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Computed Tomography of Temporal Bone Pneumatization:
2. Petrosquamosal Suture and Septum

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The degree of visualization of the petrosquamosal (Körner's) septum on high-resolution axial computed tomography (CT) in 141 temporal bones (100 subjects) was analyzed. The superior and inferior parts of the septum were assessed separately and were seen in 75% and 41% of cases, respectively. There was no relation between the size of Körner's septum and pneumatization. The clinical relevance of this finding is discussed. The CT features of the ventral petrosquamosal suture also were investigated. The crista tegmentalis, a contribution of the petrosal tegmen to the mandibular fossa, was seen on CT as a polypoid excrescence projecting from the ventrolateral petrous pyramid. This knowledge is useful in the radiographic analysis of the course of longitudinal fractures of the petrous bone.

The petrosquamosal septum and suture, formed at the junction of the mastoid and the temporal squama, is a well known landmark to otologists. This thin, osseous septum can be recognized on coronal conventional tomography as an oblique lamina projecting into the mastoid antrum (fig. 1A). In the appropriate clinical setting (e.g., an acquired cholesteatoma), its absence may imply destruction [1]. The septum is also seen on axial computed tomography (CT) as a thin osseous bar, subdividing the mastoid antrum into two parts. The recognition of this septum on CT is important because it is an integral part of temporal bone pneumatization. Previous authors have alluded to a relation between its size and temporal bone pneumatization [2–5]. This radiographic study is an attempt to assess the validity of this belief.

Developmental and Adult Anatomy

Ossification of the membranous squamous temporal bone occurs at about the eighth week of gestation [6]. The ossification of the cartilaginous petrous bone does not commence until the 16th week, when the otic capsule first ossifies. Bone deposition occurs rapidly from this central focus, and the petrous pyramid develops by 24 weeks [7, 8]. During this period, a lamina of bone from the petrosa extends laterally to meet a corresponding projection from the squama to form the tegmen, which constitutes the roof of the middle ear cleft and mastoid. For reasons unknown, an overlap between the two bones may occur, the petrosal tegmen "driving" the squamous tegmen downward to form a septum of variable height, obliquely angulated in a medial direction [9, 10] (fig. 1B). A pocket of dura may be lodged within the osseous dehiscence. In the juvenile temporal bone, this sulcus houses the petrosquamosal sinus and connecting blood vessels between the dura and the tympanic cavity. The petrosquamosal sinus usually drains into the sigmoid sinus dorsally. This venous drainage pattern, which disappears in the adult after sutural fusion, may explain the frequent meningeal irritation in children with otitis [10]. The superior temporal artery, a branch of the middle meningeal artery, also passes through this suture [9]. The tegmen tympani and mastoideum in the adult

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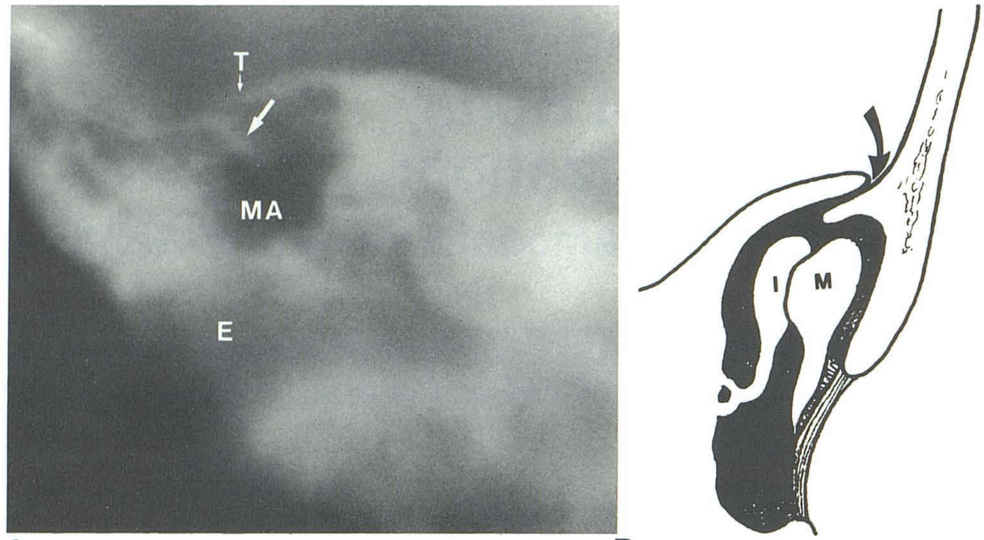
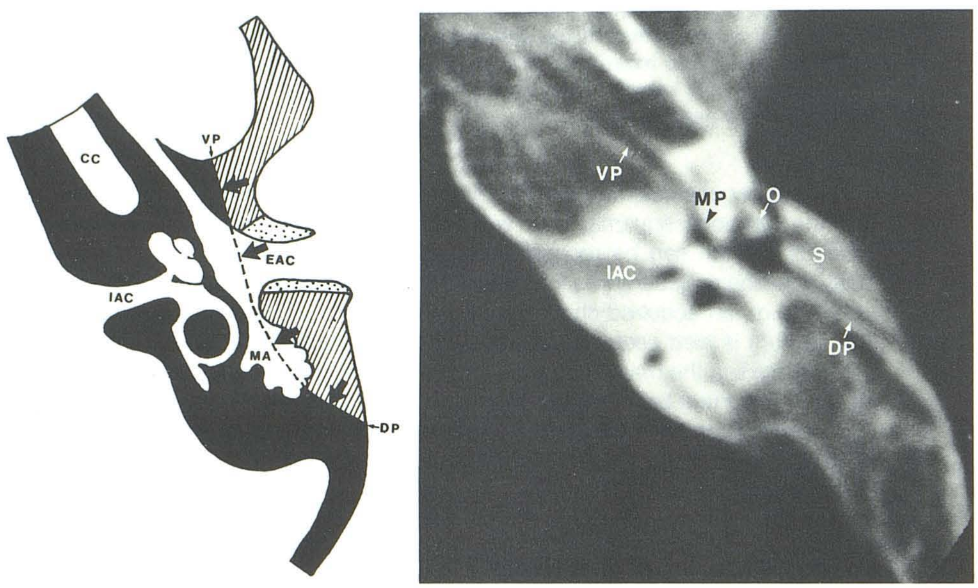


