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# Computed Tomographic Anatomy of the Temporal Bone

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**With the recent development of high-resolution computed tomography (CT), there is a growing need to explore the full potential of this new method in demonstrating the detailed anatomy of the temporal bone. For this purpose, dry skulls with intact ossicles were scanned in axial and coronal projections. The detailed CT anatomy of the temporal bone was documented, complemented by images from live patients. Because of its superior contrast resolution, CT was able to demonstrate numerous structures, such as the tympanic membrane, ossicles, and supporting structures, hitherto never or poorly visualized by any other method. In addition, the ease by which axial sections of the temporal bone could be obtained is of great benefit in displaying several structures previously difficult to evaluate.**

Computed tomographic (CT) scanning has proven to be indispensable in the evaluation of intracranial pathology, but its role in the evaluation of the temporal bone anatomy and pathology has not been fully explored [1]. Recent improvements in CT scanners have made available detailed information of the temporal bone [2], and certain structures that were previously poorly visible by other methods are now clearly seen [1–6]. The wealth of anatomic data displayed in various projections on CT poses a diagnostic challenge to neuroradiologists and clinicians. Furthermore, the understanding of the CT anatomy of the temporal bone is difficult due to complex structural relations that cannot be visualized on a single plane [7]. Our systematic CT analysis of the temporal bone was undertaken to demonstrate and document this detailed anatomy.

## Materials and Methods

All scans were obtained with a Pfizer 0200FS scanner in a "neuropack" configuration. The scanner contains a detector array of 30 calcium fluoride crystals, each 2.5 × 3.5 mm. The detectors are collimated so that only the central 1.5 × 1.5 mm are open to the x-ray beam. The x-ray beam width is narrowed to 2 mm by a manual slide, and the slice thickness is collimated to 2 mm by a removable stainless steel tube-side collimator.

The scanning algorithm is modified by increasing the sampling rate by a factor of two and by decreasing the translation arm speed to about 40 sec. The combination of these two software modifications and decreasing the detector size improves the geometric resolution allowing visualization of 0.75 mm pins in the American Association of Physicists in Medicine phantom. The image is then back-projected onto 0.3 mm pixels and recorded in the usual manner.

Hounsfield [8] suggested that scans of the bones of the middle ear would not be degraded by graininess at pixel sizes greater than 0.25 mm. We have successfully back-projected the epithympanum into 0.15 mm pixels, but suggest that, unless the sampling rate would again be halved, 0.3 mm pixels seem a better compromise. Because of the small pixel size, the zone of reconstruction is constricted to only 200 cm$^2$.

It is possible to reconstruct only one temporal bone at a time, although both are scanned simultaneously. This disadvantage is circumvented by storing the raw data on disk and recomputing the opposite temporal bone from this data at the completion of the study. If it

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is crucial to see both temporal bones at the time the scans are obtained, it is possible to back-project the scan onto 0.5 mm pixels and display a rectangular area of reconstruction aligned to encompass both temporal bones. The resolution in this scanning mode is not as good as in the 0.3-mm-pixel scan, but if the data are stored on disk or magnetic tape, the two temporal bones can be recomputed with 0.3 mm pixels at the termination of the examination.

More than 80 unprepared dry skulls were examined in an attempt to find skulls with intact ossicular chains. Ossicles are absent in commercially available skulls as the result of destruction of the ligaments, tendons, and the tympanic membrane during the preparation process. In vivo, these soft-tissue structures form the natural support of the ossicles, tethering them to each wall of the middle ear cavity. It is not uncommon to find an intact ossicular chain either in one or both ears in a newborn prepared skull, since often the tympanic membrane is left intact, providing the ossicles with their lateral support. In the adult skull, as a rule, the ossicles are absent. Most of the dry skulls examined had lost their tympanic membranes and ossicles.

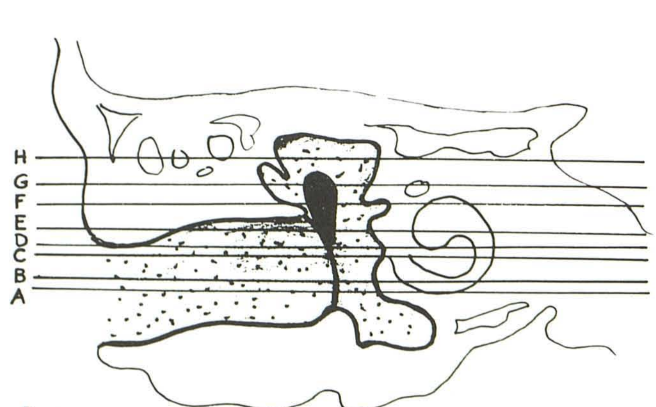
Dry skulls were scanned in the axial and coronal planes. Two techniques were considered and compared. A "low" kilovoltage technique using 80 kV and 50 mA and a "high" kilovoltage technique using 140 kV and 35 mA were performed on each skull. The latter technique offered the best detail, and all the CT scans in this study, including scans of clinical subjects, were performed in this manner. All scans were obtained at 40 sec.

Forty-five patients were scanned. In most, only the axial projection was used, primarily due to the ease of patient positioning and patient comfort. The coronal projection was attempted in some, but occasionally resulted in a poor image due to patient motion. At the termination of the study, reconstruction of the opposite ear was performed.

The illustrations in our anatomic study are a combination of those provided from dry skulls and those from our normal clinical subjects. The individual images were chosen to display discrete anatomic structures, some of which are best displayed in the dry skull, while others require delineation of soft tissue best demonstrated in live patients.

## Observations and Discussion

Our observations are divided into sections based on each major part of the ear and also on arbitrary grouping of a set of structures of special interest. Each section contains an anatomic description followed by observations and comments, so that each set of anatomic structures is dealt with sequentially in its entirety.




A

### External Auditory Canal

*Anatomy.* In the adult, the external auditory canal is about 2–3 cm in length, oriented directly along the coronal plane. Except for the most superior part, it is completely surrounded by the tympanic bone, which forms an incomplete ring over the meatus. It is covered superiorly by the squamous temporal bone. The mandibular fossa, containing the mandibular condyle, constitutes its anterior relationship, while the mastoid process and air cells are situated posteriorly. Most medially, at the attachment of the tympanic membrane, the most posterosuperior edge of the tympanic rim protrudes slightly into the canal, forming the posterior (greater) tympanic spine (fig. 1F). Superiorly, the squamous temporal bone provides the most superior attachment of the pars flaccida of the tympanic membrane.

