Otology & Neurotology
35:260–270 © 2014, Otology & Neurotology, Inc.

Cochlear Implantation Versus Auditory Brainstem Implantation in Bilateral Total Deafness After Head Trauma: Personal Experience and Review of the Literature

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Objective: To determine the effectiveness of cochlear implant (CI) in hearing restoration after temporal bone (TB) fractures and investigate the adequacy of auditory brainstem implant (ABI) indication for TB fractures.
Study Design: Retrospective clinical study; a systematic review of the literature in PubMed was also performed to identify all published cases of bilateral TB fractures or bilateral deafness after head trauma treated by means of CI or ABI.
Settings: Quaternary otology and skull base surgery referral center.
Patients: Eleven consecutive patients presented with bilateral severe-to-profound sensorineural hearing loss after head trauma.
Interventions: CI as primary intervention or following a previous treatment.
Main Outcome Measures: CI performances were evaluated in the auditory-only condition in both closed-set and open-set formats.
Results: Fourteen CI were placed, 11 as primary treatment and 3 after ABI failure. At the last follow-up, all patients gained useful open-set speech perception. In secondary CI, all patients obtained better auditory results with the CI if compared with ABI. CI performance did not decrease with time in any case.
Conclusion: Cochlear implantation after TB fractures has proved to have excellent audiometric results. The aim of the initial evaluation of a patient with bilateral anacoustic ears from head trauma should always be to rehabilitate their hearing with a CI. The incidence of labyrinthitis ossificans, negative electrophysiologic testing, the risk of postoperative meningitis or facial nerve stimulation should not be the determinant factors that favor ABI placement. **Key Words:** Auditory brainstem implant—Cochlear implant—Head trauma—Temporal bone fracture.
Otol Neurotol **35:**260–270, 2014.

Temporal bone (TB) fractures occur in 22% of head traumas. The fracture line may involve functionally important structures, including the fallopian canal, the internal auditory canal (IAC) and the anterior and posterior labyrinth. Otic capsule involvement arguably carries a high risk of severe loss of cochlear and vestibular function (1). Bilateral TB fractures with otic capsule involvement expose patients to a high risk of bilateral deafness and meningitis. Hearing loss may also follow traumatic head injury without evidence of fractures (2). Cochlear implants (CI) have been used as effective means for hearing rehabilitation in patients with TB fractures and head trauma related sensorineural hearing loss (SNHL) (3–8). However, some authors choose auditory brainstem implants (ABI) in bilateral TB fractures treatment, even when CI placement is possible. (9).

Reasons for considering bilateral TB fractures as extended indications for ABI are unsatisfactory CI results because of possible cochlear nerve damage, labyrinthitis ossificans, or facial nerve stimulation (10–13). Another reported drawback is that CI surgery could be challenging because of displaced fracture lines than may impede electrode insertion (6). Furthermore, some authors state that transverse fractures may lead to loss of spiral ganglion cells over time (14), and progressive decrease of CI results.

Feasibility of CIs depends on three factors: 1) patency and integrity of the cochlea, 2) integrity of cochlear nerve, and 3) functional neural connection between these 2 entities.

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The authors disclose no conflicts of interest.
No funding has been received from any public or private organization.

Patients with bilateral severe-to-profound SNHL should primarily undergo clinical and radiologic evaluation aiming for CI placement, leaving ABI as a second option (9). In addition, CIs give better and more predictable results than ABI (15).

The aim of this study was to report the authors' experience on the management of bilaterally deaf patients after head trauma; summarize current results reported in the literature; and discuss the role of ABI in this setting, previous experience, results, and possible indications.

MATERIALS AND METHODS

This retrospective study was approved by the local institutional review board; all clinical investigations were conducted according to the principles expressed in the Declaration of Helsinki.

Patients were included if they presented with bilateral severe-to-profound SNHL after head trauma (with or without radiologic evidence of TB fracture) and were treated with a CI as primary or secondary modality.

Patients' charts and imaging data were systematically reviewed for causes of deafness, fracture location, cochlear patency, and IAC integrity, together with hearing performance and treatment results.

Systematic review of the literature in PubMed was performed to identify all the cases of bilateral TB fracture, or patients bilaterally deafened by head trauma, treated by means of CI or ABI. Filters were ''human'' and language ''English, Spanish, Italian, French.''

Postoperative auditory performances were evaluated in the auditory-only condition in both closed- set (vowel identification) and open-set formats (bisyllabic word recognition, sentence recognition, and common phrase comprehension) with monitored live voice through the sound field at a level of 70 dB sound pressure level. Hearing results are reported as measured at the last available follow-up visit. The protocol used for audiologic evaluation is described elsewhere (16).

RESULTS

Patients

A total of 11 patients fitting inclusion criteria were identified. There were 8 men and 3 women, with an average age at implantation of 51 years (range, 19–62 yr). In total, 14 CI were placed, 11 as primary treatment, and 3 as secondary treatment after ABI failure. All patients underwent high-resolution computed tomography scan (HRCT) of the TB, and magnetic resonance imaging (MRI) was obtained in 9 of 11 patients. Complete clinical management data and audiologic results are presented in Tables 1 and 2.

