Research Article

Evaluation of Temporal Bone Anatomical Variations Using High-Resolution Computed Tomography: A Cross-Sectional Observational Study

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Abstract

Background: High-resolution computed tomography (HRCT) is the imaging modality of choice for evaluating temporal bone anatomy because of its excellent spatial resolution and ability to delineate intricate osseous structures. Recognition of anatomical variants before otologic surgery is crucial to avoid potentially serious intraoperative complications involving the facial nerve, jugular bulb, dura, sigmoid sinus, and internal carotid artery. Knowledge of these variants facilitates accurate diagnosis, appropriate surgical planning, and improved patient safety.

Objectives: To evaluate the prevalence and spectrum of anatomical variations of the temporal bone using high-resolution computed tomography and to determine their distribution in patients undergoing HRCT temporal bone examination.

Materials and Methods: A prospective cross-sectional observational study was conducted in the Department of Radiodiagnosis, Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals (VMKV MCH), Salem, Tamil Nadu, India, over a period of 18 months. A total of 155 consecutive patients referred for HRCT temporal bone examination were included. HRCT imaging was performed using a 16-slice multidetector CT scanner after obtaining informed consent. Ten temporal bones demonstrating extensive pathology causing distortion of normal anatomy were excluded. Consequently, 300 temporal bones were analyzed for the presence of anatomical variants including high-riding jugular bulb, facial nerve dehiscence, Korner's septum, dural exposure, aberrant internal carotid artery, and other anatomical variations.

Results: Among 155 patients, the majority belonged to the 21–40-year age group (54.19%), followed by 41–60 years (23.22%), 0–20 years (19.35%), and >60 years (3.22%). There were 91 males (58.7%) and 64 females (41.3%). Anatomical variants were observed in 155 temporal bones, while 145 (48.3%) demonstrated normal anatomy. The most common anatomical variant was high-riding jugular bulb, identified in 67 temporal bones (22.3%), followed by Korner's septum in 33 (11.0%), facial nerve dehiscence in 28 (9.3%), dural exposure in 9 (3.0%), aberrant internal carotid artery in 1 (0.3%), and other anatomical variants in 17 temporal bones (5.6%). Anatomical variants were slightly more frequent on the left side (52.2%) than on the right side (47.7%).

Conclusion: HRCT provides comprehensive evaluation of temporal bone anatomical variations and remains indispensable for preoperative assessment. High-riding jugular bulb was the most frequent anatomical variant encountered, whereas aberrant internal carotid artery was extremely rare. Routine identification and reporting of these anatomical variants can significantly reduce operative morbidity, facilitate surgical planning, and improve outcomes in otologic and skull-base procedures.

Keywords: High-resolution computed tomography; Temporal bone; Anatomical variations; High-riding jugular bulb; Facial nerve dehiscence; Korner's septum; HRCT; Otologic surgery.

Introduction

The temporal bone contains one of the most anatomically intricate regions of the human body, housing the organs responsible for hearing and balance along with several critical neurovascular structures. These include the facial nerve, vestibulocochlear nerve, internal carotid artery, jugular bulb, sigmoid sinus, cochlea, vestibular apparatus, and mastoid air cell system. Because of this complex anatomy, even minor anatomical variations may substantially influence surgical planning and increase the risk of intraoperative complications.

High-resolution computed tomography (HRCT) has become the imaging modality of choice for evaluating the temporal bone due to its excellent spatial resolution and superior depiction of osseous anatomy. Thin-section multidetector CT allows accurate visualization of normal anatomical structures as well as congenital, developmental, and acquired anatomical variations. Identification of these variants before surgery is particularly important in patients undergoing mastoidectomy, cochlear implantation, tympanoplasty, skull-base surgery, and other otologic procedures.

Several anatomical variants—including high-riding jugular bulb, facial nerve dehiscence, Korner's septum, low-lying tegmen tympani, aberrant internal carotid artery, persistent stapedial artery, enlarged vestibular aqueduct, and sigmoid sinus variations—may alter the surgical approach or increase the likelihood of vascular injury, cerebrospinal fluid leak, facial nerve injury, or incomplete disease clearance. Although many of these variants are asymptomatic, failure to recognize them preoperatively may lead to significant surgical morbidity.

The reported prevalence of temporal bone anatomical variations differs considerably among populations because of ethnic diversity, genetic factors, imaging techniques, and varying diagnostic criteria. Consequently, regional studies are important to establish local prevalence patterns and to familiarize radiologists and otologic surgeons with the anatomical variants encountered in their patient population.

