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Ossicular chain disruption – a case report and literature review

Uszkodzenie kosteczek słuchowych – opis przypadku i przegląd literatury

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SŁOWA KLUCZOWE:

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SUMMARY

The ossicular chain, consisting of the malleus, incus, and stapes, plays a critical role in the sound transmission and amplification in the middle ear. Disruptions of this chain, caused by factors such as trauma, chronic otitis media, congenital abnormalities, or idiopathic conditions, like otosclerosis, can lead to the significant conductive hearing loss. Trauma, particularly temporal bone fractures, is a leading cause of the ossicular chain dislocation. The right diagnosis often requires high-resolution imaging, such as CT scan of the temporal bone (high resolution computer tomography – HRCT), though some cases are confirmed only during surgical exploration. Persistent conductive hearing loss, especially over six weeks post-trauma, strongly suggests ossicular chain disruption. Treatment options include conservative management, like hearing aids, or surgical intervention.

We would like to present a case of a girl with conductive hearing loss diagnosed 4 months after head injury due to ossicular chain disruption. We also performed literature analysis concerning this problem.

STRESZCZENIE

Łańcuch kosteczek słuchowych, składający się z młoteczka, kowadełka i strzemiączka, odgrywa kluczową rolę w przekazywaniu i wzmacnianiu dźwięku w uchu środkowym. Rozłączenie łańcucha kosteczek słuchowych, spowodowane czynnikami, takimi jak: uraz, przewlekłe zapalenie ucha środkowego, wrodzone nieprawidłowości lub idiopatyczne, m.in. otoskleroza, mogą prowadzić do znacznego przewodzeniowego upośledzenia słuchu. Urazy, w szczególności złamania piramidy kości skroniowej, są główną przyczyną przemieszczenia kosteczek w obrębie łańcucha kosteczek słuchowych, w tym z ich zwichnięciem w odpowiednich stawach. Prawidłowa diagnoza zazwyczaj wymaga obrazowania wysokiej rozdzielczości, takiego jak tomografia komputerowa kości skroniowej (HRCT), chociaż niektóre przypadki są ostatecznie potwierdzane dopiero śródoperacyjnie. Utrzymujący się niedosłuch przewodzeniowy, zwłaszcza powyżej 6 tygodni od urazu, z dużym prawdopodobieństwem sugeruje przerwanie łańcucha kosteczek słuchowych. Możliwości leczenia w tej sytuacji obejmują leczenie zachowawcze, takie jak aparaty słuchowe lub interwencję chirurgiczną.

Chcielibyśmy przedstawić przypadek dziewczynki z niedosłuchem przewodzeniowym rozpoznanym 4 miesiące po urazie głowy, w którym tomografia komputerowa ujawniła uszkodzenie łańcucha kosteczek słuchowych. Przeprowadziliśmy także analizę literatury obejmującej to zagadnienie.

INTRODUCTION

We analyzed articles available in the published literature dealing with the problem of an ossicular chain disruption. The most important issues concerning the diagnosis, differentiation and treatment of the different types of disruption are gathered and discussed below. We would also like to present a clinical case of a child with ossicles' dislocation after a traffic accident as an illustration of the problem.

There are three bones in the middle ear, which form the ossicular chain – malleus, incus and stapes (fig. 1). The malleus is formed by the head, the neck, the manubrium, the anterior process, and the lateral process. The incus is divided into the body, the short crus, the long crus, and the lenticular process. In the stapes the head (capitulum), the neck, the anterior crus, the posterior crus, and the footplate are distinguished (1). The malleus connects with the tympanic membrane at three key points: the lateral process, the manubrium, and the umbo. Meanwhile, the stapes footplate is anchored to the otic capsule by the annular ligament. The incus, positioned between the malleus and stapes, connects with these ossicles through two synovial diarthrodial joints: the incudomalleolar joint with the malleus and the incudostapedial joint with the stapes. The ossicles take part in the mechanical transduction of the acoustic wave from the tympanic membrane into the fluid-filled cochlea. In addition to the sound transmission, they amplify it through their lever mechanism and natural resonance. Disruption of this conductive pathway can result in a significant hearing loss of approximately 50-60 dB (2).