Fractures

HRCT scan showed bilateral TB fractures in 6 patients (54.5%), unilateral fracture in 3 patients (27%), and no fracture lines in 2 patients (18%). When analyzing the structures involved by the fracture line, the vestibule was affected in 80% (12/15) cases, the cochlea in 40% (6/15) cases, jugular foramen in 26% (4/15) cases, semicircular canals in 20% (3/15) cases, and IAC in 6% (1/15) case (Figs. 1, 2, and 3).

Patients Primarily Treated With CI

Eight patients (D–K) received CI as the primary and only treatment. To prevent the risk of meningitis, a subtotal petrosectomy was performed with all implantations in which a fracture line in the otic capsule was evident. We did not encounter any difficulties while inserting the electrodes. There was 1 case of preoperative meningitis (patient G). A preoperative cerebrospinal fluid leak occurred in 1 patient that was successfully surgically treated (patient E). All patients were enrolled in the *Streptococcus pneumonie.* vaccination program (Table 1).

One patient (patient D) received bilateral simultaneous cochlear implantation, and 2 patients (patients G and I) received bilateral staged implantation.

All patients obtained open-set abilities.

Patients Previously Treated With an ABI

Three patients (patients A, B, and C) had been previously treated in another center with an ABI; these patients were evaluated for the poor results obtained with their brainstem implants. A comprehensive radiologic evaluation was performed; MRI confirmed the presence and continuity of VIII cranial nerve bilaterally and complete cochlear patency in at least 1 side in the 3 cases. On these basis, they underwent insertion of CI on the contralateral side to the ABI (2 cases; patients A and C) and ipsilateral to the ABI (1 case; patient B) (Table 2; Fig. 4).

All 3 patients obtained better auditory results with the CI if compared with the ABI (Fig. 5). Only patient B had a poor result with CI (30% of open set speech recognition), but it was still superior to the ABI outcomes.

Stability of Audiologic Results With Time

Figure 6 compares audiologic CI results for each patient at 6 months and at the last available follow-up, showing that CI performance does not decrease with time in fractured ears. Mean follow-up is 53 months (range, 16–156 mo).

Systematic Review of the Literature: CI for Hearing Restoration in Head Trauma

Tables 3 and 4 summarize literature review results for CI in patients bilaterally deafened by head trauma. Table 3 shows fracture location, side of implantation, and detailed hearing results for the largest series of CI. Table 4 shows the same data for the most recent case reports, which are also mentioned along the discussion of this article. There is 1 case of bilateral simultaneous CI (17) and 2 cases of bilateral staged CI (3,18).

CI results are tough to summarize because of the heterogeneity of auditory evaluation tests, but the most patients achieved satisfactory results both objectively and subjectively.

Systematic Review of the Literature: ABI for Hearing Restoration in Head Trauma

After detailed revision of the articles retrieved by PubMed search engine, only 3 reports (10–12) were identified wherein

TABLE 1. *Summary of patients primarily treated with cochlear implant in our centers*

Patient	Fig	Hearing status and etiology	Fracture location (computed tomographic scan)	Magnetic resonance imaging	Treatment	Results (VI:BWR:SR:C) (Last follow-up)	Complications
D	1C	Bilateral anacoustic Head trauma	R: Vestibule L: Vestibule	Bilateral cochlear patency and intacts cochlear nerves	Bilateral simultaneous CI + bilateral SP	At 31 mo[a] 100:85:100:100	No
E	1D	Bilateral anacoustic Head trauma with rhinoliquorrhea and bilateral sudden HL 15 days later	R: Vestibule and SCC L: Vestibule and SCC	Bilateral cochlear patency and intact cochlear nerves	CI left side + SP	At 60 mo 100:80:100:100	No
F		Profound bilateral SNHL Head trauma	R: Extralabyrinthine (JF) L: Extralabyrinthine (JF)	Bilateral cochlear patency and intact cochlear nerves	CI right side + SP	At 48 mo 100:100:100:100	No
G	1A 3	Bilateral anacoustic Head trauma	R: C, V, SCC L: No visible fracture	Bilateral cochlear patency and intact cochlear nerves	CI left side Staged CI right side + SP	At 156 mo[a] 100:100:100:100	No
H		Bilateal profound SNHL Head trauma	R: No visible fracture L: No visible fracture	Bilateral cochlear patency and intact cochlear nerves	CI left side	At 58 mo 94:40:74:65	No
I		Left anacoustic Right profound SNHL Head trauma	R: JF, V and C L: JF, V and C	Bilateral cochlear patency and intact cochlear nerves	CI left side + SP Staged CI right side + SP	Left CI (16 mo) 100:60:77:60 Right CI (activation) 80:30:47:35 Both CIs (at right CI activation) 90:35:76:80	No
J	2	Bilateral anacoustic Head trauma	R: No visible fracture L: C, V, IAC Partial cochlear obliteration on the left side	NA	CI right side	At 68 mo 100:65:94:75	No
K		Bilateral profound SNHL After trauma progressive SNHL	R: C, V L: Vestibule	NA	CI right side + SP	At 54 mo 100:75:79:80	No

Pt indicates patient; Fig, figure; VI, vowel identification; BWR, bisyllabic word recognition; SR, sentence recognition; C, common phrases comprehension; R, right; L, left; CI, cochlear implant; SP, subtotal petrosectomy; HL, hearing loss; SCC, semicircular canals; JF, jugular foramen; SNHL, sensorineural hearing loss; V, vestibule; C, cochlea; IAC, internal auditory canal; NA, not available.
[a]With both CIs.

