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Auditory brainstem implant technology and use: Auditory implants

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ABSTRACT

Cochlear implant (CI) technology is used in the treatment of deep sensorineural hearing loss (SNHL). However, an intact cochlea and an intact cochlear nerve are needed for CI applications. CI does not help in pathologies that may occur in these regions, and it is necessary to ensure the continuity of auditory conduction by direct stimulation of the cochlear nuclei. The method developed to ensure this auditory continuity is auditory brainstem implant (ABI) applications. In short, the ABI functions without the cochlea and the cochlear nerve. It does not need these structures. According to CI practices, postoperative gains are unfortunately not at the desired level. Auditory information can be helpful in lip-reading, although its benefits on speech perception are generally limited. In addition, ABI applications enable environmental sounds to be heard even if they are not fully perceived, and it is known to be beneficial on quality of life.

Key words: Brainstem implant technology, auditory implant, cochlea, cochlear aplasia, hearing loss.

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Introduction

The auditory brainstem implant (ABI) was first developed for patients undergoing neurofibromatosis type 2 (NF2) or bilateral vestibular schwannoma surgery with a rupture in the bilateral cochlear nerve continuum [1].

Cochlear implant (CI) is applied in the treatment of deep sensorineural hearing loss (SNHL). With CI technology, the electrical stimulation coming through the electrode is transmitted to the cochlear nerve by the cell bodies of the spiral ganglion. The message that occurs in the next process is transmitted to the cochlear nucleus (CN) in the brain stem [2]. Any disconnection in the cochlear nerve prevents this transmission. It has been proven that the anatomical location of the CN in the immediate vicinity of the cochlear nerve and directly on the auditory brainstem can allow direct electrical stimulation of this region and be a suitable surgical location [2].

Applications of non-tumor ABI in adult patients have led to promising results. In light of these trials, ABI applications were started in patients with cochlea and cochlear nerve pathology and in whom CI could not be applied. These apps are seen as the only way out for the formation of auditory perception. [1, 3, 4]. In short, the ABI does not need cochlea and/or cochlear nerves to provide meaningful stimulation of the cochlear nucleus and higher auditory pathways [1].

Historical development of auditory brainstem implants

ABI was first developed in the late 1970s [5]. French Andre' Djourno and electrophysiologist Charles Eyrie performed the first direct

electrical stimulation of the human auditory system with an induction coil electrode he developed in 1957 [6]. In light of these experimental studies, the first cochlear implant device was developed and implanted for the first time in 1961. However, due to biocompatibility issues, the device was withdrawn. In 1967, the first successful CI without biocompatibility problems was produced and applied [7]. From the 1970s to the present, device improvements and processing advances have resulted in the cochlear implant being the most successful neuro-prosthetic device currently in use [8]. CI demonstrated the feasibility of electrically stimulated auditory perception and provided a basis for the development of ABI devices.

ABI was originally available for stimulating the cochlear nuclei in NF2 patients with severe hearing loss. The first ABI was performed in 1979 with electrode placement in the lateral recess of the fourth ventricle after removal of an acoustic neuroma [9, 10]. This prototype was used until 1992 and was applied in 25 patients [11]. The first ABI surgery was performed in a pediatric patient with auditory nerve aplasia in 2001, as applicable in the pediatric age group [12].

Only in patients older than 12 years of age with NF2 was the application of ABI approved by the Food and Drug Administration (FDA) in 2000. In 2005, Colletti and Shannon reported that ABI can be applied to adults and children with non-NF2 hearing loss who would not benefit from CI surgery [13]. However, the use of ABI in these patient groups is not FDA approved [14].

Although the results are not completely clear, it is known that ABI has been applied to approximately 1000 patients to date. However, ABI applications continue to offer hope for the patient population [15].

Auditory brainstem implant design and function

ABI device consists of two parts, external and internal parts. A receiving microphone, a battery as a power source, a speech processor, an external magnet that supports the physical connection and transmission with the internal part, and the transmitting antenna form the outer part. An internal magnet placed under the skin, an antenna that acts as a receiver, a receiver stimulator that allows the message to reach the electrodes, and an electrode array positioned in the form of a silicone spoon form the inner part. First, the microphone detects the sound and converts it into an electrical signal. This signal is transferred to the sound processor and encoded as an electronic code [15]. The magnet on the skin receives this code and transmits it to the receiver stimulating unit through the skin in the form of a radiofrequency wave. Then, this message is transmitted to the electrode array placed along the surface of the brain stem with the conductive wires, and thus the cochlear nucleus is directly stimulated [15]. The cochlear nuclei are arranged obliquely along the pons. The ABI electrode array is contained within a silicone, flexible, spoon-like structure for comfortable stimulation of all nuclei. Thus, it can also provide stimulation of the nuclei located at deeper levels. This structure also allows for selective excitation of frequencies. However, the results of penetrating ABI electrode placement are disadvantageous compared to surface electrodes due to difficulties in definitively identifying the cochlear nucleus [16].

The ABI device manufactured by Cochlear© (Sydney, Australia) is the only device approved by the FDA in the United States, measuring 8.5*3.0 mm, with platinum electrodes extending along a silicone spade-shaped structure. Various ABI devices are also

produced by MED-EL© (Innsbruck, Austria) and Oticon© (Vallauris, France) and are used outside the USA [15].