There are different disorders of the middle ear space that may affect the ossicular chain, like:

- otitis media – acute or chronic,
- trauma – blunt or penetrating,
- congenital factors – aural atresia, congenital ossicular fixation, malformation, or absence,
- idiopathic causes – otosclerosis,
- neoplasms.

Chronic otitis media and its complications, such as cholesteatoma and ossicular erosion, account for more than

80% of all ossicular chain disruption cases (3). The most common injury leading to the ossicular chain dislocation is the temporal bone trauma (4) and can occur with or without a temporal bone fracture (5). Most popular mechanisms of such trauma are road traffic collisions, falls and interpersonal violence (4-6). Other, less frequent, causes include:

- indirect traumas – affecting contralateral side of the head (7),
- blast injuries (4, 8),
- direct traumas – instruments or foreign bodies inserted in the external auditory canal and overcoming the barrier of tympanic membrane (9, 10),
- barotrauma (sudden pressure changes) (11).

Ossicular chain dislocation is most frequently observed in young males aged 16 to 30 (12). Up to 50% of temporal bone fractures result in the ossicular injury (13), with ossicular discontinuity or fixation accounting for approximately 55% of conductive hearing loss cases (14). Hearing loss is reported in 75% of patients during the first week after a head injury, decreasing to 37% after 3 to 6 weeks. Persistent conductive hearing loss beyond six weeks is often due to ossicular chain dislocation, occurring in about 4% of all head trauma cases (15). Additionally, cholesteatoma, a frequent complication of chronic otitis media, is responsible for 80% of ossicular chain disorders (fig. 3), with the incus being the most affected bone (fig. 3) (16).

Most patients with ossicular chain injuries present after head trauma, with hearing loss as a primary complaint. A thorough otoscopic examination is essential and may reveal posttraumatic injuries, that can also cause hearing loss and should be ruled out, such as blood in the external auditory canal, hemotympanum, perforated tympanic membrane, or cerebrospinal fluid (CSF) leakage. Additional associated findings may include facial palsy, tinnitus, vertigo (13).

Meriot et al. (12) identified five primary types of ossicular chain injuries, including:

- disarticulation of the incudostapedial joint (fig. 2),
- disarticulation of the incudomalleolar joint (fig. 4),
- luxation of the incus (figs. 5, 6),

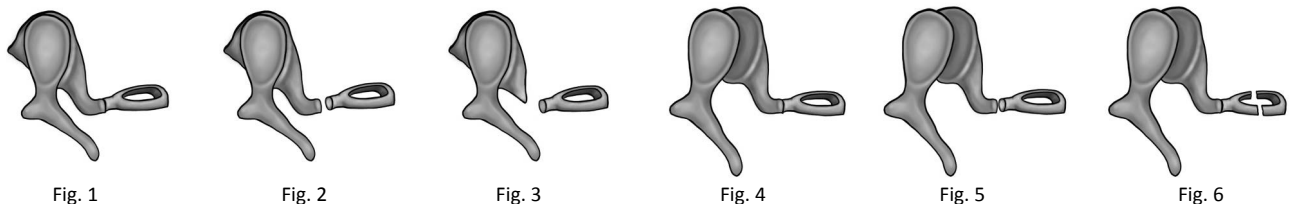


Fig. 1. Normal ossicular chain: malleus, incus, stapes. Author's own graphics, G. Łocik

Fig. 2. Incudostapedial joint separation

Fig. 3. Erosion of the long process of the incus most often occurs because of chronic otitis media or cholesteatoma. The long process sometimes fractures, especially following stapes surgery or in osteogenesis imperfecta

Fig. 4. Incudomalleolar joint separation

Fig. 5. Dislocation of the incus – incudomalleolar joint separation associated with the incudostapedial joint separation

Fig. 6. Dislocation of the incus – incudomalleolar joint separation associated with the stapes fracture

- luxation of the incudomalleolar complex,
- luxation of the stapes.