TABLE 2. *Summary of patients previously treated with uuditory brainstem implant in another center*

Pt	Fig	Hearing status and etiology	Fracture location (CT scan)	MRI	First treatment	First treatment results	Second treatment	Second treatment results (VI:BWR:SR:C) last follow up
A		R: Anacoustic Post-meningitis deafness in childhood L: Anacoustic Head trauma in 2006	R: No visible fracture L: Vestibule	Cochlear patency on the right side and partial obliteration on the left side Bilateral intact cochlear nerves	ABI left side in 2006 (other department)	Free-field PTA 55 dB WR 35% with visual and auditory stimulation 6 active electrodes Progressive decrease of results until no use of ABI	CI right side + SP (Parma University 2009)	At 24 months NA:90:90:NA Telephone use
B	4B	Profound bilateral SNHL Head trauma	R: No visible fracture L: No visible fracture	Cochlear patency on the right side and total obliteration on the left side Bilateral intact cochlear nerves	ABI right side 2001 (other department)	After one year 45% open-set SR Progressive decrease of results until no use of ABI	CI right side + SP 2008 (Gruppo Otologico)	At 48 months 0:0:30:0 No telephone use
C	1B 4A	Profound bilateral SNHL Head trauma	R: Promontory L: Vestibule	Bilateral cochlear patency and bilateral intact cochlear nerves	ABI right side 2000 (other department)	After three months 20% open-set SR No use of ABI	CI left side + SP 2010 (Gruppo Otologico)	At 24 months 100:55:69:70 Telephone use with family

Pt indicates patient; Fig, figure; CT, computed tomography; MRI, magnetic resonance imaging; VI, vowel identification; BWR, bisyllabic word recognition; SR, sentence recognition; C, common phrases comprehension; R, right; L, left; ABI, auditory brainstem implant; PTA, pure tone average; WR, word recognition; CI, cochlear implant; SP, subtotal petrosectomy; NA, not available; SNHL, sensorineural Hearing loss.

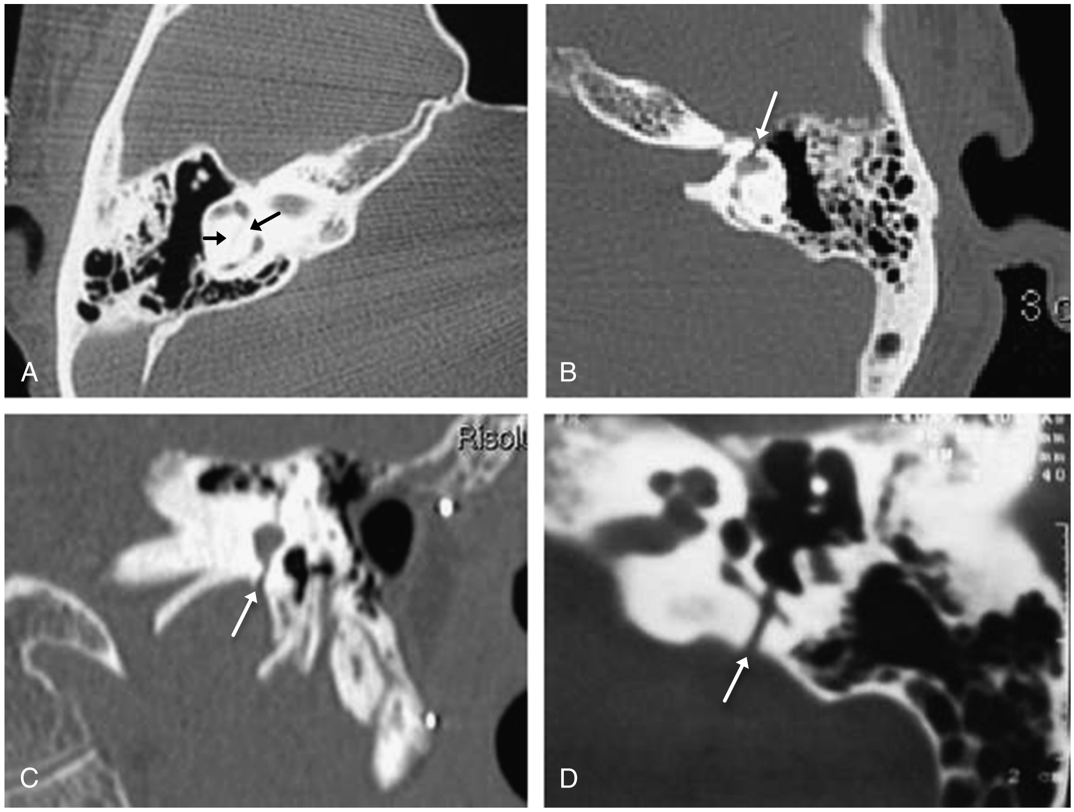

FIG. 1. *A*, CT scan, axial view, right ear. Labyrinthine fracture involving the lateral semicircular canal (*black arrows*). *B*, CT scan, axial view, left ear. Labyrinthine fracture involving the vestibule (*white arrow*). *C*, CT scan, coronal view, left ear. Labyrinthine fracture involving the vestibule (*white arrow*). *D*, CT scan, axial view, left ear. Labyrinthine fracture involving the posterior semicircular canal (*white arrow*).

a total of 7 patients were implanted with an ABI after traumatic deafness. In these series, at 1-year follow-up, 3 patients (50%) failed to achieve satisfactory open set sentence recognition. In the other 3 patients, auditory-alone-mode open-set sentence recognition was 45%, 60%, and 100%, respectively. The authors reported no complications after ABI placement.

