Microsurgical anatomy around the foramen of Luschka in relation to intraoperative recording of auditory evoked potentials from the cochlear nuclei

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Three cadaveric heads were dissected to investigate the microsurgical anatomy around the foramen of Luschka. It was found possible to place a recording electrode in proximity to the cochlear nuclei by inserting it in the lateral recess of the fourth ventricle through the foramen of Luschka. In operations of the cerebellopontine angle using the retromastoid approach, access to the foramen of Luschka and the lateral recess is obtained by retracting the biventral lobe of the cerebellum in a caudal–rostral direction under a caudal–rostral/medial field of vision. The craniectomy might need to be enlarged a few millimeters in the caudal direction. A wick electrode can be inserted in the lateral recess beneath the choroid plexus in a rostromedial direction and to a depth of approximately 3 to 5 mm from the foramen of Luschka without excessive retraction of the cerebellum. The optimum position for the recording electrode is in the triangle formed by the axis of the cochlear nerve and the glossopharyngeal nerve and by the lip of the foramen of Luschka. The caudal retromastoid approach is more suitable than the translabyrinthine technique for recording from the cochlear nuclei as well as for implantation of stimulating electrodes into the cochlear nuclei for use as hearing prostheses.

Key Words • brainstem auditory evoked potential • cochlear nucleus • foramen of Luschka • retromastoid approach • translabyrinthine approach • anatomical study

Intraoperative recording of brainstem auditory evoked potentials (BAEP) has proven to be a useful and reliable method for intraoperative neurophysiological monitoring of the function of the auditory nerve in neurosurgical operations of the cerebellopontine angle. One obstacle in the use of BAEP, however, is that it is necessary to collect many responses to obtain an interpretable record, usually taking at least 1 minute but often more than 2 minutes to do so. Conditions and circumstances in the operative field of the cerebellopontine angle may change rapidly; for instance, surgeons may change the position of a brain spatula, the arachnoid membrane may be cut, vessels may be moved, and electrocoagulation may conduct heat to the auditory nerve. All such manipulations may affect the BAEP, and the delay in obtaining an interpretable record often makes it difficult to identify which step in the operation was responsible for a specific change in the BAEP. If there is a change in latency of any component of the response during the time responses are being added, it will result in a recording that has a low amplitude and a waveform that may be difficult to interpret.

To avoid these problems, direct recording of compound action potentials (CAP) from the exposed eighth cranial nerve has been used intraoperatively to monitor the auditory nerve in operations in the cerebellopontine angle, such as microvascular decompression (MVD) to relieve trigeminal neuralgia, hemifacial spasm, disabling positional vertigo, or tinnitus. Direct recording from the cochlear nerve has been found useful in intraoperative monitoring, because it provides an interpretable record within a few seconds. One of the disadvantages of this type of recording, however, is that the recording electrode itself may be in the way in the operative field and may be dislodged by surgical manipulations. This is especially a problem in operations to remove acoustic tumors, in which it may be difficult to place the wick electrode on the nerve and to keep it there. Evoked potentials from the vicinity of the cochlear nuclei can be recorded from an electrode placed in the lateral recess of the fourth ventricle. Such recordings yield evoked potentials of a large amplitude, and we have recently shown that they offer several advantages in monitoring the function of the audiological systems.
tory nerve compared to recordings from the exposed eighth nerve.\textsuperscript{21} Thus, recording electrodes placed in the lateral recess of the fourth ventricle remain stable and undisturbed by operative manipulations. Because this position is close to the cochlear nuclei, the recordings provide potentials of large amplitude and, because they are derived from structures that are central to the intracranial portion of the auditory nerve, reflect changes in neural conduction over the entire length of the intracranial portion of the auditory nerve. For both types of direct recording (from the eighth nerve or cochlear nuclei) the recording electrode is a malleable, Teflon-insulated, multistrand, silver wire with a wick of cotton or shredded Teflon sutured to its uninsulated tip.\textsuperscript{16,18,19,21} Auditory stimulation is supplied by clicks or tonebursts presented through miniature earphones placed in the external ear or earphones inserted in the ear canal on the side on which the recording is to be made.\textsuperscript{16}

Despite considerable studies of the region of the cerebellopontine angle by Lang and coworkers\textsuperscript{10-12} and Rhoton,\textsuperscript{27} as well as of the fourth ventricle,\textsuperscript{44} the anatomical relationship of the cochlear nerve and nuclei around the foramen of Luschka in humans is not completely understood. A more precise understanding of the microsurgical anatomy of these structures would facilitate the use of recording auditory evoked potentials from the cochlear nuclei. The surgical anatomy of the cochlear nuclei is also of interest in respect to the further development of the cochlear nucleus implant for deaf patients.\textsuperscript{1,30,31} The development of cochlear nucleus implants was pioneered by House and coworkers\textsuperscript{3,15,23} more than 20 years ago. Research aimed at improving the cochlear nucleus implants has involved a surgical approach to the cochlear nuclei through a narrow translabyrinthine access, similar to the one that most otolaryngologists choose in operations to remove acoustic tumors. The retrosigmoid (or retromastoid) approach commonly used by neurosurgeons for MVD procedures to relieve cranial nerve compression syndromes\textsuperscript{7,8} as well as for removing tumors in the cerebellopontine angle may also be useful when implanting a hearing prosthesis in the cochlear nucleus.