The incudostapedial joint is the most common site of dislocation identified during surgical exploration (17-19) (fig. 2). It is often the first to sustain injury, due to its delicate enarthrosis structure. An additional proposed mechanism for its disruption involves the stapedius and tensor tympani tendons. The stapedius tendon, which attaches to the stapes head near the joint, and the tensor tympani tendon, which anchors the malleus neck, may undergo reflexive tetanic contractions during severe head trauma. These contractions can force the incus medially while simultaneously pulling the stapes head posteriorly, leading to joint disarticulation (12).

The incudomalleolar joint is a saddle-shaped diarthrodial articulation located in the tympanic recess. The malleus, being firmly anchored by its attachment to the tympanic membrane, anterior ligaments, and the tendon of the tensor tympani muscle, is typically more stable. In cases of trauma, the malleus usually remains in place or exhibits minimal movement due to its secure positioning. In contrast, the heaviest ossicle – incus, has no muscular anchor and has the weakest soft-tissue attachments among the ossicles. As a result, displacement of the incus can range from moderate to severe (12). Radiographic studies often report the incudomalleolar joint as the most frequently dislocated (18, 20) (fig. 4), this discrepancy between surgical and radiological findings probably arises as the incudostapedial joint is harder to detect on CT imaging (21). The incudomalleolar disarticulation is easily identified on the axial CT scans, which typically reveal the malleus head (“scoop of the ice cream”) separated from the incus body and short process (“cone”). Coronal CT scans can further clarify the positions of the ossicles, particularly in cases of significant displacement or when the incus is slightly displaced laterally. Dislocation of the incus occurs when the incudomalleolar joint separation is associated with the incudostapedial joint separation (fig. 5) or stapes fracture (fig. 6). Dislocation of the incudomalleolar complex happens when the incudomalleolar joint resists traumatic forces, causing the entire complex to shift into the lower portion of the tympanic cavity. This type of an injury is often accompanied by the separation of the incudostapedial joint (12) (fig. 2).

Stapedovestibular dislocation is a rare injury due to the strong attachment of the stapes to the oval window by the annular ligament. There are two types of this dislocation: internal and external. Internal dislocation occurs when the stapes is displaced from the oval window and pushed into the vestibule. In contrast, external dislocation happens when the annular ligament is torn, causing the stapes footplate to shift into the tympanic cavity (12).

Ossicles’ fractures are extremely rare. The malleus typically fractures at the neck or manubrium and such trauma is often associated with other severe middle ear injuries. Incus fractures usually involve the long or lenticular process,

though, in rare cases, the body of the incus can also be affected. Stapes fractures generally result from torsional forces, while fractures of the footplate primarily occur due to the translabyrinthine fractures that pass through the oval window (12).

When assessing a head-injured patient, the primary focus is on identifying and ruling out severe injuries. A thorough neurological examination should be conducted, including the establishment of a Glasgow Coma Scale (GCS) score, comparison of pupil sizes, and evaluation of the motor strength and sensation (22). A CT head scan is typically performed, and if a temporal bone fracture is identified, it is essential to differentiate between otic capsule-sparing and otic capsule-violating fractures, as this distinction serves as the most reliable indicator of potential middle and inner ear damages (23). Once the patient is stable, an audiogram should be performed promptly to establish a baseline for hearing loss. Hearing loss exceeding 25 dB in a patient with a longitudinal fracture of the temporal bone pyramid warrants suspicion of an incudostapedial joint damage or incus dislocation (24). At this stage, conductive hearing loss may be due to the ossicular disruption, tympanic membrane perforation or hemotympanum, making differentiation difficult (12). In some cases, such as stapedovestibular subluxation, mixed hearing loss may occur. It is also important to remember that multiple pathologies can coexist, such as post-traumatic inner ear hemorrhage, perilymphatic fistula or endolymphatic hydrops (20). A follow-up audiogram should be repeated after at least six weeks, by this time hemotympanum is expected to resolve. Persistent conductive hearing loss with an intact tympanic membrane strongly indicates ossicular chain dislocation. Tympanometry can further confirm this by showing increased compliance, which is characteristic of ossicular discontinuity (13). A dedicated temporal bone high-resolution CT scan is recommended to provide sufficient detail for the ossicles’ imaging. However, even with advanced imaging techniques, certain ossicular chain dislocations may remain undetected and can only be confirmed and evaluated during surgical exploration of the middle ear. Tympanotomy continues to be the “gold standard” audiological tool for diagnosing ossicular chain injuries (19).