The present study was conducted in the Department of Radiodiagnosis, Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals (VMKV MCH), Salem, Tamil Nadu, India, to evaluate the prevalence and spectrum of temporal bone anatomical variations using high-resolution computed tomography. The study also aimed to highlight the clinical significance of these variants in surgical planning and their importance in routine radiological reporting.

Materials And Methods

Study Details

This prospective cross-sectional study was conducted in the Department of Radiodiagnosis, Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals (VMKV MCH), Salem, Tamil Nadu, India, in collaboration with the Department of Otorhinolaryngology, to evaluate the prevalence and spectrum of temporal bone anatomical variations using high-resolution computed tomography (HRCT). A total of 155 consecutive patients referred for HRCT temporal bone evaluation were prospectively enrolled after obtaining written informed consent using purposive sampling. HRCT assessment was performed on 310 temporal bones, of which 10 with extensive pathology causing distortion of normal anatomical landmarks were excluded, resulting in a final analysis of 300 temporal bones.

Eligibility Criteria: Patients referred for high-resolution computed tomography (HRCT) of the temporal bone who provided written informed consent were included. Patients with a history of bilateral temporal bone surgery, extensive temporal bone pathology causing distortion of normal anatomical landmarks, or those who declined participation were excluded.

HRCT Imaging Protocol

All examinations were performed using a 16-slice Siemens Multidetector Computed Tomography (MDCT) scanner.

Patient Preparation

Patients were positioned supine with the head immobilized to minimize motion artifacts during image acquisition.

Image Acquisition Parameters

- Scanner: Siemens 16-slice MDCT
- Technique: High-Resolution Computed Tomography (HRCT)

- Slice thickness: Thin-section HRCT protocol
- Axial acquisition with multiplanar coronal reconstructions
- Bone reconstruction algorithm
- Images evaluated in axial and coronal planes using standard bone windows

Image Analysis

Each HRCT examination was independently evaluated for the presence or absence of important anatomical variations of the temporal bone.

The following anatomical variants were specifically assessed:

- High-riding jugular bulb (HRJB)
- Facial nerve dehiscence (FND)
- Korner's septum (KS)
- Dural exposure (Low-lying tegmen)
- Aberrant internal carotid artery (AICA)
- Other anatomical variants, when present
- Each temporal bone was evaluated separately, and bilateral findings were documented independently.

Outcome Measures

The primary outcome was the prevalence of anatomical variations identified on HRCT.

Secondary outcome measures included:

- Age distribution of study participants
- Gender distribution
- Laterality of anatomical variations
- Frequency of individual anatomical variants

Statistical Analysis

Collected data were entered into Microsoft Excel and analyzed using descriptive statistical methods.

Continuous variables were summarized as frequencies and percentages. Categorical variables were presented using tables and graphical charts. The prevalence of each anatomical variant was calculated as a percentage of the total number of temporal bones evaluated.

No inferential statistical analysis was performed because the study primarily aimed to describe the frequency and distribution of anatomical variations.

Figure 1 Sixteen-slice Siemens Multidetector Computed Tomography scanner used for HRCT temporal bone imaging.

RESULTS

A total of 155 patients underwent HRCT examination of the temporal bone during the study period. HRCT evaluation included 310 temporal bones. Of these, 10 temporal bones demonstrated extensive pathology resulting in distortion of normal anatomical landmarks and were excluded from analysis. Therefore, 300 temporal bones (145 bilateral pairs and 10 unilateral temporal bones) were included in the final analysis.

Demographic Characteristics

Age Distribution

The majority of study participants belonged to the 21–40 years age group (54.19%), followed by 41–60 years (23.22%), 0–20 years (19.35%), and >60 years (3.22%).

Table 1. Age Distribution of Study Participants (n = 155)

Age Group (Years)	Number of Patients	Percentage (%)
0–20	30	19.35
21–40	84	54.19
41–60	36	23.22
>60	5	3.22
Total	155	100.00

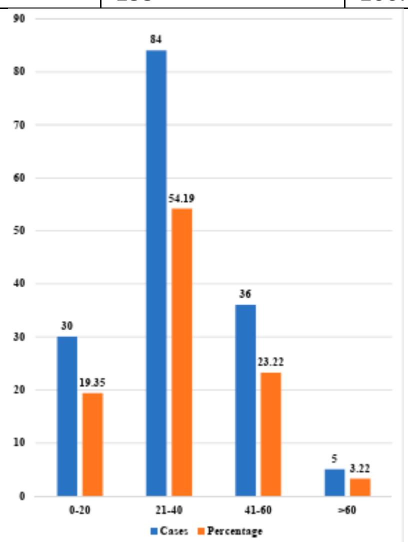

Figure 2. Age distribution of study participants.

