CT Appearances of Ossicular Injuries[1]

Philippe Meriot, MD • Francis Veillon, MD
Jean François Garcia, MD • Michel Nonent, MD
Joseph Jezequel, MD • Pierre Bourjat, MD • Michel Bellet, MD

Trauma of the ossicular chain is a frequent complication of temporal bone injury. Skull trauma from blows to the temporal, parietal, or occipital region (with or without fracture of the temporal bone) is the main cause of ossicular injury; other modes of injury are rare. Ossicular injury usually occurs as a dislocation, of which there are five types: incudostapedial joint separation, incudomalleolar joint separation, dislocation of the incus, dislocation of the malleoincudal complex, and stapediovestibular dislocation. Fracture of the malleus, incus, or stapes is uncommon. High-resolution computed tomography is the method of choice for evaluation of ossicular trauma. Joint separation and fracture of the stapes are seen on axial images; coronal images may aid visualization. Both axial and coronal images are needed for evaluation of a dislocated malleus or incus. Fracture of the malleus or incus is detected with axial or coronal images; reformatted images may also be useful.

■ INTRODUCTION

Trauma to the middle ear usually manifests as conductive hearing loss. Trauma-related conductive hearing loss can be due to laceration of the tympanic membrane, hematotympanum, or ossicular damage (concomitant tubotympanic disease or preexistent fenestral otosclerosis can also cause conductive hearing loss). If the conductive hearing loss persists after resolution of the hematotympanum or healing of the tympanic membrane, ossicular dislocation or fracture must be suspected.

Trauma to the temporal bone is the main cause of ossicular disruptions and fractures; to manage these injuries, accurate radiologic evaluation should be performed as soon as possible. High-resolution computed tomography (CT) is the method of choice for evaluation of ossicular trauma. However, the radiologist must have a thorough knowledge of ossicular anatomy as seen on axial and coronal CT scans and reformatted images. In this article, we describe the normal anatomy of the ossicles, our clinical experience with ossicular trauma, and the mechanisms and CT features of ossicular injuries.

Index terms: Bones, injuries, 2121.40 • Ear, abnormalities, 2121.40 • Ear, CT, 2121.12118 • Ear, injuries, 2121.40

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[1]From the Departments of Radiology (P.M., M.N., M.B.) and Otolaryngology (J.J.), Centre Hospitalier Universitaire, Brest, France; the Department of Radiology, Hôpital d'Instruction des Armées Clermont Tonnerre, Brest, France (J.F.G.); and the Department of Radiology, Hôpital Hautepierre, Strasbourg, France (F.V., P.B.). Recipient of a Certificate of Merit award for a scientific exhibit at the 1995 RSNA scientific assembly. Received February 18, 1997; revision requested April 9 and received July 25; accepted July 25. **Address reprint requests to** P.M., Department of Radiology, Hôpital de la Cavale Blanche, Boulevard Tanguy Prigent, 29609 Brest, France.

■ NORMAL ANATOMY OF THE OSSICLES

In the axial plane, the malleoincudal complex is centered within the epitympanic recess (Fig 1); the position of the malleoincudal complex is sometimes slightly lateral but is never medial. The short process of the incus is centered in the incudal fossa. The malleoincudal complex resembles an ice-cream cone on axial images: The head of the malleus corresponds to the scoop of ice cream, and the body and short process of the incus correspond to the cone (1). The thin incudomalleolar articulation is best seen in the axial projection. However, the coronal plane can be helpful: Subtle disruption of this articulation is sometimes well seen on coronal images (1).

Axial images provide excellent information about the incudostapedial joint (2,3) (Fig 2). The head of the stapes and the lenticular process of the incus are seen, separated by the thin incudostapedial joint. The head, crura, and footplate of the stapes are evaluated on thin, overlapped axial sections; coronal sections through the oval (vestibular) window show the positions of the crura inside the oval window niche.