In patients with conductive hearing loss lasting more than six months, treatment options include conservative management, with or without hearing aids, or surgical intervention in a form of ossiculoplasty (5, 19). Surgery is contraindicated in cases with ongoing middle ear infections, reduced middle ear space, repeated surgical failures with similar prostheses. Special care (with conservational non-surgical treatment or transfer to a specialist center) should be taken in cases when there is a stapes fixation, middle or inner ear malformations, or when the affected ear is the patient’s only hearing ear. Alternative options, such as conventional hearing aids or bone-conduction devices, should always be considered as part of the rehabilitation plan (25).

According to the literature, surgical intervention is sometimes delayed, with successful hearing results, even with the average time between the injury and surgery exceeding five years (4, 5, 19). Middle ear exploration is conducted under general anesthesia to evaluate the continuity and mobility of the ossicular chain with the intention to identify any ossicular chain disruptions and perform ossiculoplasty if needed. There are many types of reconstruction methods for the ossicular pathologies, depending on the type and location of the ossicular injury. Access to the middle ear cavity can be achieved using either a transcanal or postauricular approach. Transcanal approach is a minimally invasive method that accesses the middle ear directly through the auditory ear canal. This approach is preferred for straightforward cases. Postauricular approach, on the other hand, is recommended for patients with a narrow external auditory canal, bony protrusions in the auditory canal that narrow the operating field and complicate the transcanal approach, or when a concurrent mastoidectomy is planned. This approach, thanks to its broader access to the middle ear, gives better visualization of the structures, like stapes and oval window niche and is advised in complex repairs (25).

Once the middle ear cavity is accessed, the ossicles are examined for potential defects, and their continuity and mobility are evaluated. Reconstruction materials are selected based on the condition of the ossicles and may include autogenous or homogenous ossicular tissue, cortical bone grafts, bone cement, serving as partial and total prostheses. If the stapes capitulum is intact, a Partial Ossicular Replacement Prosthesis (PORP) is used to connect the stapes to the tympanic membrane or malleus. If the stapes footplate is intact and mobile, a Total Ossicular Replacement Prosthesis (TORP) is used to link the footplate to the tympanic membrane or malleus. Ensuring stapes footplate mobility is essential for achieving successful hearing outcomes (25).

The main complications associated with ossiculoplasty include failure to restore conductive hearing loss, necrosis of autologous bone grafts or remaining native ossicles, as well as prosthesis extrusion or migration. Less common complications include fractures of the stapes's superstructure, stapes displacement, disruption of the annular ligament at the oval window leading to a perilymphatic fistula, severe or total sensorineural hearing loss, and vertigo (26).

CASE REPORT

A 16-year-old girl was admitted to the Department of Pediatric Otorhinolaryngology at the Medical University of Warsaw due to right-sided hearing loss and periodic episodes of imbalance. Patient's medical history revealed that she had been involved in a pedestrian accident 5 months prior, in which she was struck by a car. Following the accident, she was hospitalized in the Intensive Care Unit (ICU) for two weeks. During her ICU stay, clinical examination documented multiple hematomas of the head and hearing impairment in the right ear. On the 1st day post-accident,