Gender Distribution

Among the 155 participants, 91 (58.7%) were males and 64 (41.3%) were females, resulting in a male-to-female ratio of approximately 1.4:1.

Table 2. Gender Distribution (n = 155)

Gender	Number of Patients	Percentage (%)
Male	91	58.70
Female	64	41.29
Total	155	100.00

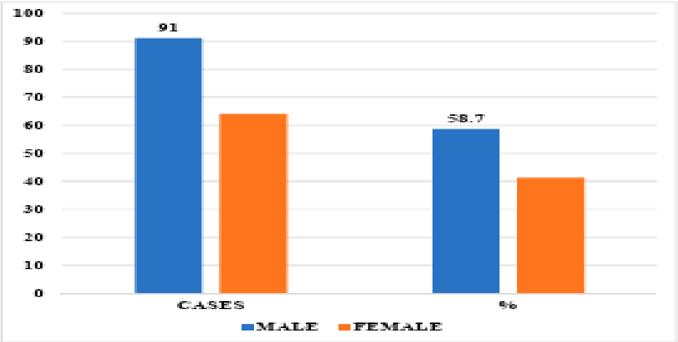

Figure 3. Gender-wise distribution of study participants.

Distribution of Anatomical Variants

Among the anatomical variants identified, 81 (52.2%) were observed in the left temporal bone, whereas 74 (47.7%) occurred in the right temporal bone.

Table 3. Laterality of Anatomical Variants

Laterality	Number of Temporal Bones	Percentage (%)
Right Temporal Bone	74	47.70
Left Temporal Bone	81	52.20
Total	155	100.00

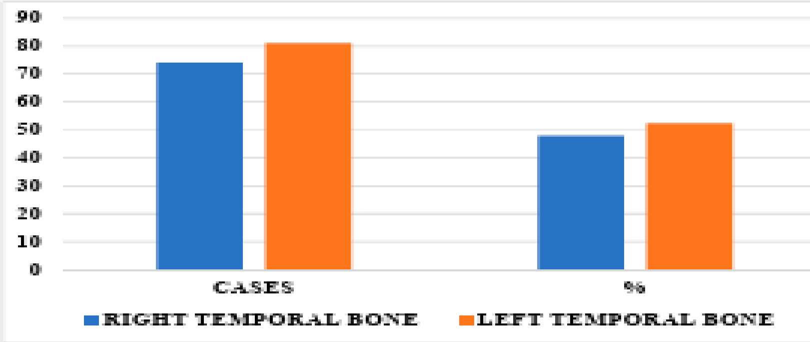

Figure 4. Laterality distribution of anatomical variants.

Frequency of Anatomical Variants

Of the 300 temporal bones evaluated, 145 (48.3%) demonstrated normal anatomy, while 155 (51.7%) exhibited one or more anatomical variants.

The most common anatomical variant identified was high-riding jugular bulb (22.3%), followed by Korner's septum (11.0%), facial nerve dehiscence (9.3%), dural exposure (3.0%), and aberrant internal carotid artery (0.3%).

Table 4. Frequency of Anatomical Variants on HRCT (n = 300 Temporal Bones)

HRCT Finding	Number of Temporal Bones	Percentage (%)

Normal	145	48.30
High-Riding Jugular Bulb	67	22.30
Korner's Septum	33	11.00
Facial Nerve Dehiscence	28	9.30
Dural Exposure	9	3.00
Aberrant Internal Carotid Artery	1	0.30
Other Anatomical Variants	17	5.60
Total	300	100.00

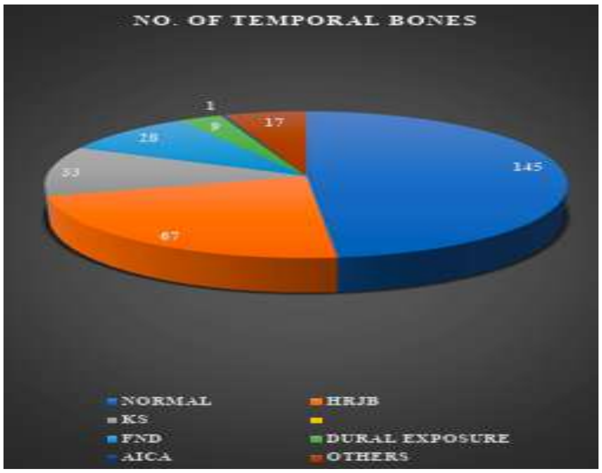

Figure 5. Frequency of anatomical variants detected on HRCT.

