nerve (GSPN) may be distorted significantly by space-occupying lesions. Image-guided surgical navigation has emerged as a viable technique in the identification of important landmarks in cranial base surgery.¹ Evaluation of image-guidance in a given surgical field can be effectively performed in a cadaveric model and simulated surgical theatre.

We performed an evaluation of the ISG wand to determine pertinent middle cranial fossa landmarks in a cadaver model.

MATERIALS AND METHODS

A suitable cadaver head without evidence of prior craniotomy or head trauma was obtained. Fiducial markers were placed using microscrews from the Synthes craniofacial plating system. Figure 1 shows that the fiducial markers were placed in the nasal root (1), zygomas (2), mastoids (2), and the occiput (1). After fiducial marker placement, a high-resolution (1 mm axial) CT scan was

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Figure 1. Fiducial marker placement. (The thin arrow denotes "permanent" fiducial placement with a titanium microscrew. The thick arrow indicates a skin fixated "temporary" fiducial marker.)

performed of the cadaver head. Information from the CT scan was placed into the Allegra software program and interfaced with the ISG viewing wand. Middle fossa craniotomy was then performed through a preauricular-temporal scalp incision. After the bone plate was removed, extradural dissection was performed, elevating the temporal lobe dura from the floor of the middle cranial fossa. On three occasions, the foramen spinosum, foramen ovale, arcuate eminence, GSPN, and internal carotid artery were visually identified and were then independently localized using the ISG wand. The location of the IAC was determined using four techniques previously described in the literature.²⁻⁵ The location of the canal was then determined by the ISG wand. The IAC was then surgically unroofed using an air-powered, high-speed drill. Correlations were performed between the visually determined location of pertinent anatomic landmarks and image-guided localization by the wand.

RESULTS

The cadaver model proved to be an acceptable technique for evaluating image-guided localization in the middle cranial fossa. Fiducial placement, CT scanning,

primary and secondary registration, surgical dissection, and wand localization were performed without difficulty. Three independent correlations were made using a 1-mm-diameter probe for location of the foramen spinosum, foramen ovale, arcuate eminence, GSPN, internal carotid artery, and the IAC (Fig. 2). Each of these structures was identified accurately and consistently within 1 mm. In addition, ISG-wand localization of the IAC compared favorably with previously described anatomic and geometric techniques of surgical localization.

DISCUSSION

Accurate identification of the internal auditory canal is paramount in any extensive middle cranial fossa dissection. Previously, cranial base surgeons have largely depended on specific anatomic landmarks, retrograde dissection of the GSPN to the facial nerve, or elaborate geometric formulations for IAC localization.²⁻⁵ House and Hitselberger described identification of the IAC in the middle fossa approach in the 1960s; their technique relies on identification of the middle meningeal artery at the foramen spinosum and retrograde dissection of the GSPN from that point to the facial nerve in the IAC.² In 1969, Fisch described identification of the IAC in the "meatal plane," which is located 60° anteromedial to the ampulla of the superior semicircular canal (arcuate eminence).³ Garcia-Ibanez described a further variation in the identification of the IAC by relying on an azimuth bisecting the blue line of the superior semicircular canal and the GSPN.⁴ Further variation was suggested by Catalano in 1993, in which identification of the IAC requires unroofing of the middle ear and identification of the head of the malleus in the epitympanum. Catalano proposes that the IAC is accurately defined by a line bisecting the root of the zygoma and the head of the malleus.⁵ Currently, the successful identification of the IAC through the middle cranial fossa is largely contingent on successful identification of bony landmarks and dissection (drilling out) of bone toward the IAC. Accurate and safe identification of the IAC using these methods may be confounded by pathologic processes that distort the normal anatomy and potentially contribute to higher rates of surgical morbidity.^{2,6} Image-guided navigation is emerging as a technically feasible means of accurately identifying normal and pathologic structures at the cranial base.¹ Image-guided navigation was employed in a cadaver model, simulating the surgical performance of middle fossa craniotomy. The ISG viewing wand was able to accurately and rapidly determine the location of the foramen spinosum, foramen ovale, arcuate eminence, GSPN, internal carotid artery, and the IAC and its contents within 1 mm. Because of the viewing wand's ability to provide accurate information in anatomically complex areas, it has special appeal in the middle cranial fossa. Improved anatomic knowledge afforded by image-guided navigation can po-

A

B

Figure 2. A: ISG probe placement in the foramen spinosum through a middle fossa approach. B: ISG correlative CT images of the foramen spinosum.

tentially increase accuracy and efficiency with a resultant decrease in complications, as well as operative time.

CONCLUSIONS

Evaluation of the ISG viewing wand for middle fossa landmark localization in the cadaver model estab-

lishes that this technology is both feasible and accurate. Image-guided surgery has the potential advantage of being able to rapidly and accurately identify important anatomic landmarks, even in the face of obscuring pathology. The IAC, which is a structure fundamental to middle fossa surgery, is currently located based on bony anatomic landmarks or geometric formulations. Use of the ISG wand in the cadaver model allowed predictably accu-

rate and rapid identification of the IAC in the middle fossa. Further anatomic and clinical correlative studies are needed.

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