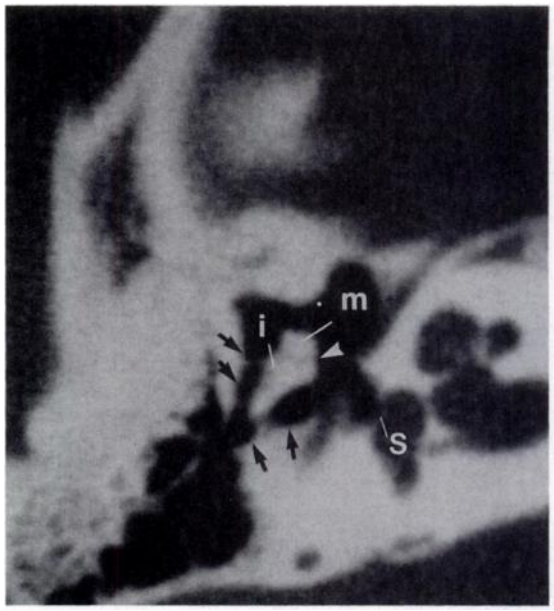


Figure 1. Normal malleoincudal complex. Axial CT scan of the right ear shows the "ice-cream cone" appearance of the malleoincudal complex. The head of the malleus (*m*) and the body and short process of the incus (*i*) are centered in the incudal fossa (arrows). Note the thin footplate (*s*) in the oval window. Arrowhead = incudomalleolar joint.

■ CLINICAL EXPERIENCE

The results of 513 CT examinations of patients with temporal bone trauma were retrospectively reviewed. The examinations were performed between 1984 and 1995 in 480 patients (33 patients had bilateral lesions). High-resolution CT was performed on CE 10000 (CGR, Paris, France), Excel 2400 (Elscint, Haifa, Israel), or Elite (Elscint) units. Scans were obtained in the axial plane only, the axial and coronal planes, or the axial plane with multiplanar reformation and were reviewed by two radiologists (P.M., F.V.).

Among the 513 cases of temporal bone trauma, there were 166 cases of ossicular injury (32%) in 163 patients (three had bilateral

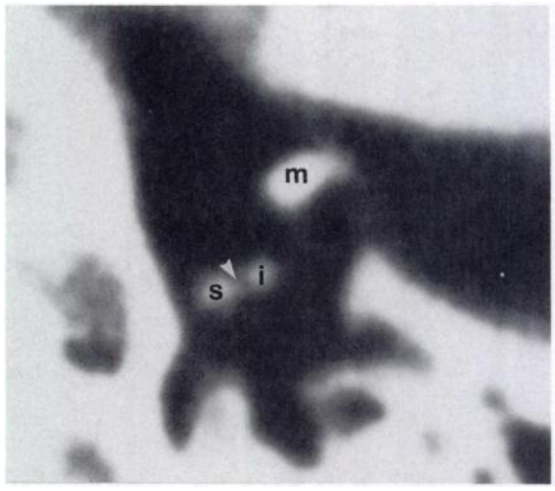


Figure 2. Normal incudostapedial complex. Axial CT scan of the left ear shows the lenticular process of the incus (*i*) and the head of the stapes (*s*). They are separated by the thin, dark line of the incudostapedial joint (arrowhead). *m* = malleus.

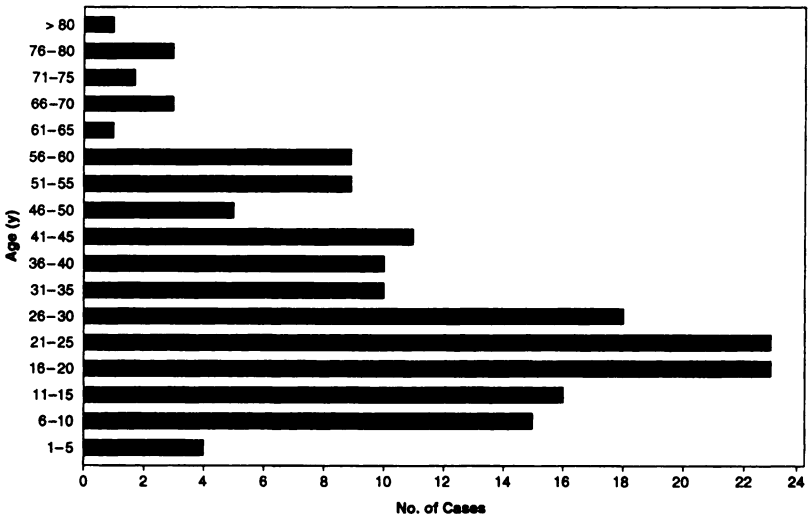


Figure 3. Age distribution. Diagram shows the age distribution of 163 patients with ossicular injury.