Figure 7 illustrates auditory sentence recognition score for ABI and CI for all patients for which numeric data were available in literature review, a clear advantage can

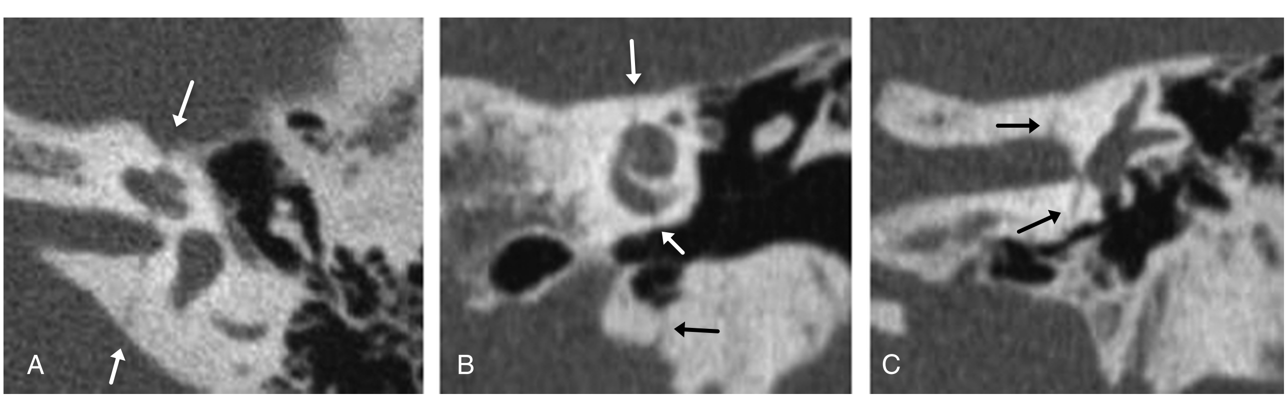

FIG. 2. CT scan of patient J, left ear. *A*, Axial view at the level of the cochlea and IAC showing labyrinthine fracture involving basal and middle turn of the cochlea and IAC fundus (*white arrows*). *B*, Coronal view at the level of the cochlea where it can be appreciated with mayor detail involvement of the basal and middle turns of the cochlea (*white arrows*). The fracture line extends to the hypotympanum (*black arrow*). *C*, Coronal view at the level of the IAC and vestibule showing the fracture line crossing perpendicular to the IAC fundus (*black arrows*).

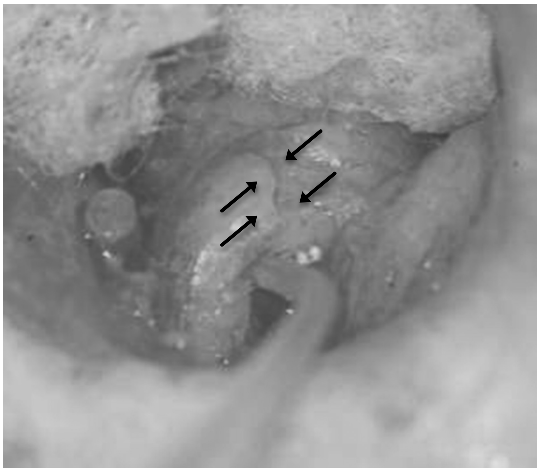

FIG. 3. Right ear. Surgical picture showing CI electrode insertion through RW. Note the fracture line involving the promontory (*black arrows*). CI, cochlear implant; RW, round window.

be observed for CI. This graph must be interpreted with caution because of the heterogeneity of auditory tests between series. Detailed information of each series is

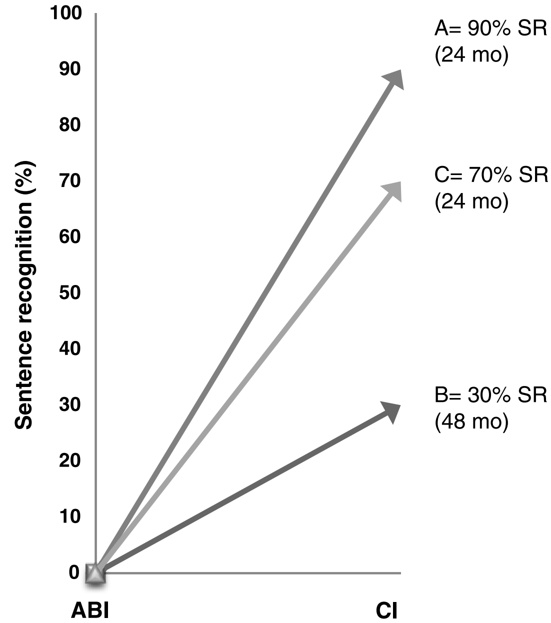

FIG. 5. Open set sentence recognition line plots of patients A, B, and C after first treatment with ABI placed in another department and improvement after second treatment with CI in our department (follow-up). SR, sentence recognition.