A B

Fig. 1.—**A**, Conventional coronal tomogram of right ear demonstrating dorsal superior petrosquamosal septum (*arrow*). E = external auditory canal; MA = mastoid antrum; T = tegmen mastoideum. **B**, Cross-sectional drawing of 22-week fetal left ear showing overlap between petrosal and squamosal tegmina, latter being driven downward to form superior septum. *Arrow* = dorsal petrosquamosal suture; I = incus; M = malleus.



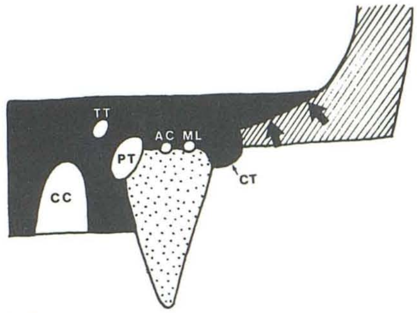
A B

Fig. 2.—**A**, Drawing of axial section of left ear demonstrating course of petrosquamosal suture (*arrows*) through temporal bone. CC = carotid canal; DP = dorsal petrosquamosal suture; EAC = external auditory canal; IAC = internal auditory canal; MA = mastoid antrum; VP = ventral petrosquamosal suture; black area = petromastoid; hatched area = squamosal, dotted area = tympanic. **B**, Axial CT scan of left ear of 2-year-old child with Treacher-Collins syndrome. Unfused petrosquamosal suture is well demonstrated. Note hypoplastic and malformed temporal squama (S) and ossicles (O). Petromastoid is unaffected because of its separate origin from cartilage. MP = mid petrosquamosal suture.

are commonly 5–6 mm thick [10], but may be very thin or replaced in some areas by a delicate membrane. In 94 cadavers, Ahren and Thulen [11] found dehiscences in 21% and extreme thinning in 16%. Thus, normal interruptions in the tegmen may be seen radiographically, a point poorly emphasized in the radiographic literature. Such an anatomic setting may also predispose to the development of tympanic encephalocele and cerebrospinal fluid leakage [12].

In the adult, the endocranial aspect of the suture is usually obliterated by petrosquamosal fusion. Occasionally, however, fusion is incomplete and the persistent petrosquamosal suture can be recognized. Under such circumstances, the suture may be used as an important landmark by surgeons during middle fossa surgery when searching for the facial hiatus (the exiting foramen of the greater petrosal nerve as it passes ventrally from the geniculate ganglion into the middle cranial fossa to supply the lacrimal gland and taste fibers to the palate). The extracranial aspect of the suture extends from the glenoid fossa to the mastoid tip, in a complex, linear or slightly curvilinear path (fig. 2). Its course is best understood by dividing it into three parts: ventral, middle, and dorsal.