Summary

A total of 300 temporal bones were analyzed after excluding 10 temporal bones with gross pathology.

- The 21–40-year age group constituted the majority of participants (54.19%).
- Males accounted for 58.7% of the study population.
- Anatomical variants were marginally more frequent on the left side (52.2%) than on the right side (47.7%).
- High-riding jugular bulb was the most prevalent anatomical variant, observed in 67 temporal bones (22.3%).
- Korner's septum was detected in 33 temporal bones (11.0%).
- Facial nerve dehiscence was present in 28 temporal bones (9.3%).
- Dural exposure was identified in 9 temporal bones (3.0%).
- Aberrant internal carotid artery was the least common anatomical variant, detected in only one temporal bone (0.3%).

Discussion

High-resolution computed tomography (HRCT) is widely regarded as the gold standard imaging modality for evaluating the complex osseous anatomy of the temporal bone. Owing to its excellent spatial resolution, HRCT accurately delineates the intricate anatomy of the middle and inner ear and facilitates identification of clinically significant anatomical variations that may influence surgical planning. Preoperative recognition of these variants is essential to minimize the risk of facial nerve injury, vascular complications, cerebrospinal fluid leakage, and incomplete disease clearance during otologic procedures.

The present study evaluated the prevalence of anatomical variations of the temporal bone in 155 patients undergoing HRCT examination at Vinayaka Mission's Kirupananda Variyar Medical College and Hospitals (VMKV MCH), Salem, Tamil Nadu, India. After excluding temporal bones with extensive pathological distortion, 300 temporal bones were analyzed. The findings demonstrate that anatomical variations are common and should be routinely assessed and documented in all HRCT temporal bone examinations.

Demographic Characteristics

Most participants in the present study belonged to the 21–40-year age group (54.19%), followed by the 41–60-year age group (23.22%). This distribution probably reflects the higher frequency of chronic otologic disorders requiring HRCT evaluation among young and middle-aged adults. Similar age distributions have been reported in previous HRCT temporal bone studies.

A male predominance was observed, with 91 males (58.7%) and 64 females (41.3%), corresponding to a male-to-female ratio of approximately 1.4:1. Comparable gender distributions have been described in several previous studies evaluating temporal bone anatomy.

Laterality of Anatomical Variants

In the present study, anatomical variants were identified slightly more frequently in the left temporal bone (52.2%) than in the right temporal bone (47.7%). Although the difference was small, it demonstrates that anatomical variants may occur on either side with nearly equal frequency. Similar observations have been reported in previous literature, where no consistent side predominance has been established.

Frequency of Anatomical Variants

Among the 300 temporal bones evaluated, 155 (51.7%) demonstrated one or more anatomical variations, whereas 145 (48.3%) exhibited normal anatomy. This relatively high prevalence highlights the importance of systematic evaluation of every HRCT temporal bone examination before otologic surgery.

High-Riding Jugular Bulb

High-riding jugular bulb (HRJB) was the most frequently encountered anatomical variation, identified in 67 temporal bones (22.3%).

The prevalence observed in the present study closely resembles the 23% prevalence reported by Kamath et al., indicating comparable findings between the two populations. In contrast, Koesling et al. reported a considerably lower prevalence of 6%, whereas Karaca et al. documented a higher prevalence of 32%. These differences may be attributed to variations in ethnicity, imaging protocols, sample size, and diagnostic criteria.

Recognition of a high-riding jugular bulb before surgery is clinically important because inadvertent injury may result in significant hemorrhage during middle ear and mastoid surgery.

Korner's Septum

Korner's septum was identified in 33 temporal bones (11.0%).

Although the prevalence observed in the present study is lower than the 26% reported by Kamath et al., it confirms that Korner's septum represents one of the more common anatomical variants encountered on HRCT. Previous studies by Alam et al. have also demonstrated good correlation between radiological identification of Korner's septum and operative findings.

Failure to identify Korner's septum preoperatively may lead to incomplete mastoid exploration and residual cholesteatoma because the septum can obscure the true mastoid antrum during surgery.