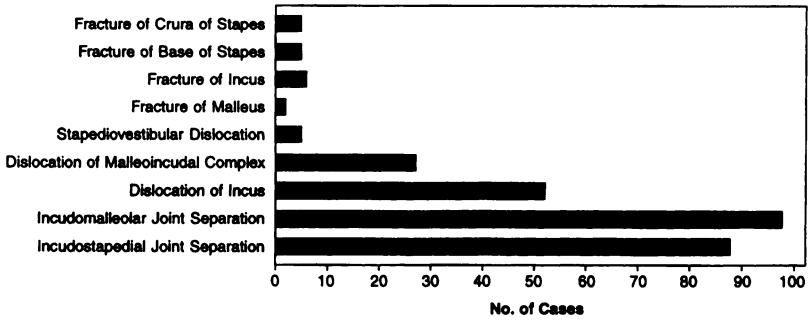


Figure 4. Injury distribution. Diagram shows the distribution of 288 cases of ossicular injury. The term *base of stapes* refers to the footplate.

lesions). These 163 patients (126 male and 37 female) were aged 5–82 years (Fig 3). Ossicular damage occurred on the left side in 77 cases and on the right side in 89 cases. The ossicular lesions often occurred in association with one another: There was a total of 288 dislocations or fractures in the 166 cases of ossicular injury. Dislocation was the major manifestation (270 cases); fractures were uncommon (18 cases) (Fig 4).

Skull trauma from blows to the temporal, parietal, or occipital bone, with (138 cases) or without (22 cases) fracture of the temporal bone, was the main cause of ossicular trauma (160 of 166 cases [96%]). Temporal bone fractures were longitudinal in 124 cases (90%), transverse in six cases (4%), and mixed in eight cases (6%). Other modes of injury occurred in six cases (4%): penetrating injury through the external auditory meatus by cotton-tipped applicators (n = 3) or a stone (n = 1), gunshot (n = 1), and surgical trauma (n = 1). Other possible modes of injury include blast, barotrauma, and lightning.

■ OSSICULAR DISLOCATION

• Incudostapedial Joint Separation

Incudostapedial disarticulation is the most common posttraumatic abnormality of the ossicular chain (4) owing to the tenuous suspension of the incus between the firmly anchored malleus and stapes (5). Because the incudostapedial articulation is a fragile enarthrosis, this joint is usually the first injured. Another mechanism for disruption of the incudostapedial joint has been postulated: The stapedius tendon most often attaches to the head of the stapes near the incudostapedial joint. The tendon for the tensor muscle of the tympanic membrane fixes the neck of the malleus. Tetanic contraction of these tendons as a result of severe head injury causes medial thrust of the incus and concomitant posterior pulling of the head of the stapes (3).

Many investigators believe that this site is the most often disrupted: At surgical exploration, Hough and Stuart (5) found incudostapedial joint separation in 82.3% of cases. However, incudostapedial disarticulation was not the most frequent injury in our series, occurring in only 88 of 166 injured temporal bones (53%). The lower prevalence of this injury in our series may have been due to the difficulty of accurately evaluating this joint in cases of hematotympanum when the joint displacement is slight; the incus and stapes can hold their positions even after trauma with preservation of a mucosal bridge (6).

The temporal bone fracture was longitudinal in 64 cases, transverse in two cases, and mixed in seven cases. In 15 cases, the injury occurred without a temporal bone fracture; in four of

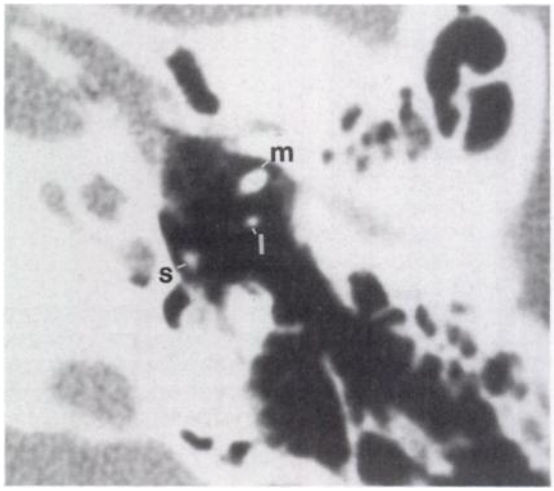


Figure 5. Incudostapedial disarticulation. Axial CT scan of the left ear shows the lenticular process of the incus (*l*) pulled away from the head and body of the stapes (*s*). *m* = malleus.