The ventral (temporomandibular) petrosquamosal suture lies anteromedial to the external ear canal. This part of the suture is related to the glenoid fossa ventrally, the eustachian tube and protympanum medially, and the external canal and tympanic bone laterally (fig. 3). Its anatomic complexity is mainly due to the tympanic bone, which forms an incomplete cylinder around the external canal. As the tympanic cylinder



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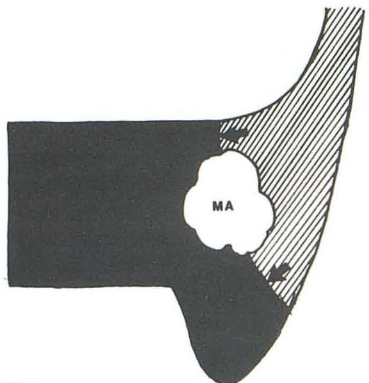

3B

Fig. 3.—Drawing of coronal section of left ear showing ventral (**A**, *arrows*) and dorsal (**B**, *arrows*) sutures. Crista tegmentalis (CT) is wedged between squamosa (hatched area) and tympanic (dotted area) in **A**. Note course of dorsal inferior suture lateral to mastoid tip. AC = anterior chordal canal (Huguier); CC = carotid canal; MA = mastoid antrum; ML = anterior mallear foramen; PT = protympanum; TT = canal for the tensor tympani; black area = petromastoid.

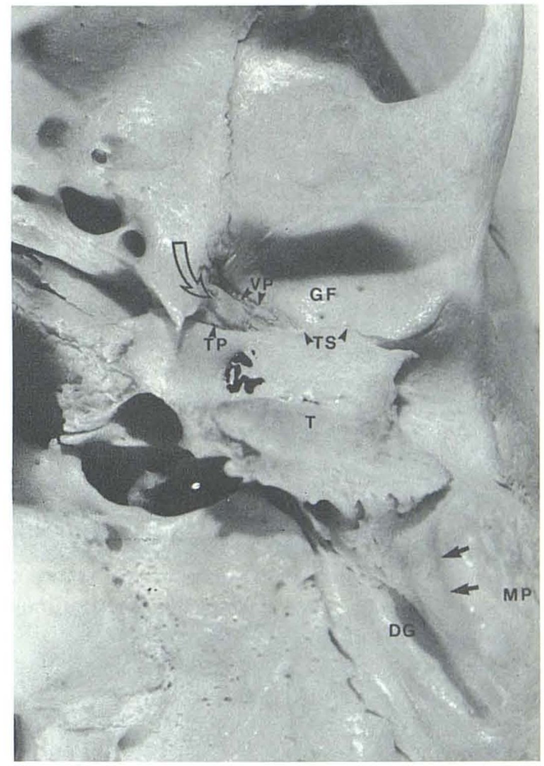

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Fig. 4.—Base view of left ear of dry skull showing crista tegmentalis (*curved arrow*) and ventral petrosquamosal suture (VP). Ridge of bone lateral to mastoid tip represents dorsal petrosquamosal suture (*straight arrows*). DG = digastric groove; GF = glenoid fossa; MP = mastoid process; T = tympanic bone; TP = tympanopetrosal suture; TS = tympanosquamosal (glaserian) suture.