*Observations.* The anterior and posterior walls are best visualized in the axial projection (figs. 1B and 1C), while the coronal plane is well suited for visualization of the roof and the inferior wall (figs. 2B–2D). The posterior tympanic spine can be visualized on the axial view as a sharp projection extending anteriorly at the junction of the middle ear and external canal (fig. 1F). The axial projection also provides excellent visualization of the relations between the mandibular fossa and the external auditory canal.

### Middle Ear

*Anatomy.* The middle ear is a narrow cavity separating the inner and external ear. This flattened rectangular chamber is oriented along the same oblique plane as the temporal bone. The many structures that traverse this space plus the irregularity of its inner wall add to its overall complexity.

The middle ear is divided into the mesotympanum or tympanum proper (the region of the middle ear cavity directly contiguous with the tympanic membrane), the epitympanic recess, and the hypotympanum. The ossicles for the most part reside within the epitympanic cavity, with the

Fig. 1.—**Abbreviations.**

AA = aditus ad antrum
C = cochlea
CA = cochlear aqueduct
CC = carotid canal
CCO = crus communis
CN = cochlear division of eighth nerve
CP = cochleariform process
EAC = external auditory canal
ER = fossa incudis and epitympanic recess
ET = eustachian tube
FC = facial canal
FI = foveate impression
FIN = fossa incudis
FR = facial recess
G = geniculum
I = incus
IAC = internal auditory canal
IMJ = incudomalleal joint
LSC = lateral semicircular canal
M = malleus
MA = mastoid antrum
MF = mandibular fossa
OW = oval window
PE = pyramidal eminence
PL = posterior incudal ligament
PSC = posterior semicircular canal
PTS = posterior tympanic spine
RW = round window niche
SC = semicanal
SEP = septum separating the semicanal from the eustachian tube
SML = superior malleal ligament
SPS = sphenopetrosal synchondrosis
SSC = superior semicircular canal
ST = sinus tympani
SU = subiculum
TM = tympanic membrane
TS = tympanic spine
V = vestibule
VA = vestibular aqueduct
VN = vestibular nerve

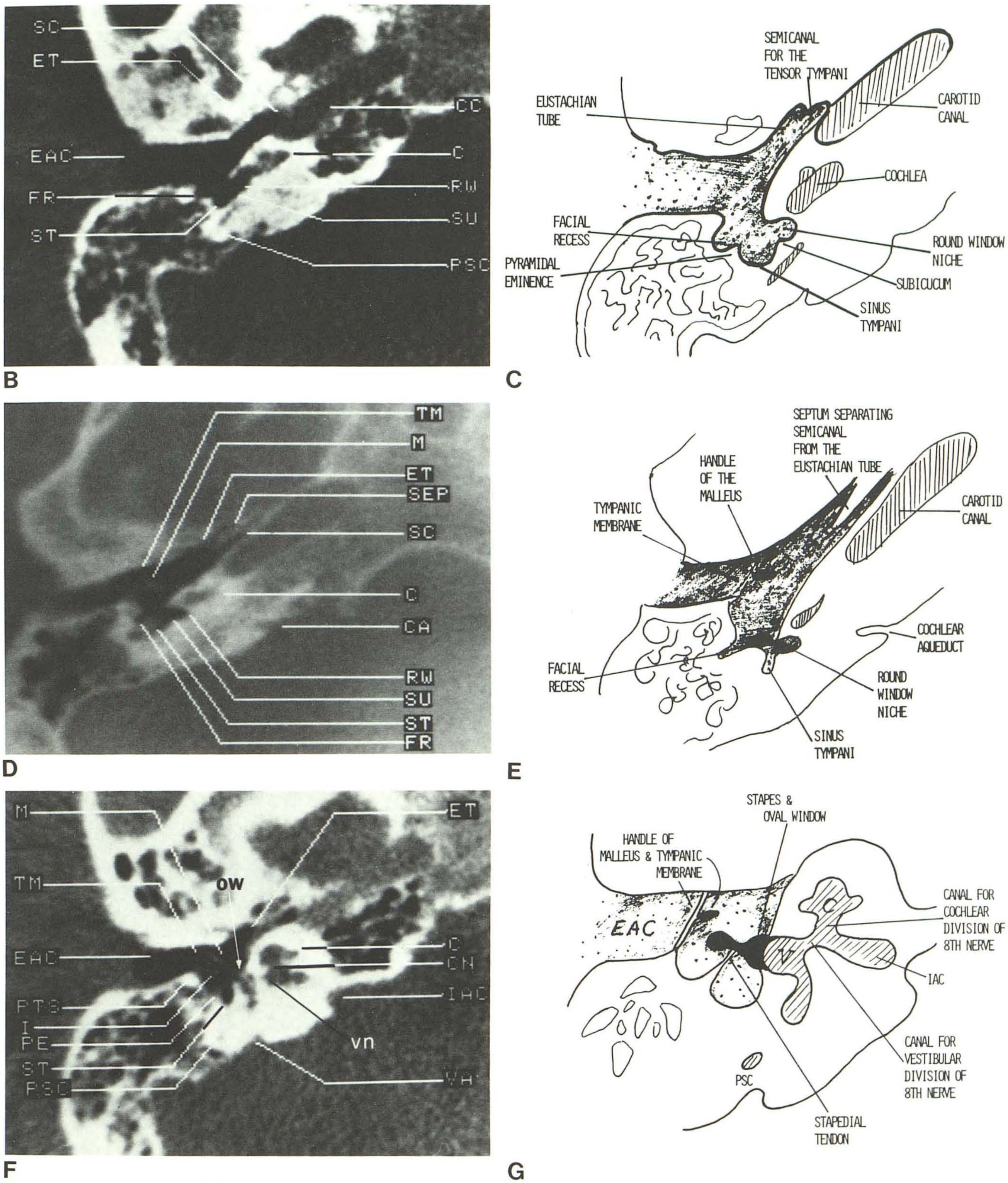



Fig. 1.—**A–G. A**, Coronal section of right temporal bone shows levels of axial views in **B–O**. Level A is most inferior. (Fig. 4 provides a more complete anatomic representation.) **B** and **C**, Level A, live patient, passing through basal turn of cochlea. Trefoil appearance formed by round window niche, sinus tympani, and facial recess. Air-filled bony part of eustachian tube is directed anteromedially parallel to carotid canal. **D** and **E**, Level B, live patient, also passes through basal turn of cochlea. Depressions along posterior aspect of tympanic cavity not as rounded as in **B**, but appear more flattened and shallow. **F** and **G**, Level C, live patient, passes through ossicular processes and oval window. Y-shaped lucency formed by internal auditory canal and canals for two divisions of eighth nerve. Oval window appears as breach in continuity of otic capsule.