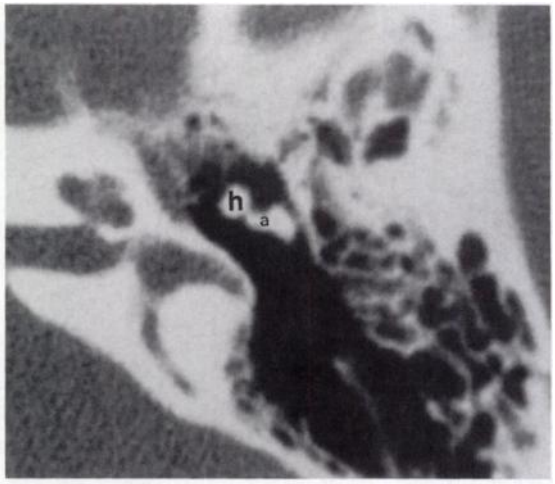
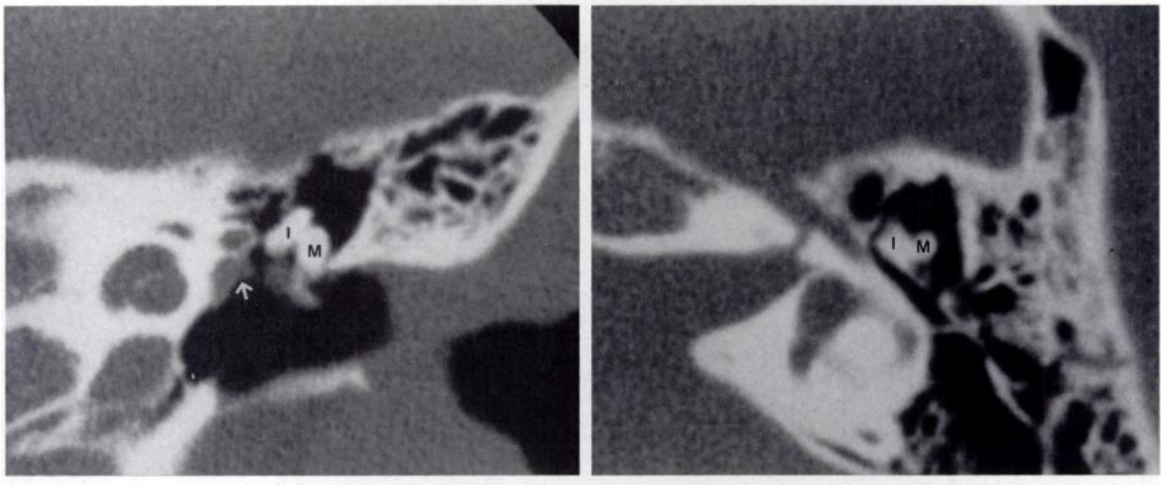


Figure 6. Incudomalleolar disarticulation. Axial CT scan of the left ear shows the body of the incus and its articulating surface (*a*) pulled away laterally from the head of the malleus (*h*).



a. b.

Figure 7. Incudomalleolar disarticulation. Coronal **(a)** and axial **(b)** CT scans of the left ear show the body of the incus (*I*) displaced medially and anteriorly, cutting the tendon for the tensor muscle of the tympanic membrane (arrow in **a**). The head of the malleus (*M*) is displaced laterally.

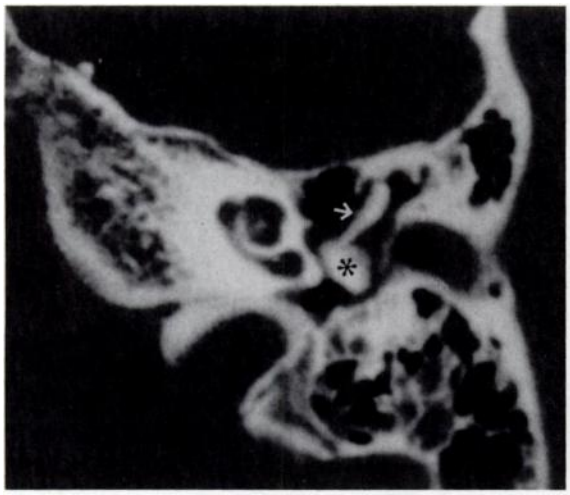
these cases, the joint separation was due to a penetrating injury through the external auditory meatus by cotton-tipped applicators (n = 2), a stone (n = 1), or unknown means (n = 1).

On axial CT scans or oblique reconstructions, disruption of the incudostapedial joint appears as abnormal enlargement of the dark cleft between the head of the stapes and the long process of the incus. This enlargement can be minor or significant (Fig 5).

• Incudomalleolar Joint Separation

The incudomalleolar joint, a saddle-shaped diarthrodial articulation, is protected in the epitympanic recess. The malleus is the more firmly attached ossicle; it is secured by the tympanic membrane, anterior and lateral mallear ligaments, and tensor muscle and tendon of the tympanic membrane. In cases of trauma, the malleus usually stays in place or moves slightly. On the contrary, the incus, the heavier ossicle (25 mg), has no muscular anchor and has the weakest soft-tissue attachments of all the ossicles. The displacement of the incus can be moderate (Fig 6) or severe (Fig 7).