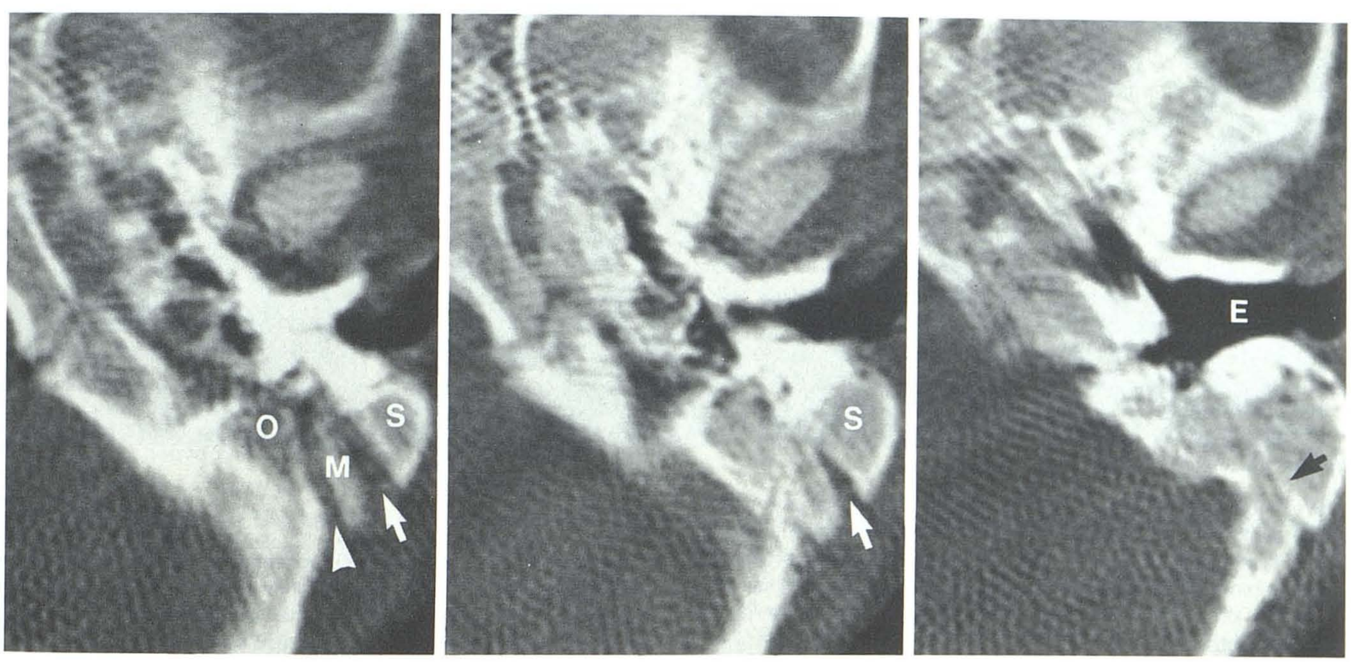


Fig. 5.—Axial CT of left ear of 2-year-old child from inferior (left) to superior (right). Inferiorly, unfused inferior petrosquamosal suture (*white arrows*) separates squamosal (S) laterally from mastoid (M) medially. Mastoid in turn is separated from occipital (O) by occipitomastoid suture (*arrowhead*). Superiorly, at level of external auditory canal (E), petrosquamosal suture has fused, forming dense line (*black arrow*), which in later life can presumably be transformed into septum by pneumatization.

curls upward, it articulates with the squama at the tympanosquamosal suture (glaserian fissure). In some skulls, the fissure is forked medially forming a "Y" as it meets an intervening segment of the petrosa (i.e., the intertympanosquamosal crest or crista tegmentalis) (fig. 4) [9]. The ventral arm of the "Y" is formed by the petrosquamosal suture and the dorsal arm by the tympanopetrosal suture (fig. 4). Medially, the crista tegmentalis is bounded by the greater wing of the

TABLE 1: **Visualization of PSS on CT**

	Superior PSS	Inferior PSS
Entire length of PSS seen	43 (30)	24 (17)
PSS partially seen	63 (45)	34 (24)
PSS not seen	35 (25)	83 (59)
Percentage of visualization of PSS	(75)	(41)

Note.—Numbers in parentheses are percentages.

sphenoid. Thus, the ventral petrosquamosal fissure allows communication between the glenoid fossa and the intracranial cavity, while the glaserian fissure and the tympanopetrosal suture provide a connection between the fossa and ear. The crista tegmentalis is a downward extension of the petrosal tegmen, which forms a concave surface for articulation with the squama ventrolaterally (figs. 3A and 4). Below, it articulates with the tympanic, which in turn forms the lateral wall of the protympanum (fig. 3A).

The middle (tympanic) petrosquamosal suture crosses the epitympanic cavity. (We believe this septum may represent "the cog" [13], a ridge of bone in the epitympanic recess that is used by surgeons during middle ear exploration. By following "the cog" [middle petrosquamosal septum] anteriad, the surgeon can locate the geniculate ganglion.) The oblique and often poorly developed septum that demarcates the position of the suture can occasionally be seen on conventional tomography. Rarely, the septum extends far downard to fix the malleus, thereby causing conductive deafness [9].

The dorsal (mastoid) petrosquamosal suture passes through air cells in the squamomastoid. Here the septum is more readily distinguishable as it separates the air cells into two compartments: the superficial squamous and the deep mastoid (fig. 3B). The suture extends downward vertically through almost the entire mastoid, passing lateral to the mastoid tip (fig. 5). Inferiorly, in the mastoid process, the inferior septum also separates the air cells into two groups. The fused suture line can often be seen on the surface of the mastoid process as a ridge of bone (fig. 4). In this thicker part of the temporal bone, the septum is a vertical lamina extending from the antrum, down laterally to the vertical part of the facial canal into the mastoid process (figs. 3B and 5).