Indications for auditory brainstem implants

ABI candidate evaluations are made by a multidisciplinary team that includes otolaryngology, neurology, neurosurgery, audiology, speech therapy, and neuropsychology [15].

The groups to be implemented in ABI applications; It can be classified into two groups as NF2 patients and non-tumor patients. In the United States of America, the indications for ABI are only those with bilateral profound hearing loss, bilateral vestibular schwannoma in which it is not possible to preserve the cochlear nerve functions, and NF-2 aged 12 years and over [15, 17]. Non-tumor indications for ABI include cases with a congenital anomaly such as a bilateral absence or aplasia of the cochlear nerve or a complete labyrinthine aplasia. [3, 13].

In addition, different scientific studies for ABI applications divide the indications into two groups as absolute and relative indications. Bilateral cochlear aplasia, including a complete labyrinthine aplasia and bilateral cochlear nerve aplasia, are definite indications. Relative indications include patients with bilateral cochlear and/or cochlear nerve hypoplasia, bilateral complete cochlear otosclerosis, and/or bilateral profound hearing loss with bilateral temporal bone trauma. [18]. However, the only indication approved by the FDA is patients aged 12 years and over with NF2 [10, 19].

In addition, for ABI applications, the absence of any contraindications, the absence of neurological deficits that may make rehabilitation stronger or even impossible, a strong motivation in adults, a motivated family and social environment for children, extensive experience of the surgical team in posterior fossa surgery, auditory rehabilitation it is necessary to have a team with extensive experience and to have a long-term, intensive rehabilitation opportunity [20].

Surgical technique

There are two standard surgical approaches in ABI applications. A translabyrinthine approach is preferred in patients with tumors [8]. This approach provides a more direct route to the lateral recess, allowing early and safe identification of the facial nerve. In addition, it prevents cerebellar retraction. However, the biggest disadvantage of this approach is that it destroys residual hearing. Therefore, it is contraindicated in patients with residual hearing [8]. The retrosigmoid approach, on the other hand, is preferred in patients who do not have tumors and who have tried to preserve residual hearing. In this technique, cerebellar retraction is required for optimal exposure of the facial nerve and internal auditory canal fundus [21, 22].

The implant activates approximately 6 weeks after implantation. Special attention is paid to children during the first activation. The first device is operated in the operating room under general anesthesia and accompanied by nerve monitoring. Close monitoring for vagal stimulation and other unexpected side effects is essential. Because side effects such as bradycardia, vertigo, tightness in the throat and syncope may occur. Therefore, cardiac monitoring and physician supervision are very important in the initial evaluation. [15].

The audiological performance of ABIs is variable and cannot reach the level of performance achieved in cochlear implantation [10]. In patients with NF2 and patients with acoustic tumors with a large cerebellopontine angle, compression of the brainstem often

occurs and causes anatomical involvement of the brainstem. Therefore, electrode implantation becomes difficult [10, 23]. The cochlear nucleus complex is close to many important nuclei and functional pathways, including the trigeminal, facial, glossopharyngeal, vagus, and accessory nerves, as well as the lower cerebellar peduncle and floculus, all of which may lead to different undesirable conductions during stimulation [23].

Acquisitions after auditory brainstem implantation

In neurofibromatosis type 2 patients, auditory performance is highly variable after ABI applications. The only truth is that unfortunately it is pretty bad according to the CI results. The variability in performance is due to differences in surgical technique, surgeon's experience, post-implantation programming, and signal coding strategies.

As a result of ABI applications in patients with NF2, 81% of auditory sensations were observed in general [24]. Unfortunately, in 20% of the patients, auditory conduction cannot occur [21]. Although auditory sensation was obtained in 81% of the patients, clear word recognition could be achieved in only 10% of the patients [15, 25]. On the contrary, the biggest benefit in ABI applications is that it increases lip reading. When combined with lip reading, 93% of patients experience significant increases in sentence comprehension 3 to 6 months after implantation [7].

Results in non-tumor applications are better compared to patients with NF2 [13, 26]. The 10% explicit word recognition rates obtained after ABI application in NF2 patients were reported to be approximately 59% in this patient group [26]. Differences in auditory gain between patients with NF2 and those without tumors may be due to additional pathological influences in the cochlear nuclei and auditory pathway in patients with NF2. Although large tumoral formations can cause deformation in the cochlear nuclei, they cannot be the cause alone. Because even small tumors can negatively affect performance [27].

When the gains in the pediatric age group are evaluated, it is known that the most common indication in pediatric ABI applications is cochlear nerve aplasia. In studies conducted with this patient group, it has been reported that the rate of understanding general expressions with lip reading is approximately 50% according to 5-year results [1]. In fact, studies have reported that the rate of speaking on the phone is 11% and the rate of recognizing clear speech is about 30% [12]. In a different study, it was concluded that sound awareness was formed in 11 out of 12 children [28].

Conclusion

Although the benefits of ABI applications on speech perception are generally limited, it should be known that auditory information can be helpful in lip reading. In addition, it should not be forgotten that ABI applications enable environmental sounds to be heard even if they are not fully perceived, and they are also beneficial on quality of life.

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