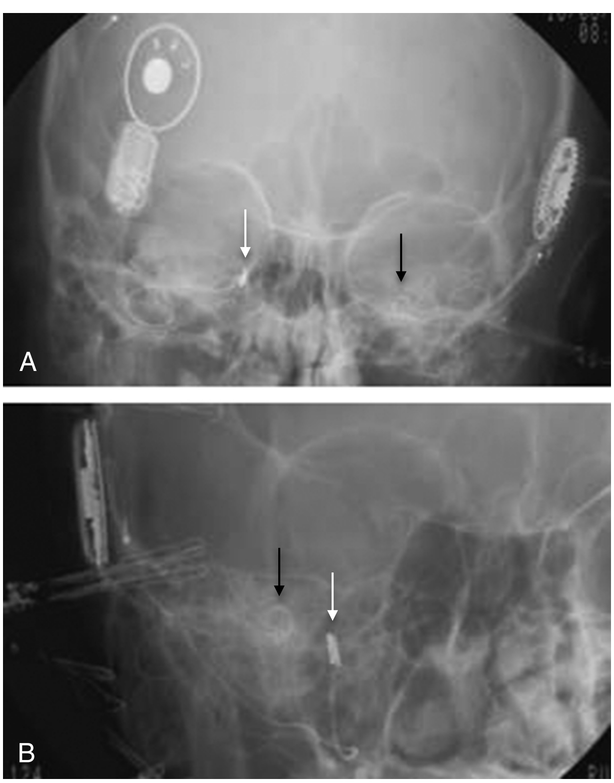

FIG. 4. *A*, X-ray of patient C, showing ABI on the right side (*white arrow*) and CI on the left side (*black arrow*). *B*, X-ray of patient B, showing ABI (*white arrow*) and CI (*black arrow*) on the right side. ABI, auditory brainstem implant. CI, cochlear implant.

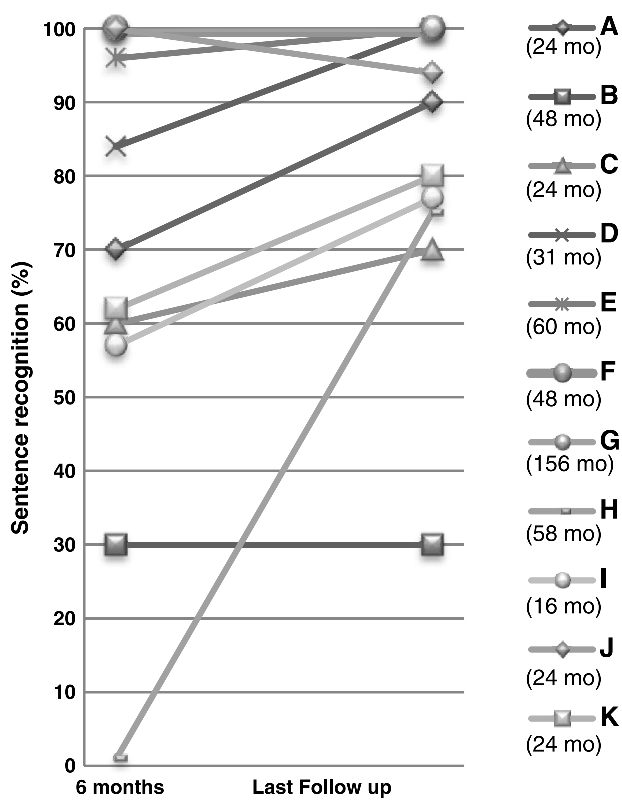

FIG. 6. Stability of audiologic results with time. Open set sentence recognition (SR%) for all the patients at 6 months and at last available follow-up, showing that CI results do not decrease with time. Mean follow-up is 53 months. Last follow-ups are specified below every patient legend in brackets. Mo, months.

TABLE 3. *Review of the literature on the largest series of patients treated with cochlear implantation after bilateral traumatic deafness*