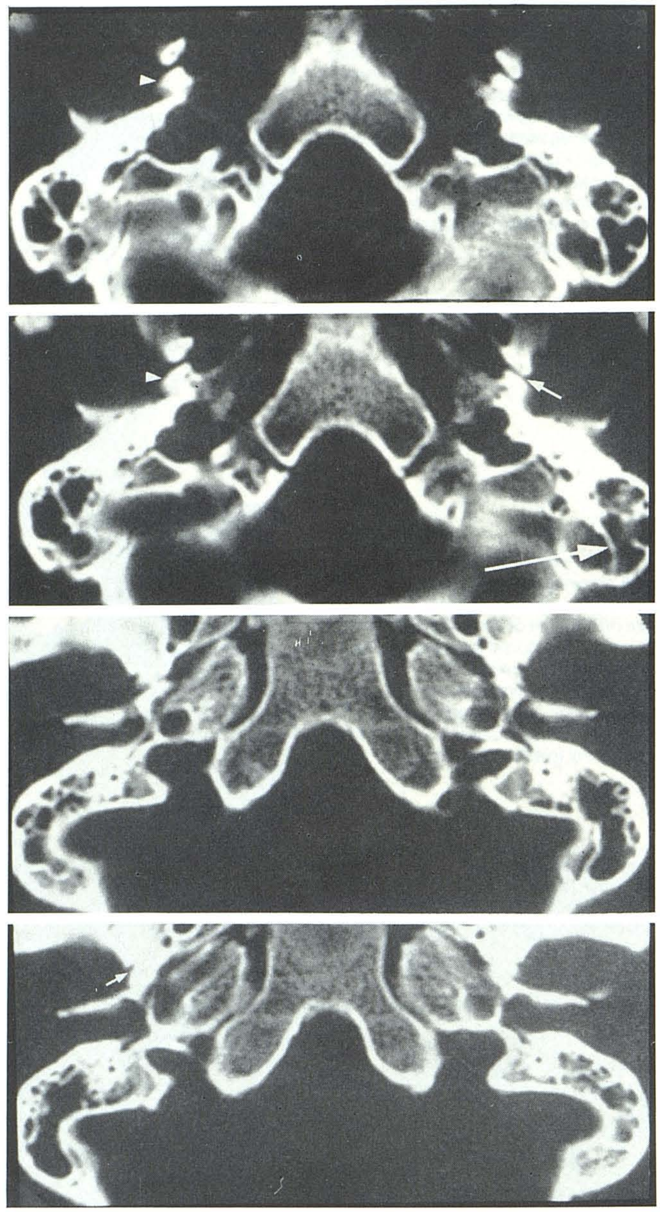


Fig. 6.—Axial CT of dry skull from inferior (top) to superior (bottom). Note polypoid petrosal excrescence representing crista tegmentalis (*arrowheads*), which abuts squamosa to form ventral petrosquamosal fissure (*short arrows*). Inferior septum is discernible in mastoid process (*long arrow*).

Materials and Methods

We determined the degree of visualization of the dorsal petrosquamosal septum (PSS) on axial CT in 141 "normal" temporal bones (100 subjects) [14]. In 41 cases, both temporal bones were evaluated (52 were male, 48 female; 68 examinations were of the right ear and 73 of the left.) The CT scanning technique has been previously described [14].

Early experience indicated that the dorsal PSS was seen primarily in two regions: (1) superiorly at the level of the epitympanic recess and (2) inferiorly at the level of the external canal, hypotympanum, and mastoid process. A complete *vertical* septum extending the entire length of the mastoid was rarely encountered. We divided the PSS into superior and inferior segments.

A scoring system was based on the degree of visualization of each segment. Since the degree of visualization is based on the anteroposterior length and the vertical height and thickness of the septum, all factors were considered in the analysis. A score of 2 was given to a septum that extended fully anteroposteriorly through the mastoid or vertically downward on at least three adjacent slices. A septum that did not correspond to these criteria was given a score of 1, and no visualization was given a score of 0. The analysis was made of each segment (superior and the inferior PSS) separately. The sum of both raw scores yielded a total PSS score for that ear. Correlates with temporal bone pneumatization were then obtained.

Results

Statistical Analysis

The mean raw score for the right and left superior PSS were 1.2 ± 0.7 SD and 0.94 ± 0.7 SD, respectively, and for