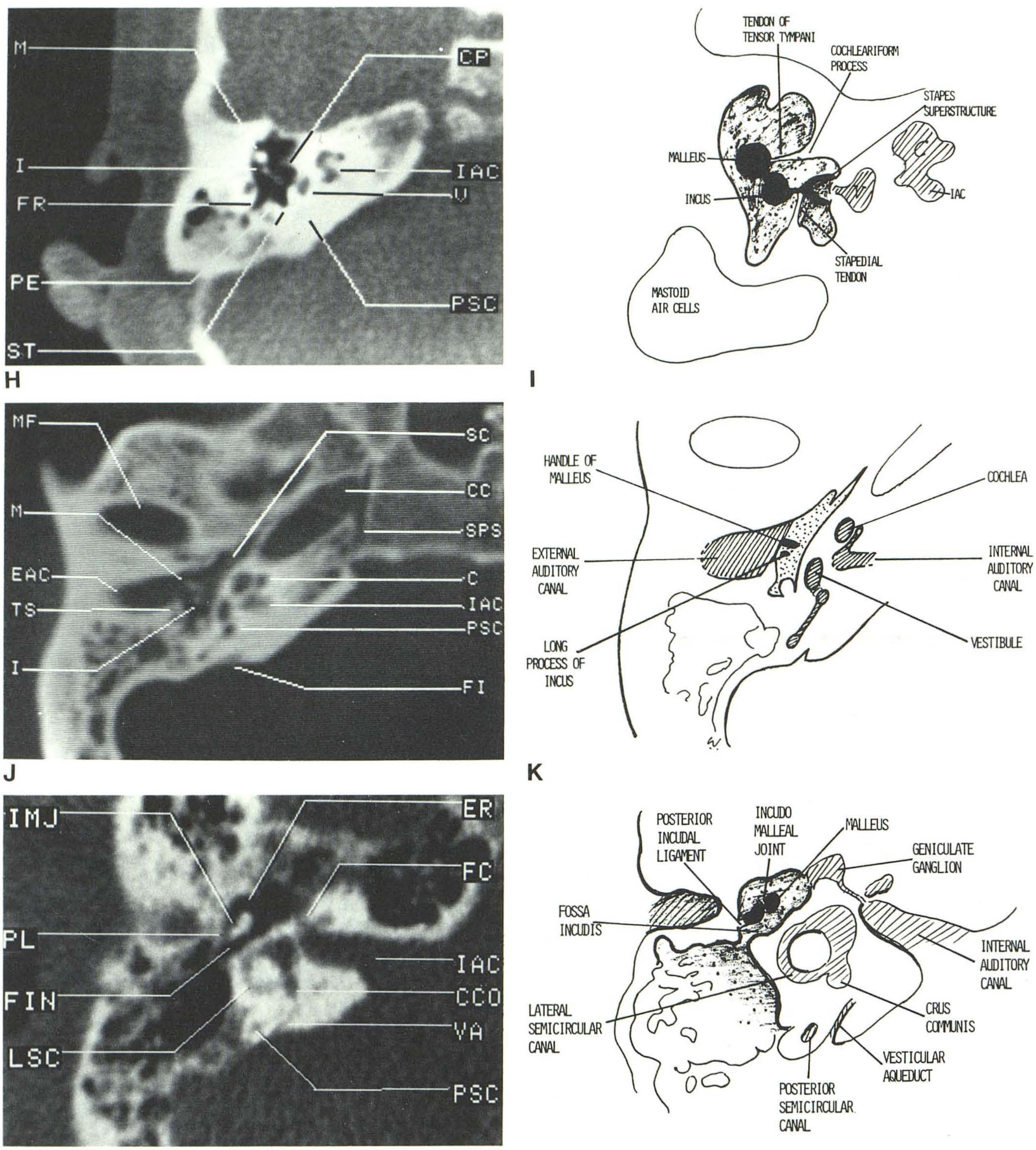
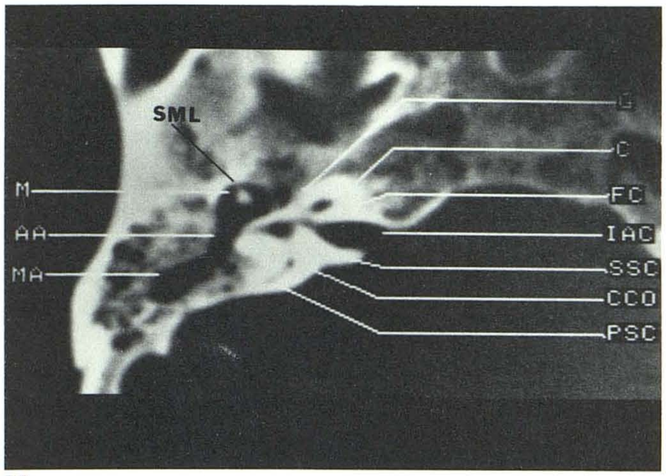



Fig. 1.—**H–M**. **H** and **I**, Through level D, juvenile temporal bone in live patient. Tensor tympanic and stapedial tendons arise from cochleariform and pyramidal processes, respectively. **J** and **K**, Through level E, dry skull, slightly above oval window, passing through ossicular processes and vestibule. **L** and **M**, Level F, live patient, passes through semicircular canal and facial canal. Circular lucency in petrous bone formed by lateral semicircular canal posterolaterally. Vestibule and crus communis anteromedially. Facial nerve passes anterolaterally dorsal to basal turn of cochlea and turns sharply posteriorly at genu.

