e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2025; 17(12); 272-276

Original Research Article

Temporal Bone Microanatomy Variability in the Indian Population High Resolution Ct Atlas Development for Surgical Optimization

Jay Vardhan[1], Priyanka Kumari[2], MD. Ozair[3], Manoj Kumar[4], Rani Rashmi Priya[5]

[1]Senior Resident, Department of ENT, Laheriasarai, Darbhanga

[2]Senior Resident, Department of ENT, Laheriasarai, Darbhanga

[3]Associate Professor, Department of ENT, Laheriasarai, Darbhanga

[4]Assistant Professor, Department of ENT, Laheriasarai, Darbhanga

[5]Junior Resident, Department of ENT, Laheriasarai, Darbhanga

Received: 05-10-2025 / Revised: 03-11-2025 / Accepted: 05-12-2025

Corresponding Author: Dr. Priyanka Kumari

Conflict of interest: Nil

Abstract:

Background: Successful otologic and neurotologic surgery relies heavily on a precise understanding of temporal bone microanatomy. Anatomical variations across populations can influence surgical approaches, complication rates, and preoperative planning. Despite India's diverse genetic and morphological landscape, comprehensive population-specific imaging atlases remain limited.

Objective: This study aims to characterize microanatomical variability of the temporal bone within the Indian population using high-resolution computed tomography (HRCT) and to develop a detailed, surgeon-oriented atlas to support optimized clinical and surgical decision-making.

Methods: HRCT scans of adult Indian patients without temporal bone pathology were retrospectively analyzed. Key anatomical structures—such as the facial nerve canal, cochlea, semicircular canals, jugular bulb, sigmoid sinus, mastoid pneumatization patterns, and carotid canal—were measured and mapped. Variations were quantified, stratified by demographic factors, and integrated into a standardized imaging atlas. Representative 3D reconstructions and multiplanar reference images were incorporated for surgical relevance.

Results: Significant variability was observed in mastoid pneumatization, jugular bulb position, and facial nerve canal morphology. Distinct patterns in cochlear dimensions and semicircular canal orientation were noted compared with reported Western and East Asian datasets. These findings were systematically compiled into a high-resolution CT atlas highlighting morphometric ranges, high-risk anatomical variants, and surgical landmarks critical for mastoidectomy, cochlear implantation, transmastoid facial recess approaches, and lateral skull base procedures.

Conclusion: The developed HRCT-based atlas provides the first comprehensive reference of temporal bone microanatomical variability specific to the Indian population. By enhancing anatomical predictability and supporting individualized surgical planning, this atlas has the potential to improve surgical safety, reduce complication rates, and serve as a valuable educational tool for trainees and practicing surgeons.

Keywords: HRCT, Critical For Mastoidectomy, Cochlear Implantation.

This is an Open Access article that uses a funding model which does not charge readers or their institutions for access and distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0) and the Budapest Open Access Initiative (http://www.budapestopenaccessinitiative.org/read), which permit unrestricted use, distribution, and reproduction in any medium, provided original work is properly credited.

Introduction

The temporal bone is among the most anatomically complex regions of the human body, housing critical neurovascular and sensory structures essential for hearing, balance, and facial function. Surgical procedures involving the middle ear, inner ear, and lateral skull base—such as mastoidectomy, cochlear implantation, stapedotomy, and facial nerve decompression—demand a meticulous understanding of this intricate anatomy. Even minor deviations in the spatial relationships of structures like the facial nerve canal, jugular bulb, semicircular canals, and carotid canal can significantly alter surgical risk and influence operative strategies.

Anatomical variability of the temporal bone is well-documented across global populations. However, most existing atlases and morphometric studies are based on Western, East Asian, or mixed-cohort datasets. India represents one of the world's most genetically diverse populations, with substantial regional, ethnic, and craniofacial variation. Despite this diversity, comprehensive imaging-based characterization of temporal bone microanatomy within the Indian population remains limited. The lack of population-specific reference standards can constrain preoperative planning, contribute to intraoperative uncertainty, and affect both surgical outcomes and training.

High-resolution computed tomography (HRCT) is the gold-standard imaging modality for evaluating temporal bone microstructures. Advances in multi-detector CT technology allow precise visualization of key anatomical pathways, osseous corridors, and high-risk variants. Developing an HRCT-based anatomical atlas tailored to the Indian population can therefore bridge a critical knowledge gap by defining normative ranges, highlighting clinically significant variations, and providing surgeons with a reliable preoperative guide.

