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Surgery for auditory brainstem implantation

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Patients with neurofibromatosis 2 present complex and challenging management dilemmas. Surgical removal of vestibular schwannomas often results in total hearing loss. Early diagnosis using gadolinium-enhanced magnetic resonance imaging and refinements in hearing preservation surgery have improved our ability to prevent total hearing loss while achieving complete removal in smaller tumors, but for patients with larger tumors or for those with no useful hearing in that ear, the auditory brainstem implant (ABI) allows restoration of some auditory function when the tumor is removed. Additionally, children with cochlear aplasia and cochlear nerve deficiency have begun to be implanted with ABIs, with varied results. This article discusses surgical placement of the ABI.

Patient selection

The Nucleus ABI (Cochlear Corporation, Centennial, CO) (Figure 1) is approved by the Food and Drug Administration (FDA) for implantation at the time of vestibular schwannomas (VS) removal. Suitable candidates are patients undergoing translabyrinthine or retrosigmoid VS removal who have (1) nonaidable hearing or an only-hearing ear with a symptomatic tumor or (2) serviceable hearing in the contralateral ear but a contralateral tumor of sufficient size to indicate that hearing will potentially be lost (a so-called "sleeper" auditory brainstem implants [ABI]). Criteria for patient selection for receiving an ABI are as follows: evidence of bilateral eighth nerve tumors, age 12 years or older, psychological suitability, willingness to comply with the follow-up protocol, and realistic expectations.

Although there are some exceptions, most patients who received the ABI at the House Clinic have neurofibromatosis 2 (NF2) and bilateral VS. In these patients, the goal is to restore some auditory function. The ABI may be implanted during removal of either the first-side or second-side tumor, even if some hearing remains on the other side, which is often the case. This "sleeper" approach allows patients to become familiar with the use of the device and prepares them for situations when all hearing is lost.[1-3]

More recently, other potential indications for ABI placement have developed, such as cochlear ossification following meningitis or cranial trauma resulting in bilateral cochlear nerve transection. Congenitally deaf young children who are deemed not to be candidates for cochlear implantation (CI) or who have failed to progress with CI owing to severe cochlear malformation or cochlear nerve aplasia have been implanted.[4-6] FDA-approved trials of patients with these diagnoses are now beginning in the United States.

Surgical technique and anatomy of the cochlear nucleus

The cochlear nucleus complex (dorsal and ventral cochlear nuclei) lies in the lateral recess of the fourth ventricle. It is partially obscured by the cerebellar peduncles. A surface electrode array introduced in the lateral recess will stimulate viable cochlear nucleus structures.

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Figure 1 Nucleus auditory brainstem implant. (Color version of figure is available online.)

At the House Clinic, we have almost exclusively used the translabyrinthine approach for placement of the ABI after removing VS, though some centers use the retrosigmoid approach. Typically, we use a C-shaped incision that starts behind the pinna and is approximately 2 cm away from the postauricular fold at the level of the mastoid tip, as shown in Figure 2. It allows the placement of the internal receiver and magnet under the scalp (Figure 3). It is important that the incision is not directly cross the area of the receiver-stimulator.

The translabyrinthine approach provides direct access to the cochlear nuclei (Figure 4). The jugular bulb is skeletonized to provide the widest access to this area. Anatomical landmarks used for placement include the stump of the eighth nerve, the glossopharyngeal nerve, the facial nerve, and the taenia choroidea as well as the mouth of the lateral recess where all of these structures converge. In the surgical setting where there is almost always distortion of the brainstem from the tumor, the lateral recess is superior to the ninth nerve. The ninth nerve is generally in a fixed anatomical position, and going from there, the lateral recess may be identified in almost every case, with a glistening lining and the egress of cerebrospinal fluid. Indeed, with a contracted mastoid and a high jugular bulb, the exposure may be more difficult although it should not be an impediment to placement of the ABI electrode. As an alternative to the translabyrinthine approach, the retrosigmoid approach may be used in cases where the sigmoid sinus is located extremely anteriorly.

Location of the ventral cochlear nucleus, the main target for placement of the ABI, can be problematic. After clearly identifying the basic anatomical landmarks of the lateral recess, including the choroid plexus and the more reflective ependymal surface (Figure 5), dissection is temporarily stopped and the posterior fossa is occluded with gelfoam. At this point, a subgaleal pocket is created superior and posterior to the mastoidectomy site. A seat is then drilled in the outer table of the skull to secure the position of the ABI receiver. Next, dissection continues in the posterior fossa with the ABI on the operative field. After placing the ground electrode under the temporalis muscle, the ABI electrode array side mesh is typically trimmed based on the size of the lateral recess and the implant carefully inserted (Figure 6). Correct anatomical placement is confirmed using electrophysiological monitoring (Figure 7). Electrically evoked auditory brainstem responses are elicited by stimulation of the nucleus, and the position of the ABI electrode array is optimized using the information derived from electrophysiological monitoring, as determined by an experienced auditory physiologist.[7] In addition to facial nerve monitoring, the lower cranial nerves are also monitored to avoid side effects and nonauditory sensations.

Once the optimal position is determined, Teflon felt or muscle is used to secure the electrode in the lateral recess of the fourth ventricle (Figure 8). In patients with NF2 who will require frequent magnetic resonance imaging, the magnetic disc in the receiver or stimulator is replaced with a nonmagnetic plug. The receiver is then placed in the subgaleal pocket before filling the mastoid cavity with abdominal fat, carefully inserting a titanium mesh cranioplasty, and closing the scalp.

In other centers, the retrosigmoid approach has been used to implant ABIs with similar success. Both supine or lateral and semisitting positions have been used. The latter may offer some benefit in terms of brain relaxation and ease of access to the lateral recess. In young children, the retrosigmoid approach is used universally.[14]

Implantation is facilitated by preservation of landmarks during tumor resection. Great care is also taken during exposure of the lateral recess, which may be obstructed by arteries, veins, or a thin membrane, and during device placement. Very gentle manipulation of brainstem, tumor, and surrounding neurovascular structures may lead to improved audiologic results. With the largest tumors, this may be very difficult or impossible. Initial testing and activation of the ABI is typically carried out 1-2 months after the surgery.

Results

Auditory outcomes and speech perception performance have generally improved significantly since the initial development