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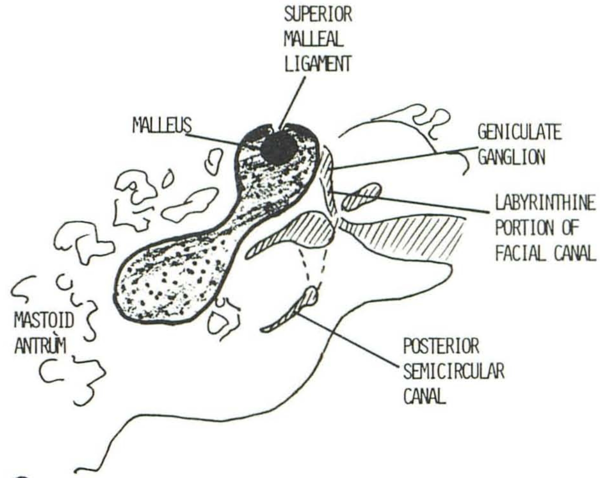


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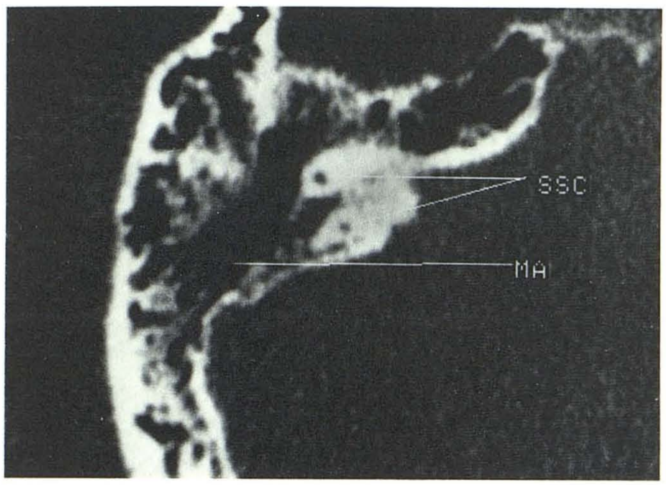


P

Fig. 1.—**N–P.** **N** and **O**, Level G, dry skull, through facial canal epitympanic cavity. **P**, Level H, live patient, through superior semicircular canal and mastoid air cells.

handle of the malleus and the long process of the incus extending downward into the mesotympanum. The hypotympanum is empty and essentially featureless. It is the smallest of the three divisions of the middle ear cavity (fig. 2B). The epitympanic recess communicates with the mastoid antrum via the aditus (figs. 1N and 1O). Körner septum, the remnant of the petrosquamosal suture [9], is a thin osseous partition vertically oriented along the sagittal plane eccentrically protruding downward into the mastoid antrum (fig. 2C).

### *Anterior Wall*

*Anatomy.* The anterior wall of the middle ear cavity has two openings: the eustachian tube and the semicanal for the tensor tympani. Both structures run parallel and almost contiguous to the carotid canal, which is more medially situated (figs. 1B–1E). The bony eustachian tube is usually air-filled for about 2–3 cm. The cartilaginous extension is collapsible and usually not air-filled. The semicanal extends further posterior than the eustachian tube and passes below the geniculum (genu of the seventh nerve), ending slightly anterior to the oval window. At its point of termination, there is a small process called the cochleariform process that houses the tendon of the tensor tympani (fig. 1H). The tendon crosses the middle ear at a 90° angle to the muscle, where it attaches to the malleus at the neck of the malleus. Therefore, the cochleariform process acts as a fulcrum for this pulleylike action.

*Observations.* Axial scans provide the best visualization of the eustachian tube, semicanal, and carotid canal. Only the air-containing bony part of the eustachian tube is visualized on CT (figs. 1B and 1D). It and the semicanal run parallel to the carotid canal, directed toward the nasopharynx. The eustachian tube and semicanal, separated by a bony septum that partially surrounds the tensor tympani muscle, are visualized in the axial projection (fig. 1D). These structures are difficult to identify on the coronal projection, particularly when the petrous bone is well aerated, since sections are obtained perpendicular to their orientation. Occasionally, however, they can be visualized (fig. 2A).

### *Medial Wall*

*Anatomy.* The promontory, the part of the labyrinthine capsule covering the basal turn of the cochlea, occupies the major part of the anteromedial wall of the tympanic cavity. It extends posteriorly up to the oval and round windows and then diverges into two ridges of bone, called superiorly the ponticulus and inferiorly the subiculum, both forming the anterior margin of the sinus tympani. The subiculum also forms the posterior aspect of the round window niche. The sinus tympani is a concavity in the posteromedial aspect of the middle ear. It is surrounded laterally by the pyramidal eminence, superiorly by the pyramidal turn of the facial nerve and lateral semicircular canal, and anteriorly by the promontory, oval, and round windows.

The second part of the facial canal traverses the middle ear anteroposteriorly along the superomedial aspect of the tympanic cavity. This part is usually covered by a thin rim of bone. At times, the covering can be partially deficient, particularly near the oval window and cochleariform process [10, 11]. The oval and round windows are located posteriorly along the medial wall. The oval window is superior and slightly ventral to the round window, where a deep depression can be seen representing the cochlear fossula (niche). The oval window communicates with the scala vestibuli, while the round window with the scala tympani; both are compartments of the perilymphatic system surrounding the membranous labyrinth.

*Observations.* The axial plane provides good visualization of the promontory, fossular cochlea (round window), and the subiculum (figs. 1B and 1D). The round window niche can be recognized as a sharp, deep, bony depression dorsal to the basal turn of the cochlea. The ridge of bone separating the round window from the sinus tympani is the subiculum (figs. 1B and 1D). The structures of the posteromedial wall of the tympanic cavity are best seen in this projection. The oval window is the only exception. This ovoid dehiscence, longer in its anteroposterior dimension than superoinferior dimension (2.99 mm versus 1.41 [12]), is difficult to visualize on the axial projection owing to partial volume effect, the slice thickness being 2 mm. When seen, it appears as a breach in continuity of the otic capsule lateral to the vestibule, the stapedial superstructure within the middle ear overlying this dehiscence more laterally (figs. 1F and 1G). It is easily seen, however, on direct coronal projection (fig. 2D).