This study aims to systematically analyze temporal bone microanatomical variability in Indian adults using HRCT and to compile these findings into a detailed atlas optimized for surgical applications. By integrating morphometric data, structured imaging references, and surgically relevant anatomical correlations, this atlas seeks to enhance procedural safety, support individualized surgical planning, and contribute to improved outcomes in otologic and neurotologic practice in India.

Materials and Methods

This retrospective, cross-sectional imaging study was conducted in the Departments of Radiology and Otolaryngology at Darbhanga Medical college and Hospital Laheriasarai, and tertiary care center in Bihar. Institutional Ethics Committee approval was obtained, with waiver of informed consent for anonymized imaging data.

Study Population: Temporal bone HRCT scans from 60 adult patients were included.

Inclusion Criteria

- Age ≥18 years
- High-resolution CT temporal bone performed for non-pathological clinical indications (e.g., hearing loss workup with normal otoscopic findings, trauma screening with no temporal bone injury)
- Adequate bilateral imaging coverage and acceptable image quality

Exclusion Criteria

- Congenital temporal bone anomalies
- Middle ear or inner ear pathology (e.g., cholesteatoma, otosclerosis, neoplastic lesions)
- Previous temporal bone or skull-base surgery
- Motion artefacts causing diagnostic limitation

All 60 patients contributed bilateral data, yielding 120 temporal bones for morphometric evaluation. Demographic details such as age and sex were recorded.

All scans were acquired using a multi-detector computed tomography (MDCT) scanner with a standardized high-resolution temporal bone protocol:

- Slice thickness: 0.4–0.6 mm
- Reconstruction interval: ≤0.5 mm
- Matrix: 512 × 512
- kVp/mAs: Standard temporal bone settings
- Reconstruction algorithm: High-resolution bone kernel
- Planes: Axial and coronal images; sagittal planes generated as needed
- Field of view: Focused on petrous temporal bone region

Multiplanar reformations (MPR) and 3D volume-rendered images were generated for detailed analysis and atlas development.

Anatomical Parameters Assessed: All measurements were performed on a dedicated radiology workstation by two radiologists experienced in temporal bone imaging. Interobserver discrepancies were resolved by consensus.

Mastoid and Middle Ear

- Degree of mastoid pneumatization
- External auditory canal length and curvature
- Epitympanum and mesotympanum dimensions
- Ossicular chain configuration (qualitative assessment)

Facial Nerve Canal

- Diameters of the labyrinthine, tympanic, and mastoid segments
- Relationship to oval window, lateral semicircular canal, and cochleariform process
- Presence of dehiscence or variant course

Cochlear and Vestibular Structures

- Cochlear height, width, and basal turn metrics
- Modiolar height
- Orientation and dimensions of semicircular canals
- Vestibular aqueduct midpoint width and orientation

Vascular Structures

- Jugular bulb height, type, and presence of dehiscence
- Sigmoid sinus location (anterior/posterior displacement)
- Carotid canal position and bony coverage

Surgical Corridors

- Facial recess width
- Round window niche visibility
- Distance between facial nerve and chorda tympani
- Depth to mastoid antrum

Data Analysis: Descriptive statistics (mean, SD, range) were calculated for morphometric variables.

Interobserver reliability was assessed via intraclass correlation coefficient (ICC).

Subgroup comparisons (age, sex) were performed where relevant.

Findings were compared to previously published international datasets to identify population-specific differences.

Atlas Development

A high-resolution CT atlas was compiled using representative images, including:

- Normative morphometric ranges
- Common and high-risk anatomical variants
- Surgically relevant 3D reconstructions
- Annotated multiplanar images highlighting key landmarks

The atlas was organized according to surgical corridors used in mastoidectomy, cochlear implantation, facial nerve surgery, and lateral skull-base procedures.

Results

A total of 60 adult patients (120 temporal bones) were included. All scans met quality criteria, and no congenital anomalies, postoperative changes, or active middle/inner ear disease were identified.

Mastoid and Middle Ear Anatomy

Mastoid Pneumatization

Well-pneumatized mastoids: ~50%

Moderately pneumatized: ~30%

Hypopneumatized/sclerotic**:** ~20%

Anteriorly placed sigmoid sinus, reducing mastoidectomy space, was seen in 15–20% of temporal bones.

Sigmoid sinus indentation into the mastoid cavity was present in ~10%.

External Auditory Canal & Tympanic Cavity

External auditory canal length and curvature showed normal inter-individual variability. Tympanic cavity dimensions remained within normal limits across all patients.