Incudomalleolar disarticulation was the most frequent lesion in our series, occurring in 98 of 166 cases (59%); a similar result was found in the surgical series (5). The temporal bone fracture was longitudinal and extralabyrinthine in 79 cases, transverse and purely labyrinthine in four cases, and mixed in five cases. In 10 cases, the injury occurred without temporal bone fracture; in one of these cases, the joint separation was caused by penetrating injury through the external auditory meatus.



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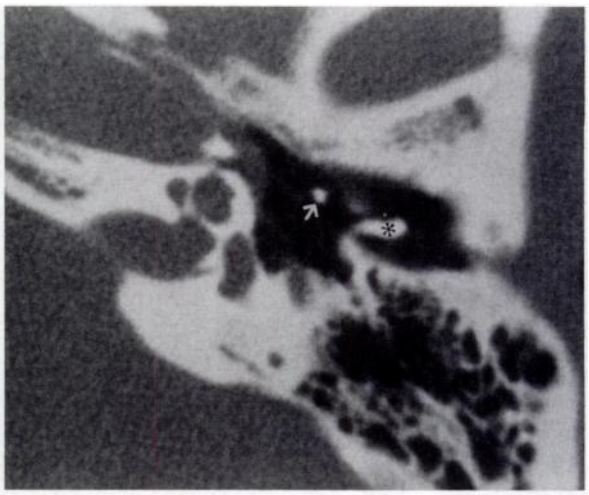
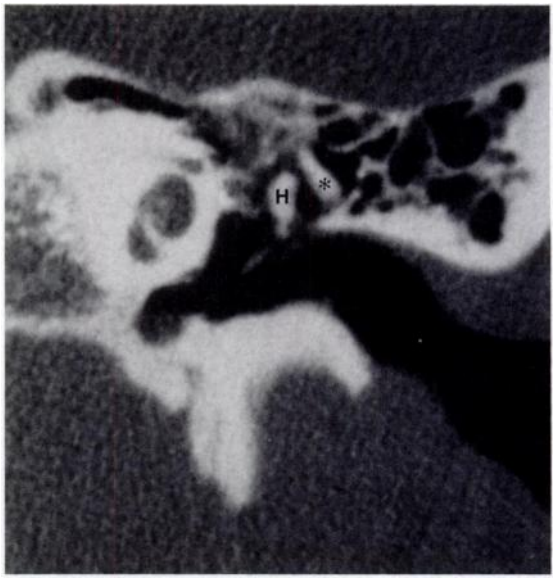


10.

Figures 8–10. **(8)** Dislocation of the incus. Coronal CT scan of the left ear shows the body of the incus (*) moved upward and forward, above the head of the malleus (*H*). **(9)** Dislocation of the incus in a 5-year-old boy. Axial CT scan of the left ear shows disruption of the ossicular chain due to a stone (*), which was pushed into the middle ear through the external auditory meatus. The incus (arrow) is displaced downward. **(10)** Dislocation of the incus. Axial CT scan of the left ear shows the incus (*) in the top of the external auditory meatus. The malleus (arrow) is in the normal position of the incus.



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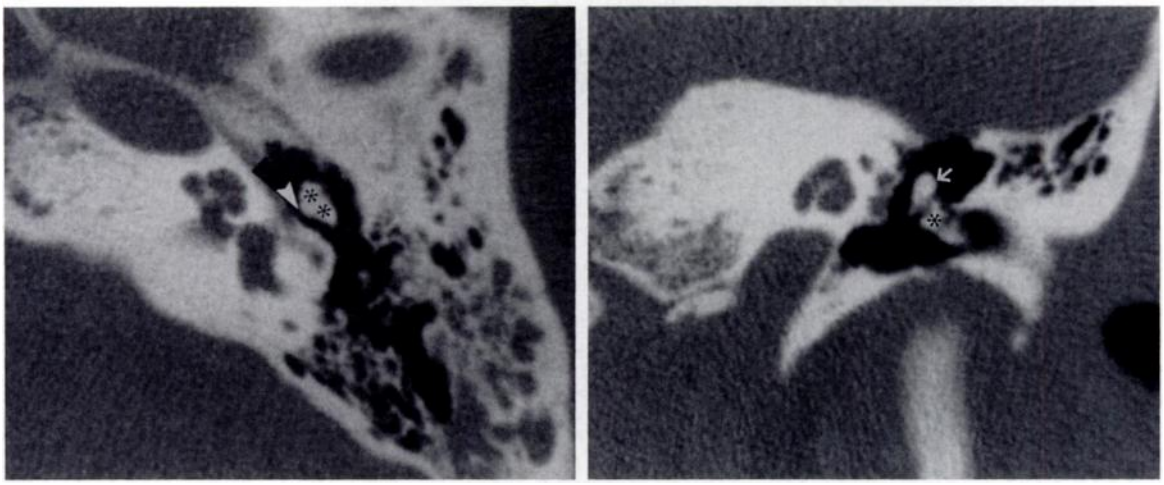
Incudomalleolar disarticulation is well visualized on axial CT scans, which show displacement of the head of the malleus (the "scoop of ice cream") from the body and short process of the incus (the "cone"). Coronal scans are useful for clarifying the positions of the ossicles in cases of significant displacement or when the incus is slightly displaced laterally (1).