### *Posterior Wall*

*Anatomy.* The posterior wall of the middle ear cavity is a complicated structure consisting of several ridges and depressions. Inferiorly, the middle ear cavity appears to extend into the mastoid and labyrinthine capsule in a trefoil pattern of bony depression. The most medial one is the round window niche, the middle is the sinus tympani, and the most lateral is the facial recess (figs. 1B and 1D). The round window niche is separated from the sinus tympani by the subiculum, and the sinus tympani is separated from the facial recess by the pyramidal eminence. The pyramidal eminence contains the stapedius muscle and projects into the middle ear cavity in an anterosuperior direction toward the stapedial head in a beaklike manner. The pyramidal eminence is a ridge of bone, extending in an anterosuperior direction along the posterior wall, which partially hides the tympanic sinus (fig. 3). The facial nerve penetrates the posterior wall of the middle ear above and slightly lateral to the pyramidal eminence and turns 90° (pyramidal turn) to descend vertically, toward the stylomastoid foramen.

*Observations.* The axial projection is ideal for the visualization of the sinus tympani and the facial recess. The ease with which the sinus tympani can be demonstrated on the axial projection has important clinical relevance, since this structure is difficult to visualize on clinical examination, being partially hidden from view by the more lateral pyramidal eminence (fig. 1H). The size and configuration of these recesses, however, are subject to individual variation from rounded deep recesses to more flattened shallow ones (figs. 1B and 1D). This is also true for the pyramidal eminence, which may not assume a pointed triangular configuration but may be blunt and broad.

### *Lateral Wall*

*Anatomy.* The lateral wall is covered to a large extent by the tympanic membrane (fig. 4). The scutum (drum spur), which forms the lateral wall of the epitympanic recess, projects downward for the attachment to the tympanic membrane at the tympanic incisura.

*Observations.* The coronal and axial views are suited for visualizing the lateral wall. The scutum is best seen in coronal section (fig. 2B).

### *Roof and Floor*

*Anatomy.* The tegmen tympani forms a thin bony roof separating the epitympanic recess from the temporal lobe. It extends posteriorly to cover the aditus and the mastoid antrum, where it is called the tegmen mastoideum. The floor of the middle ear also consists of a thin bony shell, which separates the major vessels from the middle ear cavity. The carotid artery and the jugular vein are separated most inferiorly by the caroticojugular spine, which has the appearance of an inverted triangular structure wedged between these two major vessels [9].

*Observations.* The coronal projection is best for demonstrating Körner septum and the tegmen tympani (fig. 2C). The thickness of the osseous floor and the hypotympanum and its relationship to the major blood vessels are best assessed on this view (fig. 2D).

The caroticojugular spine can be demonstrated on axial CT as an area of bone separating the carotid canal from the jugular bulb on a low section through the temporal bone. Körner septum, the tegmen tympani, and mastoideum are difficult to identify on this projection.

### *Ossicles, Tendons, and Ligaments*

*Anatomy.* The auditory ossicles provide a lever mechanism for the transfer of sound energy. The malleus, incus, and stapes form a chain from the tympanic membrane to

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Fig. 2.—**Abbreviations.**

C = cochlea
CC = carotid canal
CCO = crus communis
CF = crista falciformis
EAC = external auditory canal
ET = eustachian tube
FC = facial canal
HC = hypoglossal canal
HT = hypotympanum
I = incus
IAC = internal auditory canal
JF = jugular fossa
JT = jugular tubercle
KS = Körner Septum
LSC = lateral semicircular canal
M = malleus
MA = mastoid antrum
MH = malleus handle
MP = mastoid process
OC = occipital condyle
OW = oval window
P = promontory
PE = pyramidal eminence
PSC = posterior semicircular canal
SC = semicanal
SCU = scutum
SMF = stylomastoid foramen
SPS = sphenopetrosal synchondrosis
SSC = superior semicircular canal
TT = tegmen tympani
V = vestibule