Series (Ref.)	No. of implants	Case	Right ear	Left ear	Treatment	Results (follow-up)
Hagr, 2011 (3)	6	1	Fracture involving cochlea	Fracture involving vestibule	Bilateral staged CI	70% SR[a] (18 mo) Full-time user
		2	Fracture involving vestibule	Fracture involving vestibule	Left CI	90% SR[a] (24 mo)
		3	Fracture involvingotic capsule	Fracture involving otic capsule	Left CI (another centre)	40% SR (36 mo)
		4	Fracture involving cochlea	Fracture involving cochlea	CI (side NS)	SR NS (follow-up NS) Full-time user
		5	No visible fracture	Fracture involving otic capsule	Right CI	70% SR[a] (18 mo)
Greenberg et al., 2010 (4)	11	1	Transverse fracture	Transverse fracture	Right CI	22% CID (12 mo)
		2	No visible fracture	Transverse fracture	Left CI	16% CID (12 mo)
		3	Transverse fracture	Transverse fracture	Left CI	73% CID (12 mo)
		4	No visible fracture	Transverse fracture	Right CI	92% CID (12 mo)
		5	Transverse fracture	No visible fracture	Left CI	NA
		6	No visible fracture	No visible fracture	Right CI	NA
		7	No visible fracture	No visible fracture	Right CI	NA
		8	Transverse fracture	Transverse fracture	Right CI	100% CID (12 mo)
		9	No visible fracture	Transverse fracture	Right CI	88% CID (12 mo)
		10	Transverse fracture	Transverse fracture	Right CI	NA
		11	No visible fracture	No visible fracture	Right CI	100% CID (12 mo)
Serin et al., 2009 (5)	5	1	Transverse fracture involving vestibule	Extralabyrinthine fracture	Left CI	100% 3-syll WR (12 mo) 92% SR open set
		2	No visible fracture	No visible fracture	Right CI	96% 3-syll WR (12 mo) 96% SR open set
		3	Transverse fracture involving vestibule	Transverse fracture involving vestibule	Right CI	100% 3-syll WR (12 mo) 88% SR open set
		4	Transverse fracture involving vestibule	Transverse fracture involving vestibule	Right CI	96% 3-syll WR (12 mo) 84% SR open set
		5	Transverse fracture involving vestibule + cochlea	Transverse fracture involving vestibule + cochlea	Left CI	84% 3-syll WR (12 mo) 80% SR open set
Camilleri et al., 1999 (20)	7	1	No visible fracture	No visible fracture	Right CI	61% BKB (9 mo)
		2	TB fracture, location NS	TB fracture, location NS	Right CI	95% BKB (9 mo)
		3	Fracture involving promontory	No visible fracture	Right CI	68% BKB (9 mo)
		4	Skull base fracture No visible TB fracture	Skull base fracture No visible TB fracture	Right CI	100% BKB (9 mo)
		5	Skull base fracture No visible TB fracture	Skull base fracture No visible TB fracture	Right CI	90% BKB (9 mo)
		6	Skull fracture, location NS	Skull fracture, location NS	Right CI	44% BKB (9 mo)
		7	No visible fracture	Labyrinthine fracture	Right CI	56% BKB (9 mo)

NS indicates not specified; CID, Central Institute for the Deaf Sentence score; NA, not available; 3-syll, trisyllabic; WR, word recognition; BKB, Bamford, Kowal and Bench sentence test; TB, temporal bone.
[a]Reported by the patient.

TABLE 4. *Review of the literature on the most recent case reports of patients treated with cochlear implantation after traumatic bilateral deafness*

Case report	No. of implants	Ref.	Right ear	Left ear	Treatment	Results (follow-up)
Chen and Yin, 2012	1	(6)	Fracture involving cochlea	Fracture involving cochlea	Right CI	Able to use telephone WRS and SRS NS
Zanetti et al., 2010	2	(17)	Fracture involving vestibule	Fracture involving vestibule	Bilateral simultaneous CI	100% WRS[a] (18 mo) 100% SRS[a] (18 mo)
Chung et al., 2010	2	(18)	Labyrinthine fracture involving promontory	Labyrinthine fracture	Bilateral staged CI	RCI: 100% WRS (2 mo) PTA 32 dB LCI: WRS NS PTA 36 dB
Shin et al., 2008	1	(7)	Fracture involving cochlea	Fracture involving cochlea + IAC	Right CI	70% SRS[b] (18 mo)
Simons et al., 2005	1	(8)	Fracture through the otic capsule involving vestibule and PSC	Fracture trough the otic capsule	Left CI	CID 174/200 (6 mo)

WRS indicates word recognition score open set; SRS, sentence recognition score open set; NS, not specified; RCI, right cochlear implant; LCI, left cochlear implant; PTA, pure tone average; dB, decibels; IAC, internal auditory canal; PSC, posterior semicircular canal.
[a]With both CIs.
[b]Understands 70% of the conversation with his/her family.

given in Tables 3 and 4 and in reference (10) for ABI auditory evaluation.

DISCUSSION

Temporal bone fractures occur from high-energy impacts, mainly but not exclusively from car accidents. Various mechanisms have been described in which the forces involved in a temporal bone trauma can account for the auditory damage: 1) direct injury to the acoustic nerve; 2) direct injury to the otic capsule with disruption of the membranous labyrinth, vascular vasospasm, thrombosis, or hemorrhage into the inner ear; 3) perilymphatic fistula; and 4) occlusion of the vestibular aqueduct by the fracture line, with secondary endolymphatic hydrops (19). In addition, 5) pressure waves can be transmitted through the cranial skeleton directly to the cochlea, resulting in damage to the organ of Corti and concussion of the temporal bone without appreciable fracture lines (2).

Cochlear implantation has been demonstrated to be effective for hearing rehabilitation in patients with bilateral TB fractures (3–7,17,18,20). It remains the standard hearing rehabilitation treatment for TB fractures without compromise of the cochlear nerve, with hearing results comparable to other etiologies of deafness (4,20). Results of cochlear implantation remain widely superior and more predictable than ABI results, regardless of the cause of deafness (9). After revising our own experience and performing an extensive literature review, we have found that the hearing outcomes from cochlear implantation in bilateral deafness after head trauma are clearly superior to ABI results. Only in cases where direct trauma to the cochlear nerve is the pathologic mechanism producing hearing loss, rehabilitation with a CI may be unsuccessful. However, total deafness from bilateral cochlear nerve trauma is exceptionally unlikely (21).