• Dislocation of the Incus

The position of the heavy, weakly anchored incus between the firmly anchored malleus and stapes makes it relatively more vulnerable to traumatic dislocation (5) when incudomalleolar joint separation is associated with incudostapedial joint separation or a fracture of the stapes. After severe skull trauma, the incus may be dislocated owing to its inertia (7). Penetrating injury through the external auditory meatus may also cause dislocation of the incus. The incus may remain in the epitympanic recess (Fig 8), prolapse into the lower part of the tympanic cavity (Fig 9) or external auditory meatus (Fig 10), or even disappear.

In our series, dislocation of the incus occurred in 52 of 166 cases (31%). The temporal bone fracture was longitudinal in 40 cases,



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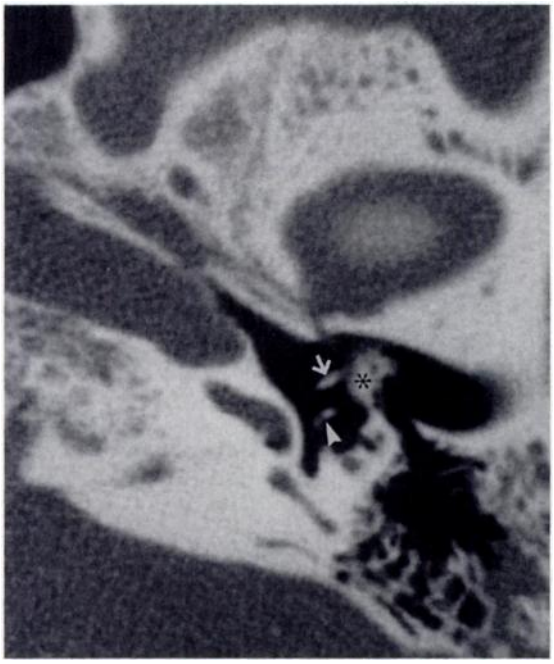

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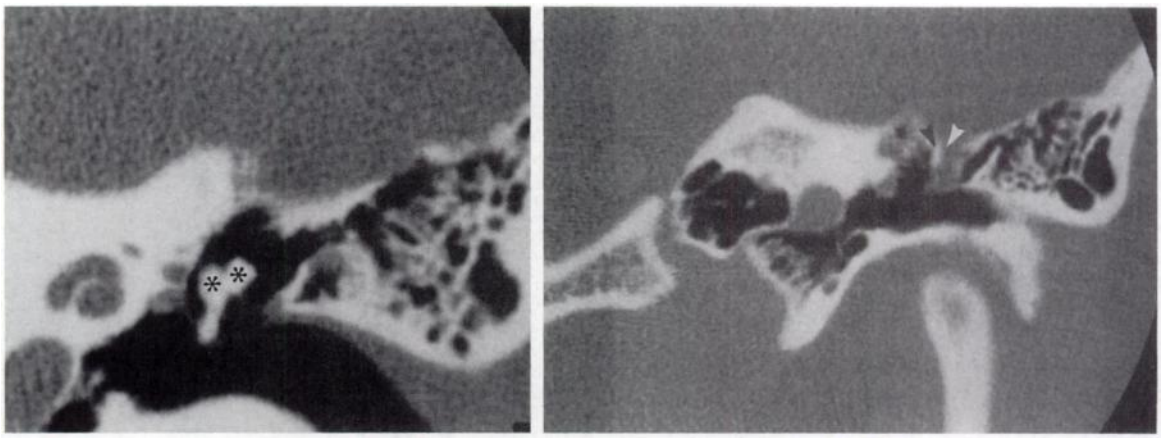
Figure 11. Dislocation of the malleoincudal complex of the left ear. **(a)** Axial CT scan shows internal displacement of the head of the malleus and body of the incus (*) with narrowing of the internal part of the epitympanic recess (arrowhead). **(b)** Axial CT scan obtained at a lower level shows a bone fragment (*) detached from the lateral wall of the epitympanic recess. The bone fragment pushes the malleus (arrow) inward without disruption of the incudostapedial joint (arrowhead). **(c)** Coronal CT scan shows medial displacement of the malleus (arrow) by the bone fragment (*).