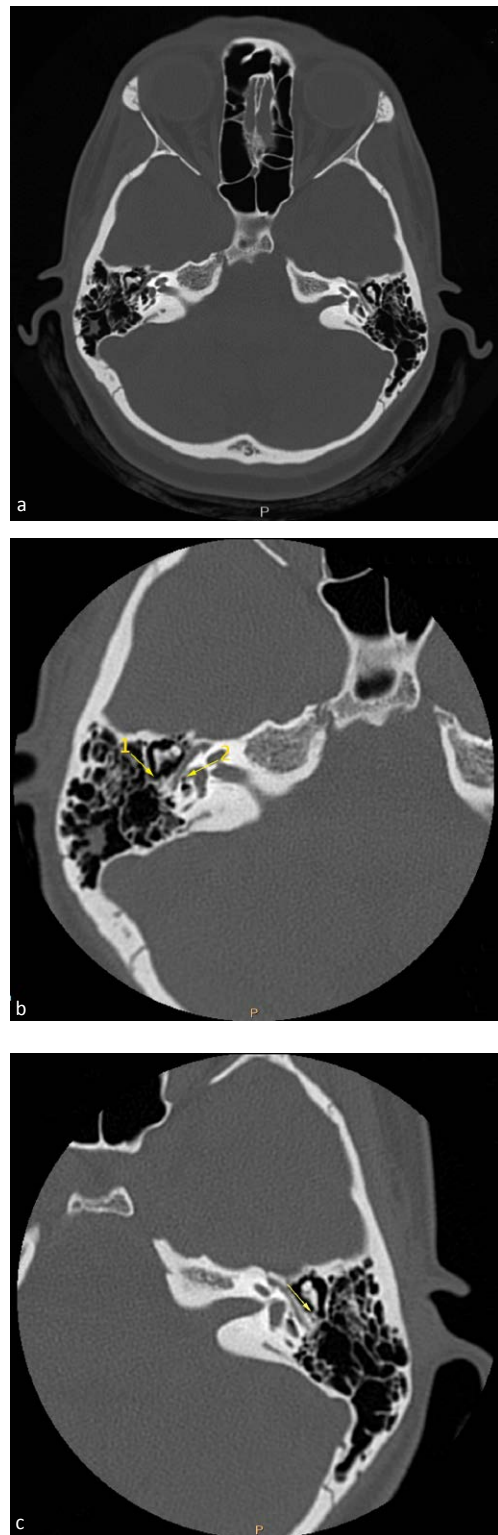


Fig. 7a-c. CT scan, axial plane, of the head, at the level of the temporal bone pyramid and tympanic cavity (a). In the right ear (b) there is a disruption of the incudomalleolar articulation – the body of the incus (1) is pulled away laterally from the head of the malleus (2). In the left ear (c) we can notice the characteristic “ice cream cone” arrangement, indicative of an intact malleoincudal complex (arrow).

audiological tests were conducted. Tympanometry showed a tympanogram type Ad in the right ear, indicative of an increased compliance of the sound-conducting apparatus (tympanic membrane, ossicles), likely due to the ossicular chain disruption. Tonal audiometry demonstrated conductive hearing loss up to 80 dB in the right ear, while the left ear remained within normal limits. Four months after the accident, advanced imaging was performed to further assess the injuries. CT scan confirmed dislocation of the auditory ossicles in the right middle ear (figs. 7-9). MRI revealed post-traumatic brain lesions, indicating accompanying intracranial injuries sustained during the accident.

Due to persistent conductive hearing loss with confirmed ossicular chain disruption in CT patient was qualified for explorative ossiculoplasty. Access to the tympanic cavity was achieved using postauricular approach. During operation ossicular chain disruption, together with its impaired mobility were noticed. The atrophy of the long process of the incus was also observed – the result of its posttraumatic dislocation. The stapes and the footplate presented normal mobility. The atrophic incus was carefully removed and reformed to become a prosthesis for reconstruction.



Fig. 9. CT scan, coronal plane, right-sided ossicular chain disruption

As a result, malleus stapes assembly (MSA) was created. A small perforation that occurred accidentally in the tympanic membrane during maneuvers with the ossicles was addressed using the underlay technique, with a temporalis fascia graft.

After procedure external auditory canal was filled with spongostan soaked with ciprofloxacin drops (Cetraxal) and seton soaked with chloramphenicol ointment (De-treomycin). The surgical dressing was removed seven days postoperatively, as the department's standard procedure. The recovery process went without complications. The graft integration was successful, the surgical site healed satisfactorily (figs. 10-13), and hearing was significantly restored.