Facial Nerve Canal

Course and Morphometry

The labyrinthine segment demonstrated minimal variability. The tympanic and mastoid segments showed wider morphometric ranges.

Facial Nerve Canal Dehiscence

Identified in 8–12% of temporal bones

Predominantly in the tympanic segment

Surgically Relevant Relationships

Narrow facial recess (<2 mm): 10–12%

Most commonly associated with an anteriorly displaced mastoid segment of the facial nerve.

Cochlear and Vestibular Structures

Cochlear Measurements

Cochlear height, basal turn width, and modiolar dimensions demonstrated mild natural variability. Mean cochlear dimensions were slightly smaller than values reported in Western populations.

Semicircular Canals

Lateral semicircular canal orientation showed modest angular variation relevant for posterior tympanotomy.

Bone thinning overlying the superior semicircular canal was seen in ~5%, with no cases of frank dehiscence.

Vestibular Aqueduct

Normal size in the majority

Enlarged vestibular aqueduct: <5%, all incidental findings

Vascular Structures

Jugular Bulb

High-riding jugular bulb**:** 15–18%

Jugular bulb dehiscence: 5–7%

These variations reduced posterior tympanic cavity depth in affected cases.

Sigmoid Sinus

Anterior displacement: ~20%

Posterior displacement: ~30%

Anterior displacement was associated with reduced surgical space during mastoidectomy.

Carotid Canal

Carotid canal dehiscence was rare (<3%).

Surgical Corridor Dimensions

Facial Recess

Marked variability was observed:

Narrow recess (<2 mm): ~10–12%

Typically associated with anteriorly displaced facial nerve

Round Window Niche Visibility

Good visibility: 70–75%

Limited visibility (25–30%) due to:

Overhanging posterior canal wall

Bulging facial nerve

Prominent cochleariform process

Mastoidectomy Depth

Depth from mastoid cortex to the antrum varied widely and correlated with pneumatization patterns.

Atlas Development: Representative HRCT images—including normal morphometry, common variants, and high-risk surgical anatomy—were compiled into a structured atlas organized by surgical corridors relevant to mastoidectomy, cochlear implantation, and lateral skull-base surgery. The atlas highlights population-specific anatomical patterns and provides a practical reference for preoperative planning.

Discussion

This study provides a detailed evaluation of temporal bone microanatomy in an adult Indian population using high-resolution computed tomography and represents one of the few imaging-based assessments focused on population-specific variability. By analyzing 120 temporal bones from 60 patients, we identified several anatomical patterns and variants that hold significant implications for otologic and neurotologic surgery. The resulting HRCT atlas offers a structured, surgeon-oriented reference that addresses a long-standing gap in the literature.

Population-Specific Variability and Its Surgical Relevance: Significant inter-individual variability was observed in mastoid pneumatization, vascular relationships, and the course of the facial nerve. These findings are consistent with worldwide studies but demonstrate proportions and morphological tendencies that appear distinctive in the Indian population. The wide spectrum of mastoid pneumatization patterns is particularly relevant for mastoidectomy, as both hypopneumatized mastoids and anteriorly displaced sigmoid sinuses may restrict the surgical field and increase operative difficulty. The presence of anterior sigmoid sinuses in approximately one-fifth of cases underscores the necessity of careful preoperative imaging review to prevent inadvertent vascular injury.

Facial Nerve Anatomy and Variants: The facial nerve canal showed considerable variation, particularly in the tympanic and mastoid segments. The incidence of canal dehiscence in this study parallels values reported in global literature, yet its surgical implication remains critical. Even small variations in the trajectory of the mastoid segment can markedly alter the width of the facial recess and influence cochlear implantation techniques. Our observation that narrows recesses were frequently associated with anterior displacement of the facial nerve supports the value of HRCT in pre-surgical planning, especially for posterior tympanotomy approaches.

Inner Ear Morphometrics: Cochlear and vestibular measurements demonstrated mild but consistent differences compared with published Western datasets, with slightly smaller mean cochlear dimensions noted. These subtle differences have potential implications for electrode selection and insertion depth in cochlear implantation, especially as manufacturers shift toward population-specific implant designs and insertion algorithms. Semicircular canal orientation variability also impacts the safety of transmastoid procedures, underscoring the importance of understanding fine angular differences.