The present study examines the microsurgical anatomical

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**Fig. 1.** Photographs showing a left retromastoid approach. Roman numerals denote cranial nerves (CNs). *Left:* The brain spatula is placed on the biventral lobule and the cerebellum is retracted rostromedially. The flocculus is seen overlying the root entry zone of CN VIII and CN IX. AICA = anterior inferior cerebral artery. *Right:* The arachnoid membrane is cut and the cerebellum is retracted further with the flocculus. The choroid plexus protrudes from the foramen of Luschka, the opening of the rhomboid lip formed by the thick membrane of tenia. Note the position and the direction of the brain spatula to retract the cerebellum.
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cal relationship of the cochlear nuclei and their surrounding structures in detail. Particular reference is made to the recording of CAP from the cochlear nuclei as well as placing auditory stimulating electrodes for use as hearing prostheses using a retrosigmoid approach to the cerebello-pontine angle.

Clinical Material and Methods

The anatomy of the region around the foramen of Luschka was investigated bilaterally in three human cadaveric heads (for a total of six foramina of Luschka) with the aid of an operating microscope. First, the foramen of Luschka was observed through a retromastoid craniectomy. The caudal and lateral surfaces of the cerebellar hemisphere were exposed and retracted in a mediorostral direction using a small spatula with a self-retaining retractor. The craniectomy was then widened and the cerebellar hemisphere was partly removed to expose the entire fourth ventricle, the choroid plexus, the tela choroidea, and the convolutions of the cochlear nuclei. The posterior wall of the internal acoustic meatus was drilled out to expose the entire vestibulocochlear nerve, and the superior and inferior vestibular nerves were identified and removed to expose the cochlear nerve. The foramen of Luschka was also exposed using the translabyrinthine approach in two cadavers, and we compared this view with that obtained in the retromastoid approach. The dissections were compared with pictures taken during actual operations to remove acoustic tumors.

Results

When the root entry (or exit) zone (REZ) of the seventh, eighth, ninth, and 10th cranial nerves was exposed, the choroid plexus was seen protruding from the foramen of Luschka (the aperture of the lateral recess). The tela choroidea and the foramen of Luschka were seen posterior and just rostral to the REZ of the ninth and 10th cranial nerves. When the flocculus and the cerebellar hemisphere were retracted further mediorostrally and the arachnoid membrane and its trabeculae were cut, the foramen of Luschka and the tela choroidea were clearly seen (Fig. 1).

To expose the lateral recess of the fourth ventricle in its medial portion, the biventral lobule and the tonsil of the cerebellum were retracted rostromedially. The lower quarter of the fourth ventricle was exposed from the foramen of Luschka to the obex. The flocculus was excised to expose the proximal portion of the vestibulocochlear nerve. After both cerebellar hemispheres were removed, the entire floor of the fourth ventricle was seen to be covered by the choroid plexus with the tela choroidea. When the recording electrode was placed beneath the choroid plexus and on the dorsal surface of the lateral recess, it was close to the surface of cochlear nucleus, a position that is suitable for recording from the cochlear nerve intraoperatively (Fig. 2). The choroid plexus was then partially removed and the tela choroidea divided and deflected; at that point the floor of the lateral recess of the fourth ventricle became visible and the convolution of the dorsal cochlear nerve could be seen (Fig. 3).

When the entire cochlear nerve (from the fundus of the internal acoustic meatus to the brainstem) was exposed to identify the junction zone between the cochlear nerve and its nuclei, the cochlear nerve was seen to have a medio-posterocaudal course from the porus to the brainstem, then it slightly changed its course to a medial direction at the REZ. The distance between the caudal part of the lip of the foramen of Luschka and the most lateral part of the convolution (presumably the posterior ventral nucleus) was approximately 3 mm. The distance from the foramen of Luschka to the center of the convolution of the dorsal cochlear nerve was approximately 5 mm (Fig. 4). Typical click-evoked auditory responses from the cochlear nuclei recorded intraoperatively using the wick electrode to monitor cochlear nerve function are shown in Fig. 5.