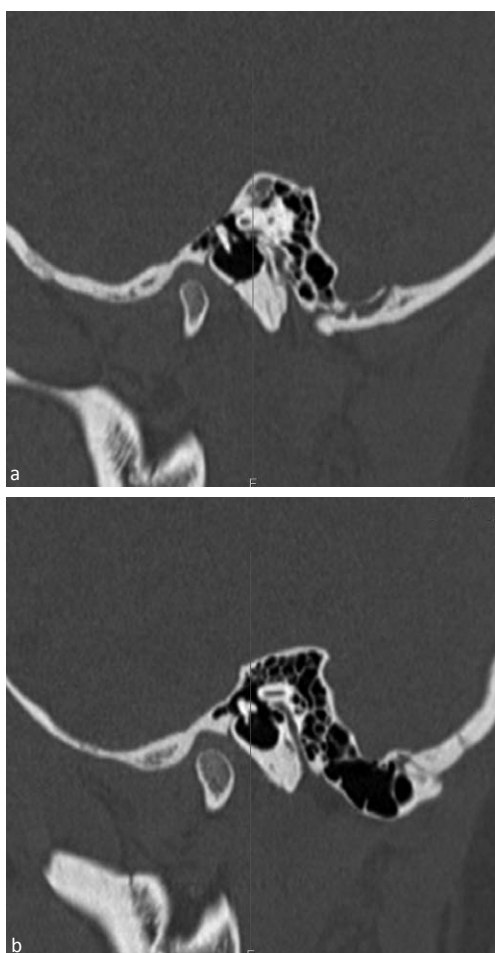


Fig. 8a, b. CT scan, sagittal plane, of the head, at the level of tympanic cavity and mastoid cells: right ear, ossicular chain disruption (a), left ear, intact ossicular chain (b)

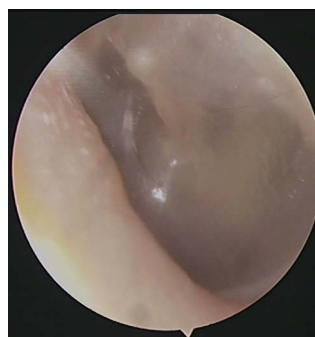


Fig. 10. Left ear otoscopy, one month after surgery: normal tympanic membrane. Authors' own material

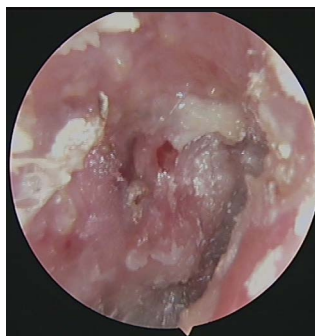


Fig. 11. Right ear otoscopy, one month after surgery: the process of healing. The graft was healing properly, with no signs of graft movement and perforation. Patient reported improved hearing. Authors' own material



Fig. 12. Right ear otoscopy, 4 months after surgery: the process of healing. Authors' own material



Fig. 13. Right ear otoscopy, 9 months after surgery: the process of healing. Authors' own material

Postoperative tonal audiometry revealed almost full closure of the air-bone gap, with air conduction reduced to 30 dB in the right ear (fig. 14). Process of healing in otoscopic examinations is presented below (figs. 10-13). Patient remains under regular controls and hearing results are monitored in an outpatient clinic.

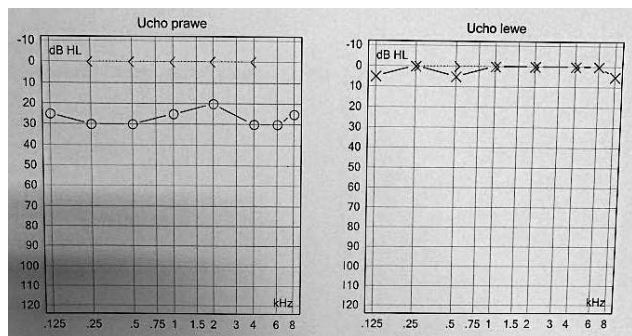


Fig. 14. Tonal audiometry results, 9 months postoperatively, right ear: air conduction reduced to 30 dB, left ear: normal

DISCUSSION

Presented above case emphasizes the importance of a thorough audiological evaluation, together with dedicated imaging tests, following a head trauma. Patient's conductive hearing loss was presumed as ossicular chain disruption through advanced CT imaging of the temporal bones, what enabled qualification and successful treatment with explorative tympanotomy (which confirmed the injury) followed by ossiculoplasty. Hearing impairment, especially in pediatric

population being at the point of intensive self-development, significantly impact quality of life.