transverse in two cases, and mixed in four cases. In six cases, the injury occurred without temporal bone fracture.

Complete examination of the middle ear and external auditory meatus with axial and coronal scans is necessary to identify the exact position of the incus relative to those of the other two ossicles.

• Dislocation of the Malleoincudal Complex

When the incudomalleolar joint proves resistant to traumatic forces, the malleoincudal complex may move into the lower part of the tympanic cavity. The direction of such displacement can be outward, inward (Fig 11), or downward (Fig 12). This injury may be associated with an incudostapedial joint separation. In our series, dislocation of the malleoincudal complex occurred in 27 of 166 cases (16%). The temporal bone fracture was longitudinal in 24 cases and mixed in one case; there were no cases of transverse translabyrinthine fracture. In two cases, the injury occurred without temporal bone fracture. Axial and coronal scans or axial and reformatted scans are necessary for accurate CT evaluation.



a. b.

Figure 12. Dislocation of the malleoincudal complex of the left ear. **(a)** Coronal CT scan shows inferior and internal displacement of the malleoincudal complex (*). **(b)** Coronal CT scan shows an associated fracture of the roof of the tympanic cavity (arrowheads).

• Stapediovestibular Dislocation

Because the annular ligament firmly attaches the stapes to the oval window, stapediovestibular dislocation is an uncommon injury. A penetrating injury through the external auditory meatus (usually by a cotton-tipped applicator [8]) may cause the stapes to be dislocated from the oval window and depressed into the vestibule (internal dislocation). In addition, traumatic force can tear the annular ligament, causing the footplate to move into the tympanic cavity (external dislocation). A comminuted fracture of the oval window can also cause stapediovestibular dislocation. Disruption of the stapediovestibular joint may cause a perilymph fistula.

In our series, stapediovestibular dislocation occurred in five of 166 cases (3%). The temporal bone fracture was longitudinal in one case and mixed in two cases. There was no temporal bone fracture in two cases, one of which was due to a cotton-tipped applicator. The stapes was located in the tympanic cavity in two cases (Fig 13) and in the vestibule in three cases (Fig 14).

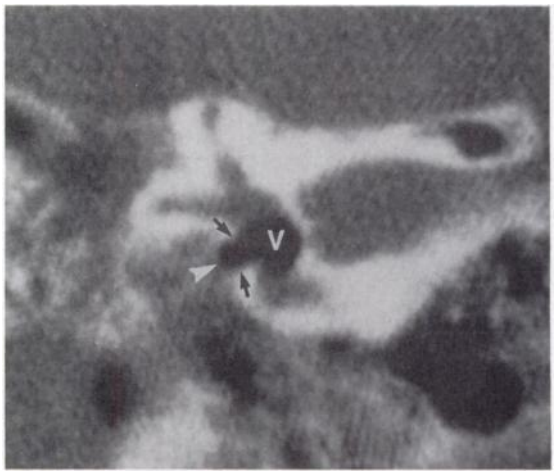


Figure 13. Lateral stapediovestibular dislocation. Coronal CT scan of the right ear shows absence of the footplate from the oval window without labyrinthine fracture. A pneumolabyrinth appears as low attenuation (arrowhead) in the vestibule (*V*) and oval window (arrows); hematotympanum is also present. At surgery, the stapes was found near the promontory.

■ OSSICULAR FRACTURE

• Fracture of the Malleus

Fracture of the malleus is a rare injury. The malleus usually fractures at the neck or manubrium; the fracture is usually associated with other severe derangements. In our series, fracture of the malleus occurred in two of 166 cases (1%). Because the manubrium can be difficult to appreciate on axial or coronal sections, contiguous oblique reformations through the long axis of the malleus may be necessary.