When the translabyrinthine approach was used to expose the cerebellopontine angle the operative view was limited, and it was necessary to retract the sigmoid sinus medially to obtain a medial view of the REZ of the cochlear nerve. In one cadaver, the jugular bulb was situated in a high position (rostral), and it was therefore necessary to drill the jugular foramen to gain access to the foramen of Luschka (Fig. 6).
Discussion

In the present report we show the microsurgical anatomical relationship of the cochlear nerve and the cochlear nuclei, with specific reference to intraoperative recording of auditory evoked potentials from the cochlear nuclei by means of an electrode placed in the lateral recess of the fourth ventricle. Only a few investigators have directed their anatomical studies specifically to the region of the cochlear nuclei in humans. The lack of detailed knowledge about the surgical anatomy of the region close to the cochlear nuclei has made it necessary to rely on neurophysiological indicators for the location of the recording electrode in relation to the cochlear nuclei.

When viewed from a retromastoid approach to the cerebellopontine angle, the entry of the cochlear nerve into the brainstem is usually obscured by the cerebellar flocculus and covered by the choroid plexus, which fills the lateral recess of the fourth ventricle and protrudes from the foramen of Luschka. To view this part of the eighth cranial nerve through an operating microscope for the purpose of placing a recording electrode close to the cochlear nerve, the flocculus together with the choroid plexus might have to be retracted. This may require a relatively strong retraction force, which could cause contusion of the brain tissue and destructive stretching of the cochlear nerve.

To approach the foramen of Luschka and the cochlear nuclei without such severe retraction, the arachnoid membrane and its trabeculae should be cut with sharp dissection and the cerebellar hemisphere should be retracted.
from a caudal-to-rostromedial direction, with a spatula placed on the caudal surface of the biventral lobule. The retromastoid craniectomy may need to be enlarged slightly so that the foramen of Luschka can be viewed in a rostromedial direction, and so that the caudal portion of the cerebellum can be retracted rostromedially to gain access to the foramen of Luschka and the lateral recess. It is important to avoid retraction of the cerebellum and the flocculus in a lateral–medial direction.\textsuperscript{25,26} The findings of this study and of previous reports\textsuperscript{30,31} that the cochlear nerve takes a medioposterocaudal course from the porus acusticus to the brainstem, then runs in a medial direction just before entering the posterior and anterior ventral cochlear and dorsal cochlear nuclei should be considered when placing an electrode for intraoperative monitoring of the auditory nerve. To achieve optimum recording conditions, the electrode should be inserted in the lateral recess in a mediorostral direction beneath the choroid plexus, which protrudes from the foramen of Luschka within a triangle formed by the axis of the cochlear nerve and the glossopharyngeal nerve and by the lip of the foramen of Luschka (Fig. 7). The electrode should be inserted to a depth of approximately 3 to 5 mm from the aperture

![Image](image_url)
of the foramen of Luschka. To record from the ventral cochlear nucleus, the electrode should be inserted in the rostral portion of the foramen of Luschka. It is not necessary to retract the cerebellum any further than is normal during an MVD procedure to relieve hemifacial spasm or glossopharyngeal neuralgia. When the choroid plexus is large and obstructs insertion of the wick electrode it can be partially coagulated and resected without any complications. Thus, understanding the microsurgical anatomy around the foramen of Luschka can make it possible to place a wick recording electrode with minimal retraction of the cerebellum, which can take only a couple of minutes, thus making this method useful for routine intraoperative monitoring of the auditory nerve.

The translabyrinthine approach to the foramen of Luschka has been used for implanting a device to stimulate the cochlear nuclei in deaf patients whose deafness is caused by neurofibromatosis type 2.1 We found that this approach provides only a limited operative view to the foramen of Luschka, as has also been reported by Brackmann, et al.1 Exposure of the lateral recess may be more difficult to secure when the jugular bulb is located in a high position. Care must be taken not to injure the jugular bulb in cases in which the jugular foramen has to be drilled when a translabyrinthine approach is used. Retraction of the sigmoid sinus in a mediad direction may be required to gain access to the medial portion of the lateral recess where the dorsal cochlear nucleus is located, and this may involve the risk of sinus bleeding. Retraction of the sinus is not required when a retromastoid approach is used. We therefore believe that the caudal retromastoid–retrosigmoid approach is as suitable for implanting stimulation electrodes in the cochlear nuclei as it is for placing recording electrodes.

Acknowledgments

The authors are grateful to Peter J. Jannetta, M.D., and Haedong Jho, M.D., who performed the posterior fossa operations. The cadaver dissections were done by the senior author with valuable help from Michael Stechison, M.D., Ph.D., and Ms. Wendy Fellows.

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Fig. 7. Drawings depicting the region around the foramen of Luschka through a left retromastoid approach. Roman numerals denote cranial nerves (CNs); REZ = root entry zone. Left: General view. Right: Schematic drawing of the cochlear nerve and the nuclei. The cochlear nuclei mainly lie beneath the lateral recess in the area of the triangle, which consists of the long axis of CN VIII, the long axis of CN IX, and the foramen of Luschka.
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Manuscript received May 12, 1994. Accepted in final form September 12, 1994.
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