According to the literature 'persistent' hearing loss requiring intervention, either conventional or operative, is the one lasting at least 6 months (5, 19). At the same time, delayed diagnosis is not uncommon, with the average time between injury and surgery exceeding five years (4, 5, 19) (with a range of even five months to 26 years (19)). This delay often arises as initial evaluations prioritize life-threatening injuries, and patients may not immediately associate hearing loss with trauma. However, when properly stated it still enables successful hearing restoration (4, 5, 19). So, our patient with four months post-traumatically was relatively quickly diagnosed and treated.

The incus is the most commonly injured ossicle due to its lack of muscular attachments, weak ligamentous support, and relatively high mass. In our patient, atrophy of the long process of the incus, which followed its posttraumatic dislocation was observed intraoperatively. During ossiculoplasty procedure the incus was removed and reformed to serve as autologous MSA prosthesis reconstruction. This aligns with the literature citing incudostapedial joint dislocation and incus damage as the most frequent outcomes of ossicular traumas (17). Management in this case was consistent with best practices for ossiculoplasty, which remains the 'gold standard' for the hearing restoration in patients with ossicular chain disruption. The use of an autologous prosthesis contributed to a successful outcome. Postoperative audiometric evaluation revealed a significant improvement, with air conduction loss reduced from 80 to 30 dB. This result aligns with the reported data concerning posttraumatic ossiculoplasty, stating an average air-bone gap closure of 35 dB following ossiculoplasty, with over 70% of patients achieving an air-bone gap of less than 20 dB (4, 5, 19).

Surgical management of post-traumatic ossicular chain disruption demonstrates favorable outcomes. Documentation of these interventions first appeared in scientific literature during the 1950s (27), establishing foundations for modern approaches. In a seminal 1973 study, Spector et al. (28) conducted a retrospective analysis of delayed reconstruction in 28 patients with ossicular fractures, documenting air-bone gap (ABG) closure within 10 dB in 66% of cases and within 20 dB in 82% of subjects. Their findings demonstrated superior audiological stability in incus replacement prosthesis and type III tympanoplasty interventions. Subsequent clinical investigations have corroborated these positive outcomes. Pedersen (29) reported a 78% success rate in traumatic ossiculoplasty, while Meriot et al. (12) achieved ABG reduction to ≤ 20 dB in 89% of patients and ≤ 10 dB in 67% of patients, with clinically significant ABG improvement (≥ 10 dB) in 84.3% of surgical recipients. More recent studies have refined these success parameters. Mundada et al. (30) achieved remarkable results utilizing fascial arthroplastic

ossiculoplasty for incus dislocation, with ABG normalization (≤ 10 dB) in 80.3% of patients. Mills and Starriit (6) demonstrated successful functional restoration through physiologic repositioning with incudostapedial joint stabilization via silicone splinting in traumatic disruption cases. Contemporary reconstructive approaches continue to show promising results. Yetiser et al. (4) implemented multiple reconstructive modalities, achieving a 72% success rate (ABG ≤ 20 dB), while Shabana (2009) documented an 89% success rate in 18 patients through innovative adaptation of teflon piston prostheses positioned directly on the mobile footplate – a technique particularly valuable in cases with stapes superstructure fracture.

CONCLUSIONS

Ossicular chain disruption should be considered in all patients with unilateral conductive hearing loss following head trauma, especially when the tympanic membrane is intact. Persistent hearing loss exceeding 30 dB, lasting beyond six weeks post-traumatically, requires advanced imaging and poses a risk of potential need for surgical exploration and intervention. In this case, ossiculoplasty with an autologous incus serving as a MSA prosthesis proved to be highly effective. A significant improvement in hearing at a short-term follow-up was achieved. However, long-term outcomes should be monitored to confirm its durability and a long-term success.

CONFLICT OF INTEREST KONFLIKT INTERESÓW

None
Brak konfliktu interesów

CORRESPONDENCE ADRES DO KORESPONDENCJI

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