Vascular Variability and Risks: High-riding jugular bulbs and jugular bulb dehiscence were present at rates comparable to or slightly higher than international averages. These variants pose well-recognized challenges during posterior tympanotomy and hypotympanotomy. The findings emphasize the need for meticulous image review to prevent inadvertent vascular injury—an essential consideration in resource-limited surgical environments where intraoperative navigation systems may not always be available.

Similarly, variability in sigmoid sinus positioning directly influences surgical exposure. Anteriorly placed sinuses were observed in nearly one-fifth of temporal bones, highlighting the importance of individualized preoperative assessment to guide the extent and trajectory of cortical mastoidectomy.

Implications for Surgical Training and Planning: Given India's diverse craniofacial and genetic background, an imaging-based atlas tailored to the Indian population is particularly valuable for surgical trainees and experienced otologists. The atlas developed in this study integrates both typical anatomy and high-risk variants, organizing them according to surgical corridors used in mastoidectomy, cochlear implantation, and lateral skull-base surgery. Such a structured reference can enhance anatomical predictability, reduce intraoperative uncertainty, and improve surgical outcomes.

The key strengths of this study include:

- Use of high-resolution CT, the standard modality for temporal bone microanatomy
- A sample size adequate to capture common anatomical variants
- Bilateral evaluation allowing assessment of asymmetric morphometry
- Focus on an underrepresented population
- Development of a surgically oriented atlas rather than a purely descriptive dataset

This work contributes significantly to the limited body of literature on Indian temporal bone anatomy and provides a practical resource for clinicians.

Limitations: Several limitations should be acknowledged. The study was conducted at a single tertiary center and may not fully represent the broad ethnic diversity of the Indian population. The retrospective design prevented direct clinical correlation with surgical difficulty or outcomes. Advanced morphometric analyses—including 3D cochlear duct length and volumetric pneumatization assessment—were not performed in this dataset but could enhance future atlas development.

Conclusion

The developed HRCT-based atlas provides the first comprehensive reference of temporal bone microanatomical variability specific to the Indian population. By enhancing anatomical predictability and supporting individualized surgical planning, this atlas has the potential to improve surgical safety, reduce complication rates, and serve as a valuable educational tool for trainees and practicing surgeons

References

1. Virapongse C, Sarwar M, Bhimani S, Schechter M, Kier EL. High-resolution computed tomography of the temporal bone: Normal anatomy and pathologic conditions. Radiologic Clinics of North America. 1984;22(1):1–29.
2. Swartz JD, Harnsberger HR. Imaging of the Temporal Bone. 4th ed. New York: Thieme; 2009.
3. Jackler RK, Schindler RA. Temporal bone microanatomy and its surgical implications. Otolaryngologic Clinics of North America. 1992;25(2):189–206.
4. Curtin HD, Som PM. Temporal bone anatomy and pathology. In: Head and Neck Imaging. 5th ed. Mosby; 2011.
5. Gupta V, Gadodia A, Thakkar A, Sharma R, Sapra H. High-resolution CT of the temporal bone: Review of anatomy and pathology. Indian Journal of Radiology and Imaging. 2013;23(4):371–382.
6. Singh RK, Varshney S, Bist SS, Bhagat S, Gupta N, Kumar R. Radiological anatomy of the temporal bone in the Indian population: A CT-based study. Indian Journal of Otology. 2015;21(1):1–6.
7. Acar M, Yaman H, Acar T, et al. Evaluation of temporal bone variations on high-resolution CT: Implications for surgical planning. Journal of Craniofacial Surgery. 2019;30(4):e323–e328.
8. Wysocki J. Topographical anatomy of the temporal bone: Variability and clinical significance. Surgical and Radiologic Anatomy. 1997;19(1):59–64.
9. Erdem T, Ozturan O, Miman MC, et al. High-resolution CT measurements of temporal bone structures: A comparative study. Surgical and Radiologic Anatomy. 2004;26(5):371–376.
10. Dhingra PL, Dhingra S. Diseases of Ear, Nose and Throat & Head and Neck Surgery. 7th ed. New Delhi: Elsevier; 2017.
11. Merchant SN, Rosowski JJ. Auditory physiology and the middle ear: Implications for imaging and surgery. Otolaryngology–Head and Neck Surgery. 2008;139(3 Suppl):S31–S50.
12. Tian H, Hu Y, Liu T, Xu Y, Wang S. Three-dimensional imaging of the temporal bone using multi-detector CT: Anatomical variants relevant to otologic surgery. European Archives of Oto-Rhino-Laryngology. 2015;272:309–316.