Traditionally, the standard indication for ABI was patients aged older than 12 years with neurofibromatosis Type 2 (22). In 2004, Colletti et al. (10) published the first and only series in the literature on ABI to restore hearing after TB trauma. Since then, other authors have also mentioned this possible indication (8,13,17). Recently, it was also included in a consensus statement from a multicenter report of ABI paediatric implantation (23).

Some authors (10,13) suggest an ABI as the treatment of choice in cases of bilateral TB fracture with avulsion of both cochlear nerves. It is questionable whether this severity of traumatism is compatible with life. There is not a single case in the literature of bilateral cochlear nerve

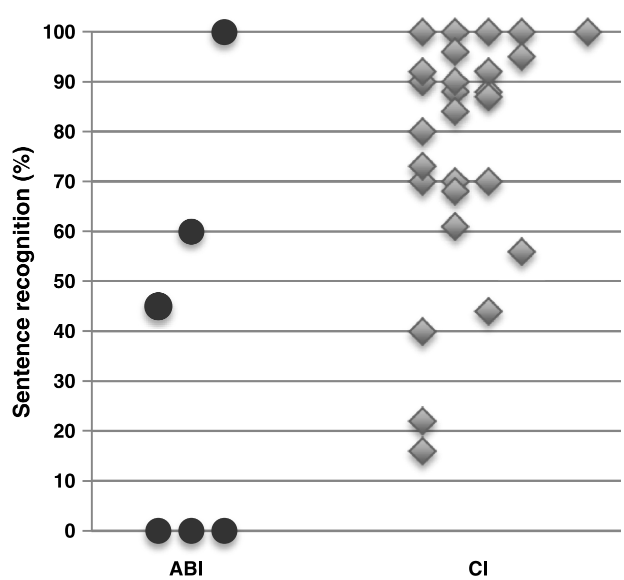

FIG. 7. Comparison of sentence recognition (SR) scores (%) in patients treated with ABI versus CI. For auditory evaluation tests, see references (3–8, 10, 17, 18, and 20).

avulsion after trauma, and the patients that have received an ABI after head trauma (10) had bilaterally intact auditory nerves on MRI, as the authors themselves reported. Only 1 case has been reported with unilateral traumatic avulsion of the VIIth and VIIIth nerve complexes (24). The authors hypothesized that it was the age of the child (3.5 yr) and the immaturity of the skull that permitted lateral displacement of the petrous bone in the occipital trauma, without lethal or serious brain injuries.

Another clinical situation is when the fracture line extends very close or compromises the IAC. In cases of bilateral TB fracture, if there is a radiologic suspicion of extension of the fracture line to the IAC on one side, a CI can be placed on the contralateral side (7) before considering insertion of an ABI. This will provide better hearing outcome. In our series of 15 fractured inner ears, we had only 1 case (6%) of unilateral involvement of the IAC (Fig. 2), this patient was implanted on the contralateral side with satisfactory results. There are no case reports in the literature of bilateral TB fractures involving both IACs.

If a lesion of the VIIIth cranial nerve is suspected, heavily T2-weighted MRI sequences should be obtained (i.e., fast imaging employing steady-state acquisition sequence [FIESTA]). MRI is very sensitive in detecting nerve compression secondary to hematoma, nerve transaction, or axonal injury. Moreover, the FIESTA sequence generates very high signals from tissues with large T2/T1 ratios, making it an ideal scan for cranial nerve assessment at the cerebellopontine angle and IAC (24).

The role of electrophysiologic testing to predict the presence and function of the cochlear nerve prior to CI placement has been largely debated. Positive promontory stimulation test (PST) is correlated with superior speech perception after cochlear implantation, but the absence of PST response does not necessarily indicate the absence of VIIIth cranial nerve function (25,26).

In the presence of bilateral labyrinthine fractures with normal cochlear nerves on MRI, some authors (10) advocate for the insertion of an ABI instead of a CI on the basis of a negative round window test (RWT). They state that this test is more sensitive than promontory stimulation test (PST). This fact that has not been demonstrated in scientific research (27).

To date, the minimum number of ganglion cells required for successful cochlear implantation is still unknown. There has not been any correlation found between the number of surviving ganglion cells and the performance of a CI (28). Postmortem studies show that as few as 3,000 surviving ganglion cells in patients that had useful auditory sensation after cochlear implantation (29).

Similarly, the minimum number of ganglion cells needed to obtain a positive response in PST is unknown. It is possible that the remaining ganglion cells after a TB trauma cannot elicit a response in PST but could be enough for successful cochlear implantation. Therefore, the only reliable way to determine if cochlear implantation will provide benefit is to perform the CI procedure.

We believe that in patients deafened after TB trauma, without evidence of cochlear nerve damage on MRI, it is not indicated to place an ABI based exclusively on the absence of response on electrophysiologic testing. This is a negative result is not demonstrative of the absence of cochlear nerve function (25,26).

Another issue to be considered after a TB fracture is the risk of cerebrospinal fluid (CSF) leak and meningitis. This risk ranges from 2% to 40% for a CSF leak and 12% to 15% for meningitis, depending on the structures involved by the fracture line (30,31). A fracture violating the otic capsule creates a communication between the central nervous system and the middle ear. It is known that the bone of the otic capsule does not heal by callous formation but with a thin layer of fibrous tissue that constitutes the new barrier between the central nervous system and the extradural space (32). Theoretically, this leaves the patient with a permanent risk of CSF leak and meningitis (33).