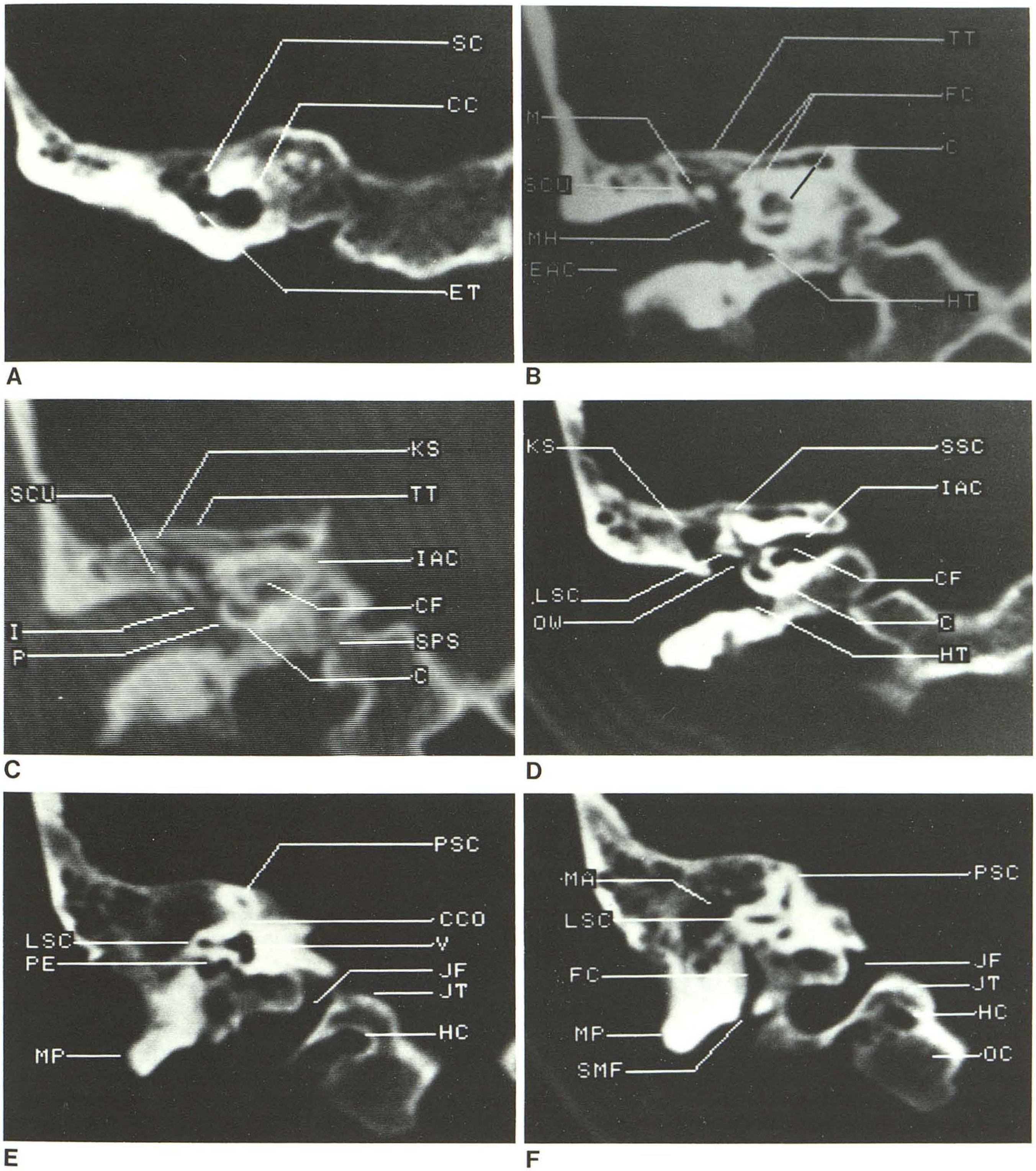


Fig. 2.—Coronal CT sections of dry skull, right temporal bone. Successive slices 2 mm apart from anterior to posterior. **A** is most anterior. **A**, Through carotid canal and eustachian tube. **B**, Through cochlea and malleus. **C**, Through basal run of cochlea of internal auditory canal. **D**, Through internal auditory canal and vestibule. **E**, Through vestibule and jugular fossa. **F**, Through jugular fossa and vertical part of facial canal.

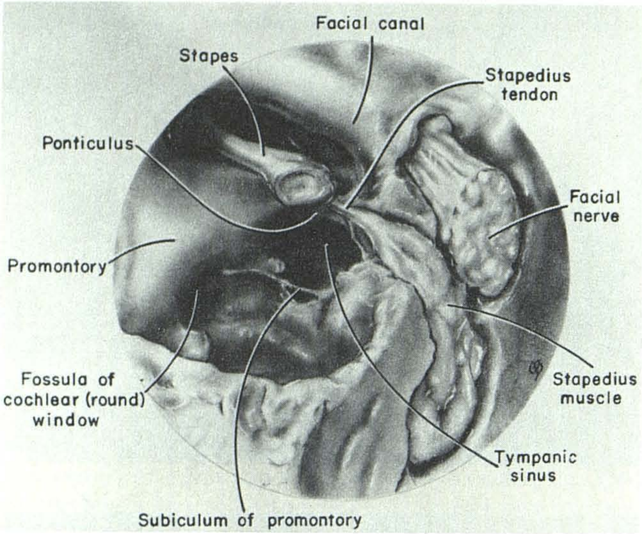


Fig. 3.—Posteromedial aspect of left middle ear viewed from external ear. Promontory extends into two ridges, ponticulus superiorly and subiculum inferiorly, forming ventral aspect of sinus tympani. Pyramidal eminence contains stapedius muscle, partially obscuring sinus tympani. (Reprinted from [12].)

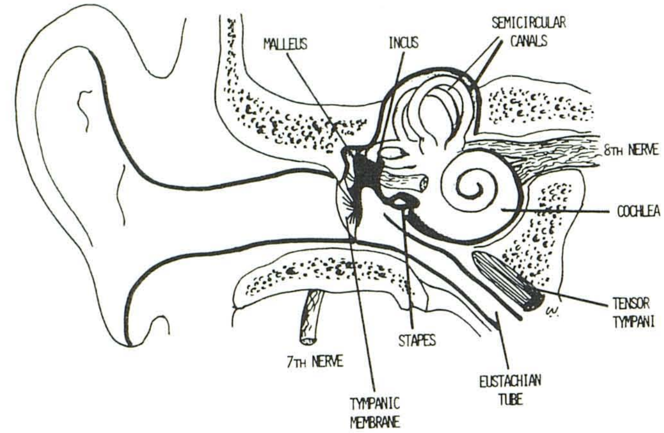


Fig. 4.—Coronal view of right ear shows relation between structures comprising inner, middle, and external ear. Ossicular chain can be seen from its attachment to tympanic membrane, extending across middle ear to labyrinthine capsule. Eustachian tube occupying anterior wall of tympanic cavity passes anteromedially toward pharynx.

the bony labyrinth (fig. 4). The malleus, lying most ventrally, consists of a head, a manubrium (handle), and an anterior process (fig. 5A). The head articulates with the body of the incus, while the manubrium and the lateral process are attached to the tympanic membrane more laterally. The head is round with a diameter of about 2–3 mm. The anterior process provides an attachment for the anterior malleal ligament.

The incus, the largest of the three ossicles, has a body and a short and long process. The long process extends downward into the mesotympanum parallel and posteromedial to the malleal handle. Its most inferior extension (the lenticular process) articulates with the head of the stapes (fig. 1H) [3, 13]. The short process projects dorsally from the body, where it is attached to the posterior wall of the epitympanic recess by the posterior incudal ligament (figs. 1L and 1M). The body of the incus, including its short process, is about 4–5 mm along its anteroposterior dimension. The epitympanic recess, where the incudal body and malleal head are located, narrows posteriorly and may be separated from the short process by 1–2 mm. This part of the epitympanic recess is called the fossa incudis (fig. 1L). The stapes consists of a head, which articulates with the incus, anterior and posterior crura, forming a crural arch (superstructure), and the stapedial foot plate. The foot plate configuration is complementary to the oval window.

The ossicles are held suspended in the middle ear by a series of struts consisting of ligaments and tendons (fig. 5B). Some of these ligaments are merely folds of the mucous membrane that cover the entire middle ear cavity and the ossicular chain. These mucosal folds are considered ligaments, because they play a supportive role in maintaining the integrity of the ossicular chain.

Laterally, the malleal handle is attached to the tympanic membrane. The anterior malleal ligament passes from the petrotympanic fissure (glaserian fissure) to insert into the anterior malleal process. Medially, the tensor tympani tendon attaches itself to the neck of the malleus. It functions primarily to dampen the malleus when the malleus is subjected to vigorous sound vibrations (figs. 1H and 1I). Superiorly, the head of the malleus is attached to the roof of the epitympanic recess by the superior malleal ligament (fig. 1N). The incus is supported by the posterior incudal ligament (fig. 1L). The tendon of the stapedius muscle, which inserts into the head of the stapes, serves a function similar to that of the tensor tympani tendon. The stapedial footplate is fastened to the rim of the oval window by the annular ligament.