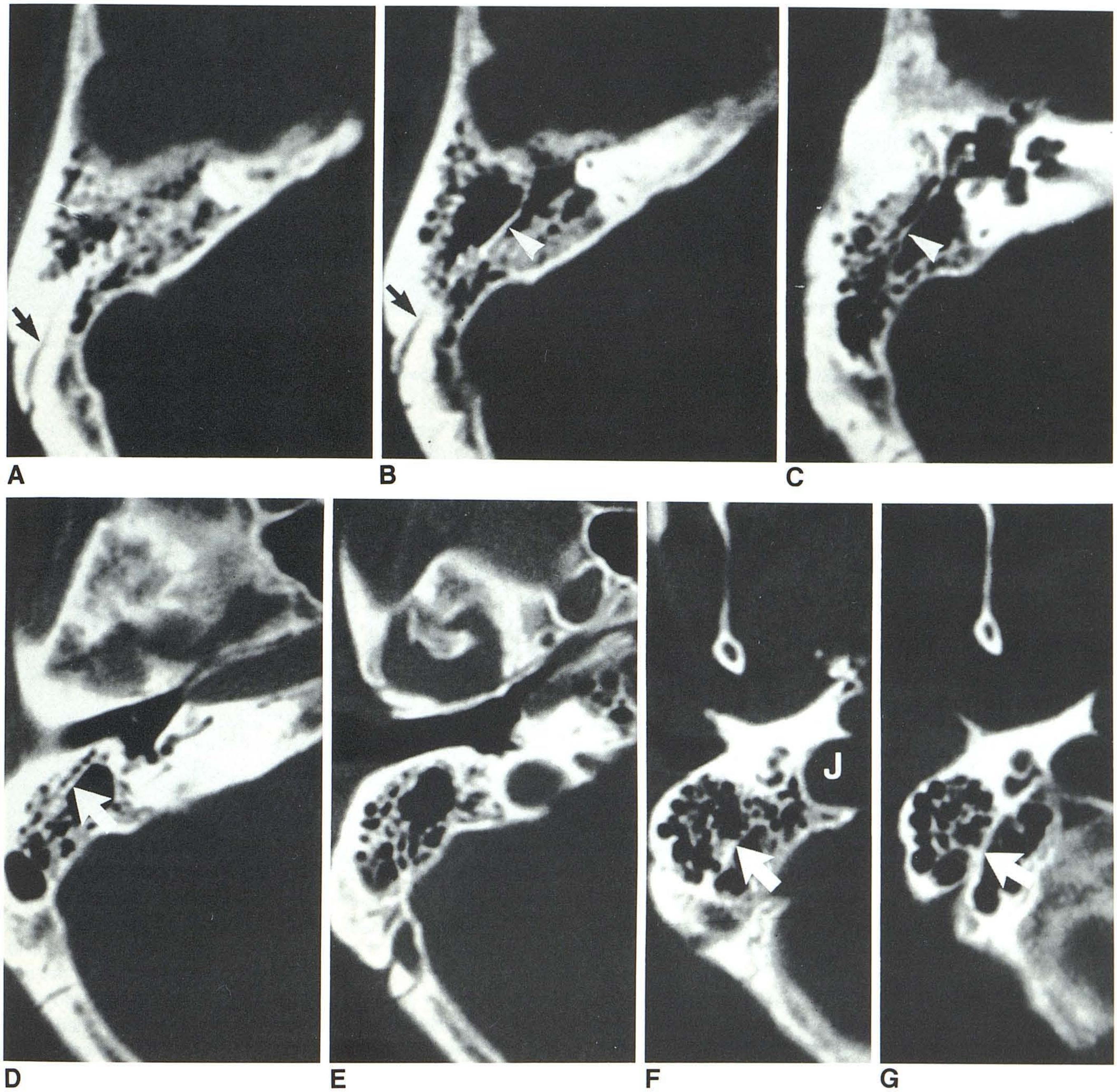
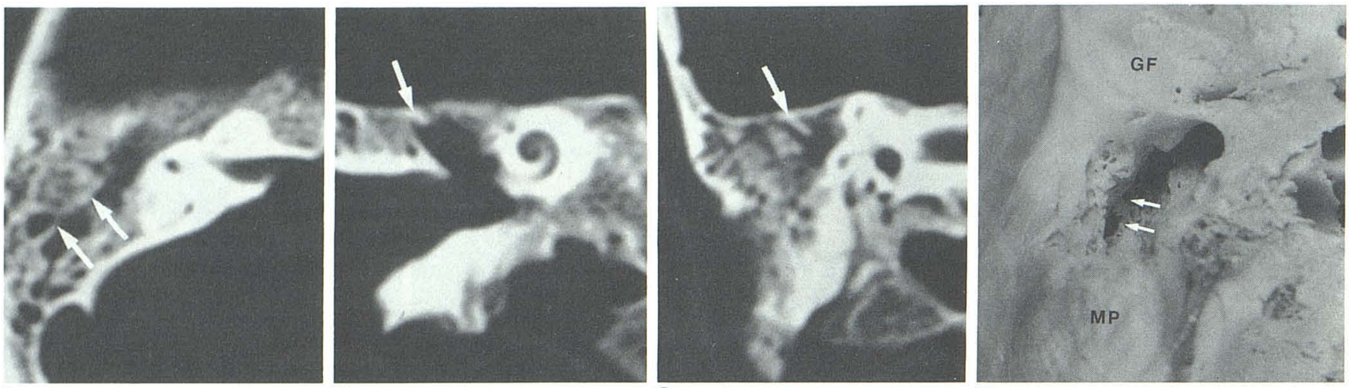