Facial Nerve Dehiscence

Facial nerve dehiscence (FND) was observed in 28 temporal bones (9.3%).
Published literature reports a remarkably wide prevalence ranging from 0.5% to 74%, depending upon imaging resolution, diagnostic criteria, and surgical confirmation. The prevalence observed in the present study falls within this reported range.
Identification of facial nerve dehiscence before surgery is essential because exposed facial nerve segments are more susceptible to inadvertent injury during mastoidectomy and middle ear surgery.

Dural Exposure

Dural exposure was identified in 9 temporal bones (3.0%).
This prevalence is comparable to the 2.9% reported by Kamath et al., suggesting consistency across studies.
Knowledge of low-lying tegmen or dural exposure allows surgeons to modify the operative approach and reduces the risk of cerebrospinal fluid leakage and intracranial complications.
Aberrant Internal Carotid Artery
Aberrant internal carotid artery (AICA) represented the least common anatomical variation, being detected in only one temporal bone (0.3%).
Karaca et al. reported an even lower prevalence of approximately 0.02%, confirming the rarity of this vascular anomaly.
Although uncommon, aberrant internal carotid artery has considerable surgical significance because accidental injury may produce catastrophic hemorrhage. Accurate HRCT diagnosis is therefore critical before any middle ear intervention.

Clinical Implications

The findings of the present study reinforce the indispensable role of HRCT in the preoperative evaluation of temporal bone surgery. Accurate recognition of anatomical variants enables surgeons to anticipate technical difficulties, select appropriate surgical approaches, and minimize operative morbidity.
Routine reporting of clinically significant variants—including high-riding jugular bulb, facial nerve dehiscence, Korner's septum, dural exposure, and aberrant internal carotid artery—should form an integral component of every HRCT temporal bone report.
The study also demonstrates that more than half of the evaluated temporal bones exhibited one or more anatomical variations, emphasizing the need for meticulous radiological assessment even in patients without obvious congenital anomalies.

Strengths of the Study

- Prospective cross-sectional design.
- Evaluation performed using high-resolution multidetector CT.
- Assessment of 300 temporal bones, providing a substantial imaging dataset.
- Systematic evaluation of surgically relevant anatomical variants.
- Findings contribute valuable epidemiological data regarding temporal bone anatomical variations in the South Indian population.

Limitations

- Single-center study.
- Relatively modest sample size.
- Surgical confirmation of all anatomical variants was not available.
- Rare anatomical variants were represented by very few cases, limiting detailed subgroup analysis.
- Inferential statistical analysis and interobserver agreement were not evaluated.

Future Recommendations
Future multicenter studies involving larger populations and correlation between HRCT findings and intraoperative observations are recommended. Such studies may further improve understanding of regional anatomical variations and strengthen the role of HRCT in surgical risk stratification. Additionally, incorporating advanced multidetector CT technology and three-dimensional reconstructions may enhance the visualization of subtle anatomical variants and improve preoperative planning.

Conclusion
The present study demonstrates that high-resolution computed tomography (HRCT) is an indispensable imaging modality for the evaluation of temporal bone anatomy and the identification of clinically significant anatomical variations. Owing to its excellent spatial resolution and multiplanar imaging capability, HRCT accurately depicts critical osseous structures and vascular relationships that are essential for preoperative planning in otologic and skull base surgeries.
In this study, anatomical variations were identified in more than half of the evaluated temporal bones, emphasizing that such variations are common rather than exceptional. High-riding jugular bulb (22.3%) was the most prevalent anatomical variant, followed by Korner's septum (11.0%), facial nerve dehiscence (9.3%), and dural exposure (3.0%), while aberrant internal carotid artery (0.3%) was the rarest finding. These anatomical variants have important surgical implications because failure to recognize them preoperatively may result in facial nerve injury, major vascular hemorrhage, cerebrospinal fluid leakage, incomplete disease clearance, or revision surgery.
The findings of the present study highlight the necessity for a systematic and comprehensive evaluation of every HRCT temporal bone examination, irrespective of the primary clinical indication. Radiologists should routinely identify and report surgically relevant anatomical variants, thereby assisting otologic surgeons in selecting the safest operative approach and minimizing intraoperative complications.
Furthermore, the prevalence pattern observed in this South Indian population contributes valuable regional data to the existing literature and demonstrates that demographic and geographic differences may influence the frequency of temporal bone anatomical variations. Larger multicenter studies with surgical correlation are warranted to further validate these findings and establish standardized reporting guidelines.
In conclusion, HRCT should remain the standard preoperative imaging investigation for temporal bone surgery, and meticulous reporting of anatomical variants should be considered an integral component of every radiological evaluation to optimize surgical planning and improve patient outcomes.

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