From the foregoing description, it is quite apparent that the incus has the least support of all three ossicles, thus explaining its increased susceptibility to traumatic dislocation.

*Observations.* The molar tooth configuration formed by the malleus and incus is a familiar lateral tomographic [9, 14, 15] projection of the auditory ossicles. On axial CT, sections are obtained perpendicular to the superorinferior orientation of the ossicles. Essentially, sections pass through either head-body or the long processes of the ossicles. Higher cuts corresponding to the level of the internal auditory canal will usually also pass through the epitympanic recess and the incudomalleal articulation (fig. 1L), while lower cuts corresponding to the external canal, drum, and mesotympanum will pass through the handle of the malleus and long process of the incus, both appearing as two small densities (fig. 1J). The stapedial superstructure, forming an arch over the oval window, lies on an axial plane, and, therefore, can be visualized in its entirety using this projection. The cochleariform process, tensor tympani ten-

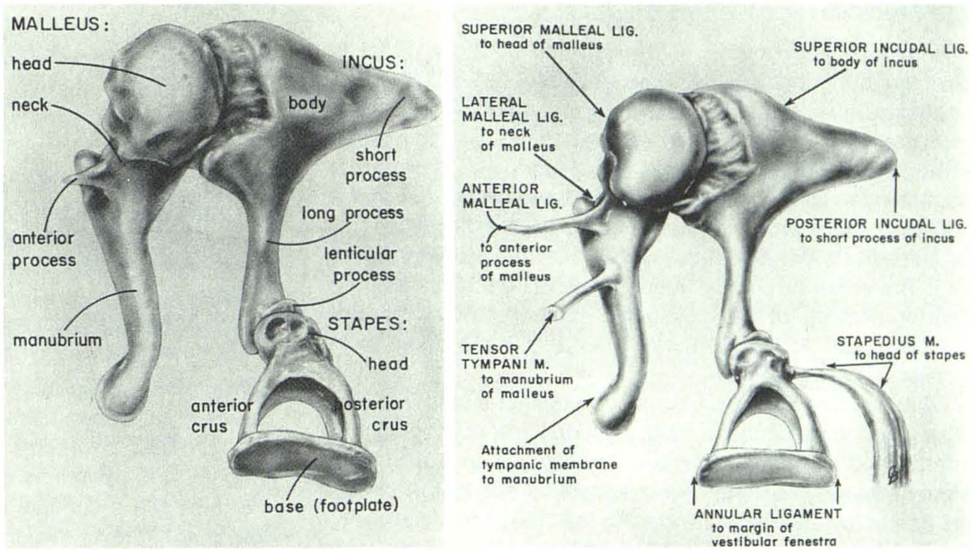


Fig. 5.—**A**, Normal anatomy of auditory ossicles. **B**, Attachments of various ligaments and tendons to auditory ossicles. (Reprinted from [12].)

don, pyramidal eminence, and stapedial tendon are also at about the same level. Frequently, a section passing through the stapedial crura will reveal all these structures (figs. 1F and 1H). The axial scan is also ideal for visualizing the superior malleal ligament and the posterior incudal ligament (figs. 1L and 1M). The coronal projection should provide superior visualization of the incudostapedial joint [13]. This was not achieved in our study.

### *Inner Ear*

*Anatomy.* The inner ear consists of osseous and membranous labyrinths surrounded by dense compact bone called the otic capsule [16]. The bony labyrinth is directed along the same oblique plane as the temporal bone (fig. 6). It consists of the cochlea, vestibule, and semicircular canals (fig. 4). The cochlea consists of 2½ turns: the apical, middle, and basal turns, the last being the largest and most distinctive. The rounded basal turn of the cochlea is separated from the middle ear by the promontory. Posteriorly, it is connected to the vestibule that surrounds the delicate membranous saccule and utricle. The vestibule is perforated posterolaterally by the oval and round windows. The semicircular canals are attached to the vestibule in a series of arches oriented along all three planes, so that head movement in any direction can be detected. The superior semicircular canal (fig. 1P) is anteriorly situated close to the internal auditory canal and the cochlea. The posterior and lateral (horizontal) semicircular canals are more dorsally positioned deep within the mastoid bone (fig 2E). The medial arms of the superior and posterior semicircular canals combine to form a common crus that is oriented superomedially (fig. 2E).

*Observations.* The axial projection is excellent for visualizing the entire lateral semicircular canal, since it lies on a horizontal plane. This structure and the vestibule combine to produce a lucent ring, with the posterior arm of the posterior semicircular canal appearing as a dot posteromedially (fig. 1L). The bony covering over the lateral semicircular canal is best evaluated in this projection. An accurate assessment of its integrity is helpful in ruling out erosions and fistulae formation before surgical exploration of the middle ear in destructive lesions such as cholesteatomas.

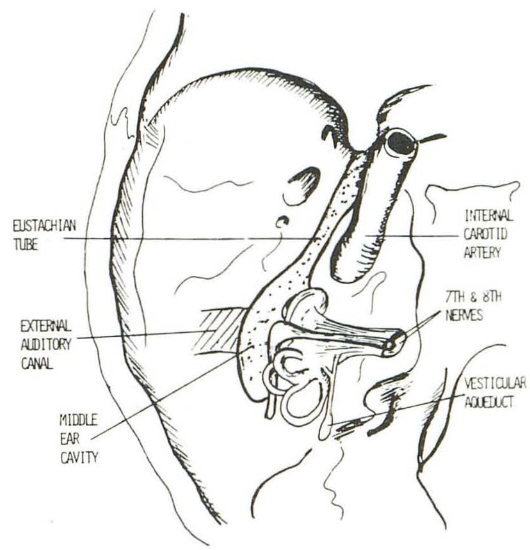


Fig. 6.—Schema of left temporal bone viewed from above shows relations of external, middle, and internal ear. Note relation of auditory tube to internal carotid artery; of genu of the seventh nerve with basal turn of cochlea and, more posteriorly, lateral semicircular canal; of vestibular aqueduct passing directly posterior to its intracranial opening along posterior aspect of temporal bone.