Fig. 7.—Axial CT of right ear from superior (**A**) to inferior (**G**) demonstrating superior (**A–C**, *white arrowheads*) and inferior (**D–G**, *white arrows*) septa. Both septa received score of 2. Note patent dorsal petrosquamosal suture (*black arrows*). J = jugular fossa.

the right and left inferior PSS 0.62 ± 0.8 SD and 0.50 ± 0.7 SD, respectively. Average total raw scores for PSS in the right and left ears were 1.8 ± 1.3 SD and 1.5 ± 1.2 SD, respectively. In most ears (75%), the superior PSS was seen, while in 59% the inferior PSS was *not* seen (table 1). There was no correlation between the degree of visualization of PSS with age ($r = -0.16$) or gender ($r = -0.03$). A poor correlation was found between the superior PSS and the degree of pneumatization of the squamomastoid ($r = 0.1$) and between the inferior PSS and the degree of pneumatization of the mastoid process ($r = 0.26$). Similarly, the correlation between the sum of the degree of visualization of the PSS and the sum total of all aeration indices for the temporal bone was poor ($r = 0.23$).

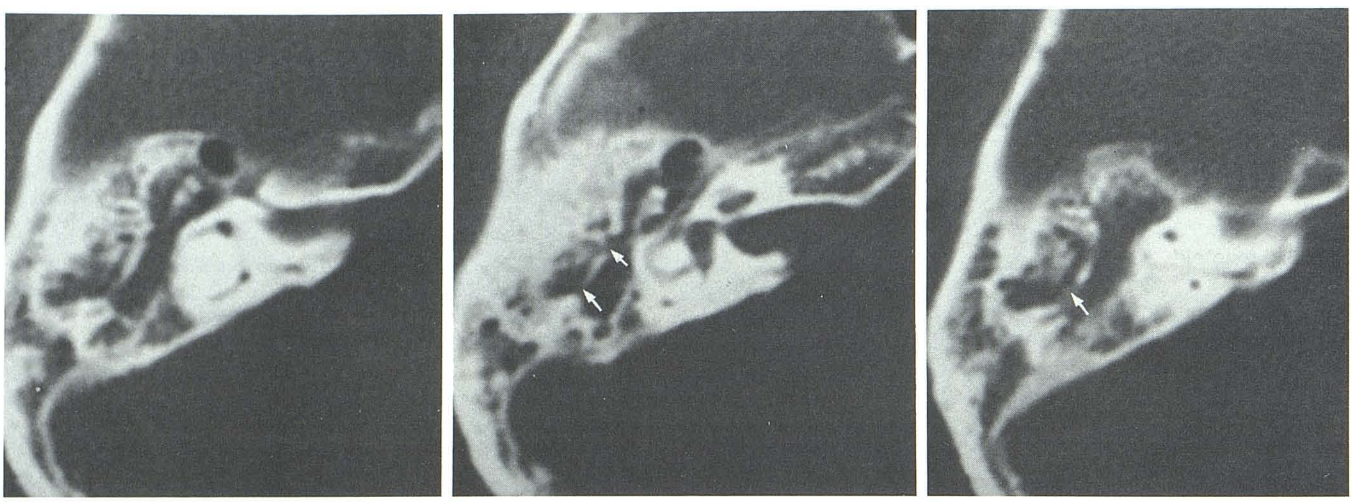
Morphology

The ventral (temporomandibular) petrosquamosal suture is seen on axial CT as a thin fissure ventrolateral to the protympanum and eustachian tube isthmus (fig. 6). When the crista



A B C D

Fig. 8.—Correlative size of superior septum (*arrows*) on axial (**A**) and coronal (**B** and **C**) CT, compared with its macroscopic appearance from below (**D**). This septum would receive score of 1. GF = glenoid fossa; MP = mastoid process.



A B C

Fig. 9.—Axial CT of right ear from inferior (left) to superior (right) in patient with sclerotic mastoiditis. Superior septum is thickened and interrupted at several intervals (*arrows*), suggesting concomitant bone formation and destruction.

tegmentalis is present, it is seen on CT as a bony excrecence, bounded laterally by the glenoid fossa, ventrally by the temporal squama, ventromedially by the petrosphenoid fissure, and dorsomedially by the carotid canal.

The mid (tympanic) PSS is difficult to see on axial CT. Rarely, a thin spicule of bone can be seen on "high" sections through the epitympanic recess, which may possibly correspond to the lamina. However, this has not been definitely proven.