• Fracture of the Incus

In our series, fracture of the incus occurred in six of 166 cases (4%). The fracture affected the long or lenticular process in five cases and the

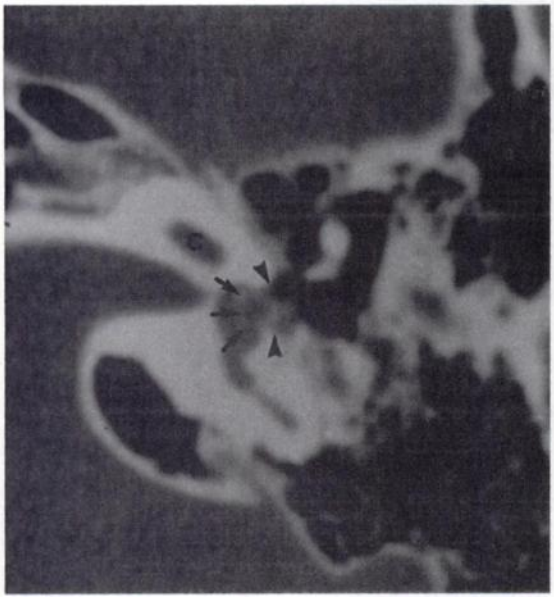


Figure 14. Medial stapediovestibular dislocation. Axial CT scan of the left ear shows the footplate (arrows) depressed into the vestibule; incudostapedial disarticulation is also present. The injuries were due to a cotton-tipped applicator. *c* = cochlea, arrowheads = oval window.

Figure 16. Fracture of the footplate. Axial CT scan of the left ear shows a folded footplate with two fracture lines (arrowheads). There is a fistula through the anterior part of the annular ligament with pneumovestibule (arrows). *c* = cochlea.

body of the incus in one case. The temporal bone fracture was longitudinal in three cases; in the other three cases, the injury occurred

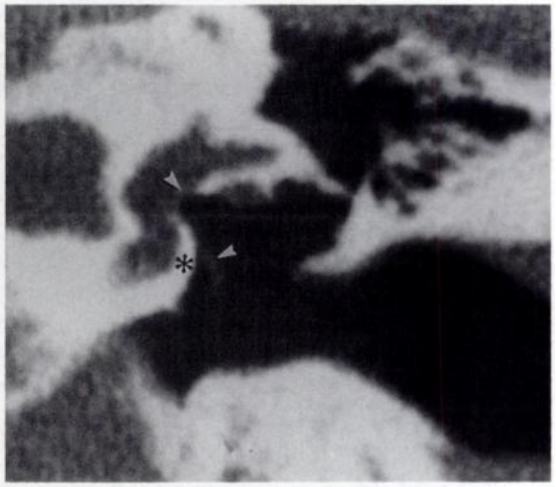


Figure 15. Fracture of the crura of the stapes. Coronal CT scan through the oval window of the left ear shows the footplate in a normal position (top arrowhead). The fractured crura and head of the stapes are displaced downward (bottom arrowhead) near the promontory (*).

without temporal bone fracture. Axial, coronal, or reformatted images through the axis of the long process allow diagnosis of this injury.

• Fracture of the Stapes

Fracture of the arch of the stapes occurs secondary to torsion. Fracture of the footplate mainly occurs secondary to transverse fractures (translabyrinthine fractures) passing through the oval window. A fracture of the footplate (with or without displacement of fragments) may cause a perilymph fistula with pneumolabyrinth (9).

In our series, fracture of the stapes occurred in 10 of 166 cases (6%). The fracture involved the crura in five cases; one crus was affected in two cases, and both crura were affected in three cases. In the other five cases, the footplate was fractured; the injury occurred in association with a fracture of the oval window in four cases and with a longitudinal fracture in one case.

Fracture of one crus is analyzed with axial sections but can be difficult to see (eg, due to hematotympanum). In cases of fracture of both crura, the footplate can be seen in the oval window, but the crura do not appear in their normal positions on axial or coronal scans (Fig 15). When the footplate is fractured, the fracture lines can be detected on axial sections (Fig 16).

■ CONCLUSIONS

There are two types of ossicular injuries: dislocation (incudostapedial and incudomalleolar joint separation, dislocation of the incus and malleoincudal complex, stapediovestibular dislocation) and fracture (fracture of the malleus, incus, and stapes). Trauma to the temporal bone is the main cause of ossicular disruptions and fractures. Incudostapedial and incudomalleolar disarticulation and dislocation of the incus and malleoincudal complex are common injuries, whereas stapediovestibular dislocation and ossicular fractures are rare. To diagnose these injuries, the radiologist must be familiar with the anatomy of the ossicular chain on axial, coronal, and reformatted CT scans.

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