Some authors (10) advocate that the risk of meningitis precludes placing an electrode inside the cochlea in the presence of fractures crossing the labyrinth. They consider it safer to place an ABI by means of a retrosigmoid approach. However, if there is an active CSF leak, this risk of meningitis can be diminished by using a subtotal petrosectomy (30,33,34) in association with CI insertion. In accordance with these authors, we prefer to perform a double blind sac closure of the external auditory canal, with sealing of the eustachian tube and obliteration of the middle ear cavity with autologous abdominal fat.

Another complication that has been described associated with cochlear implantation in fractured cochleae is a higher incidence of facial nerve stimulation. Camilleri et al. (20) reported this complication in 2 of 7 patients with CI after TB fracture. It is assumed to be caused by electrode stimulation of the facial nerve in the area of geniculate ganglion through the low resistance of the fracture line. In contrast, from our series of 8 cochlear implantations in fractured temporal bones, we had no incidence of facial nerve stimulation; this is consistent with reports by other groups (3,4). In the majority of cases, this complication can be solved by programming adjustments (20) and should not be considered an argument in favor of ABI placement.

One possible mechanism hampering CI insertion may be ossification of the cochlea after trauma (10). As soon as the patient is medically stable, cochlear patency should be evaluated, similar to meningitis patients (9). From reviewing the literature, the incidence of labyrinthitis ossificans after temporal bone fracture and the period needed for new bone formation is relatively unknown (3,7).

Among our 15 fractured inner ears, imaging showed total cochlear obliteration in 1 case and partial obliteration in 2 cases. These patients were implanted on the contralateral side.

Hagr (3) found no cases of labyrinthitis ossificans on MRI from a series of 5 patients with bilateral temporal bone fractures.

Camilleri et al. (20) in his series of 7 patients implanted with CI after bilateral TB fracture, observed unilateral partial obliteration of the basal turn of the cochlea in 2 patients and unilateral total obliteration in 1 patient. The 2 patients with partial obliteration were successfully implanted and benefited from a CI. The patient with the total obliteration had to be explanted because poor CI performance and facial nerve stimulation. An implantation was then performed on the contralateral side, achieving a satisfactory result. None of these patients had any indication for an ABI.

Greenberg et al. (4) with a total of 13 patients with a CT proven TB fracture, found unilateral labyrinthitis ossificans in 1 patient and bilateral labyrinthitis ossificans in another patient (17.6% incidence of labyrinthitis ossificans in fractured cochleae). The patient with unilateral labyrinthitis ossificans was successfully implanted; no abnormal intraoperative findings were reported. He had a poor outcome with the CI and was lost to follow-up. The patient with bilateral labyrinthitis ossificans was judged not to be suitable candidate for implantation because of the severity of his brain injuries and subsequent cognitive deficit.

It is our belief that the correct indication for an ABI in advanced cochlear obliteration is if no lumen is found after a drill-out attempt (35).

The only case described in the literature of complete bilateral cochlear ossification was assessed only by means of CT scan. Moreover, because of his brain sequelae, this patient was not considered candidate for implantation. Therefore, this indication of ABI remains theoretical.

The idea that fractures involving the cochlea may present with difficult CI electrode insertion because of distorted anatomy and fracture line displacement is widely reported in the literature. In this report, we have 6 cases of fractured cochleae, four of them underwent CI placement (patients G and K single-sided and patient I bilaterally). We did not encounter any difficulty during CI insertion (Fig. 3), and patients achieved sentence recognition ranging from 70% to 100% (mean follow-up of 75 mo; range, 16–156 mo). In a literature review, we identified 6 cases with fractures involving the cochlea being implanted ipsilaterally; authors report successful CI insertion and similar results to our series, ranging from 70% to 100% for sentence recognition (3,5–7,18).

Fractures that damage the cochlea may lead to the loss of spiral ganglion cells over time. (14). Some authors state that these secondary postganglionic injuries could cause the CI to fail (6) or decrease the results with the passage of time. The risk of osteoneogenesis, after hemorrhage in the cochlea, has also been postulated as other possible mechanism of decreased CI performance (10). In contrast to these observations, we have not experienced a decrease in the hearing performance in any of our patients with the passage of time (Fig. 6).

CONCLUSION

Cochlear implantation after TB fractures has proven to have excellent audiometric results. These results are clearly superior to ABI and comparable with other etiologies of deafness. The aim of the initial evaluation of a patient with bilateral anacoustic ears from head trauma should always be to rehabilitate their hearing with a CI. The incidence of labyrinthitis ossificans, negative electrophysiologic testing, the risk of postoperative meningitis, or facial nerve stimulation should not be the determinant factors that favor ABI placement. If cochlear nerve damage is suspected on MRI, cochlear implantation should be performed on the contralateral side. Therefore, ABI may be indicated in TB fractures when cochlear implantation has failed to provide a hearing benefit or CI insertion was not successful because of cochlear ossification. In addition, brainstem implants may have a theoretical role in patients with petrous bone fractures associated with transection of both cochlear nerves. As far as we know, such cases have never been described in the literature and probably are not compatible with life. After literature review and our own experience of 30 years of being a quaternary otologic referral center, we have not identified a single case in which an ABI was a correct indication for hearing restoration after a bilateral TB fracture.

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