The dorsal (mastoid) PSS: The superior PSS is seen on axial CT as a delicate, linear osseous partition. It is usually about the same thickness as the wall of the air cell and does not exceed two to three times the thickness of the latter (fig. 7). It extends ventrally from the apex of the triangular epitympanic recess through the mastoid antrum and then through the periantral cells to attach to the endosteal surface of the temporal squama (fig. 7B). The obliquity of its course may vary depending on the anteroposterior dimension of the mastoid, which in turn is dependent on the degree of pneumatization [14]. To determine whether the septum is complete anteroposteriorly, juxtaposition of adjacent sections is necessary. When incomplete, either its ventral third with its attachment to the tegmen tympani or its more dorsal part attached to the temporal squama may be seen. The vertical height of the septum varies, extending in some skulls down to the mid external auditory canal. Septa that were poorly seen (score = 1) may be visible only in the uppermost CT slices through the tegmen (fig. 8). Most of the septa that were well visualized (score = 2) were seen at the level of the heads of the ossicles. The septum is usually convex inward, presumably depending on the growth relation between the petrous and squamous bones; rarely it is convex outward. Occasionally the squama and mastoid fail to fuse, leaving a fissure readily visible on CT, which should not be mistaken for a fracture (figs. 7A and 7B).

The inferior PSS is the more distinctive when present. It

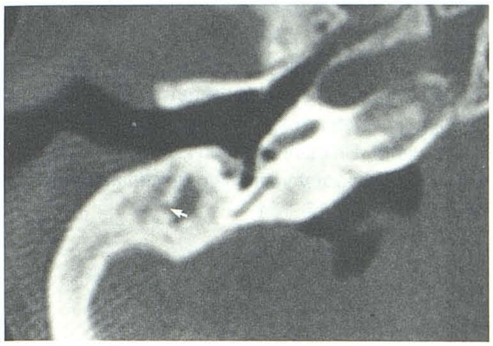


Fig. 10.—Axial CT of right ear in another patient with sclerotic mastoiditis. Again note thickened and interrupted septum typical of this disease (*arrow*).

passes ventrally from either the greater tympanic spine (fig. 7D) or a point lateral to it and runs obliquely posterolaterally, lateral to the jugular fossa (fig. 7B), where it attaches to a cortical plate in the region of the sigmoid sulcus. In the mastoid process, it runs parallel and lateral to the digastric groove (fig. 4). The thickness of the lamina varies from one to five times the thickness of the wall of the adjacent air cells. The obliquity of the inferior septum, like that of the superior PSS, is determined by the degree of pneumatization of the mastoid. This has a more coronal course in the poorly pneumatized mastoid.

Discussion

Although the anatomy of the PSS has been known to anatomists for some time, it was Körner [15] who pointed out its clinical significance. Since then, the septum has been the subject of several reports in the otologic literature [9, 16–18]. Occasionally, a well developed PSS at surgery may be mistaken for the posteromedial wall (Körner's "false bottom") [15] of the mastoid, and the deep pneumatic system of the mastoid may be overlooked and not explored. When the septum is extensive, the squamosal and mastoid group of periantral cells may open separately into the antrum, requiring removal of the septum for better drainage. Also, the mastoid part of the facial nerve may be injured because of mistaken identification of the PSS. Radiographically it is important to (1) be cognizant of a well developed or thick septum on CT, (2) determine its relation to the sinodural plate and facial canal so that these structures are not inadvertently breached during surgery, and (3) determine the size of the antrum and degree of sclerosis on either side of the septum for surgical planning.

Some authors indicate that the septum may be poorly developed in a well pneumatized squamomastoid and vice versa [2–5]. However, our study indicates otherwise; that is, the axial CT visualization of the septum has no relation to age, gender, laterality, or degree of pneumatization of the squamomastoid. It is tempting to conclude that the surgeon may not be able to anticipate the size of the septum during surgery on the basis of an assessment of temporal bone pneumatization, further enhancing the role of CT. Theoretically, however, an ideal analysis should accurately quantitate the surface (two dimensional) area of the PSS, which is difficult on axial images. Our experience has shown that the vertical height of the septum is probably best assessed on direct coronal CT. Because reformatted images lack resolution, our analysis can be subject to an error as yet undetermined.

So far, our experience has shown that the PSS may be used as a radiographic "yardstick" to evaluate squamomastoid sclerosis (figs. 9 and 10) in addition to its traditional role of gauging bony destruction in cholesteatoma. This is not surprising, because like other parts of the squamomastoid, it is subject to the osseous destruction and subsequent new bone formation that occurs in sclerotic mastoiditis.

As for the ventral petrosquamosal fissure, the complexity of the radiographic anatomy of this region has been alluded to in a previous communication [19]. The curious participation of the petrosal tegmen in the formation of the glenoid fossa may be related to the phylogenetic development of the temporomandibular fossa during the evolution of the unique mammalian temporomandibular jaw apparatus [20]. The radiographic anatomy of the crista tegmentalis and the ventral petrosquamosal suture is important because of the frequent involvement of this part of the temporal bone in longitudinal fractures.

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