The coronal projection is probably the best for visualizing the cochlea [17]. Virtually the entire extent of the basal turn can be visualized on the one section (fig. 2B). The middle and apical turns (columella) are difficult to separate since they seem to blend into one another.

### *Internal Auditory Canal*

*Anatomy.* The course of the internal auditory canal is directed along the coronal plane similar to, but slightly more cephalad than, the external auditory canal [18]. The falciform crest (crista falciformis), which consists of a thin piece of horizontal bone, is thickest at the fundus of the internal auditory canal. It divides the internal auditory canal into a superior and inferior compartment [19–21] (fig. 2C). The facial nerve and the superior division of the vestibular nerve lie in the superior compartment, while the cochlear and the inferior division of the vestibular nerve lie in the inferior compartment. At the fundus of the canal, each nerve exits through its own foramen.

*Observations.* The axial projection is best suited for visualizing the exit foramina at the fundus. At this point, the internal auditory canal forks in a Y configuration. The ventral arms represent the canals for the cochlear and facial nerves; the dorsal for the vestibular nerves (fig. 1F). The facial canal lies directly above the cochlear canal (figs. 1L and 1N). The coronal projection is ideal for visualizing the integrity of the falciform crest, which can be seen as a linear density medially dividing the internal auditory canal into two compartments (fig. 2D).

### *Aqueducts*

*Anatomy.* The vestibular and cochlear aqueducts drain the endolymph and the perilymph, respectively. The vestibular aqueduct consists of ventral and dorsal arms, which are directed posteriorly in a widened inverted V configuration [22–24]. The termination of the aqueduct widens to accommodate the endolymphatic sac [25]. This widening along the posterior aspect of the petrous bone forms a small plateau called the foveate impression.

The cochlear aqueduct provides a potential communication with the subarachnoid space. It arises from the scala tympani near the round window and extends medially to open along the medial aspect of the petrous bone below the internal auditory canal and is separated from the jugular fossa by a thin ridge of bone. While the cochlear aqueduct often assumes a funnel shape at its intracranial opening, the size and meatal configuration of both aqueducts are subject to considerable variation.

*Observations.* The axial projection is ideally suited for demonstrating the cochlear aqueduct. This structure is usually seen at the level of the carotid canal and eustachian tube (fig. 1D) and may appear as a thin, slitlike structure much like the vestibular aqueduct or as a widened canal. It should not be mistaken for the internal auditory canal, which lies just above it and is considerably larger. These two structures are separated by about 3–4 mm of bone on the medial aspect of the petrous pyramid; sequential scans should be carefully scrutinized in order to differentiate these structures. The vestibular aqueduct can also be visualized in this projection (fig. 1L) lying medial to the posterior semicircular canal.

In our study, only the dorsal arm of the vestibular aqueduct can be visualized, probably owing to its larger size compared with the ventral arm. On axial CT, this canal widens posteriorly and merges with the foveate impression along the posterior aspect of the petrous pyramid.

### *Facial Canal*

*Anatomy.* The facial canal can be divided into three sections: the first two parts are called the horizontal segments; the last the vertical segment [26–28].

The facial canal begins at the fundus of the internal auditory canal. It courses anteriorly ending at the geniculate ganglion. At this point, the canal makes a hairpin turn and extends posteriorly along the medial wall of the tympanic cavity to the pyramidal eminence. This part of the canal lies superior to the semicanal for the tensor tympani, cochleariform process, oval window, lateral semicircular canal, sinus tympani, and pyramidal eminence.

Behind the pyramidal eminence, the canal turns sharply downward toward the stylomastoid foramen and is related anteriorly to the external auditory canal and middle ear and posteriorly to the mastoid air cells [29, 30].

*Observations.* The axial projection usually provides excellent visualization of the horizontal parts of the facial canal. It is particularly good for demonstrating the first segment of the facial nerve as it leaves the internal auditory canal (figs. 1L and 1N).

The second part of the facial canal traversing the middle ear is difficult to visualize, owing to its thin bony covering, which is microscopically perforated by blood vessels [10, 11]. Occasionally, when this bony covering is thick, the entire horizontal course of the facial nerve can be demonstrated on one section.

In the normal adult, the canal of the descending segment of the facial nerve is difficult to identify in the axial plane due to surrounding mastoid air cells. It can be readily identified in young children and in patients with mastoid disease who have obliterated mastoid air cells. The coronal projection is helpful for visualizing the genu of the facial nerve. It is also useful in assessing the vertical part of the facial nerve (fig. 2F).

## Reconstruction

In a cooperative patient, it is possible to obtain a series of axial scans and reformat them in any number of planes. This technique has the advantage of being able to display the complex anatomy in all of the conventional projections, although only exposing the patient to radiation one time.

There are two technical drawbacks to this technique. The resolution of reformatted images along the *z* axis is limited to 1.5–2.0 mm. As a result, some slight degradation of the image is expected when compared with direct coronal or sagittal scans. Patient motion is also very critical when evaluating small bony structures. The minute proximity of the many important intratemporal structures make even a small amount of patient motion intolerable. Therefore, it is desirable to perform the scanning sequence as quickly as possible to limit patient motion.

## Comment

A large number of structures previously not visualized or poorly visualized by other means can now be seen by CT. These include: the tympanic membrane, the ossicles and their associated tendons and ligaments, the eustachian tube, and the semicanal for the tensor tympani, the cochleariform process. The round window niche, subiculum, sinus tympani, the first portion of the facial canal, the canals for the vestibular and cochlear nerves, and the cochlear aqueduct can also be seen.

For maximum resolution, scanning patients directly in the two projections is advantageous. When this is not possible, reformatted images can be obtained, although there is some loss in resolution.

There are many clinical implications of this new methodology. CT provides a precise technique for the evaluation of soft-tissue masses within the air-filled middle ear and mastoid. Defining the extent of erosion or destruction of the walls of the middle ear, the capsule of the semicircular canals, and the ossicular chain is crucial in the evaluation and treatment of cholesteatomas and other middle ear lesions. It is also very helpful in evaluating postoperative complications from a mastoidectomy. CT is especially useful in assessing the tympanic membrane and in visualizing partly hidden structures such as the sinus tympani. Detailed anatomic knowledge is essential for the increasingly important role that high-resolution CT can be expected to have in the evaluation of the normal and abnormal temporal bone. This study offers some of that information.

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