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Title: Transpetrosal Approach: an anatomical study of temporal bone

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Keywords: Transpetrosal Approach; Temporal bone; Anatomical landmark; Middle ear prosthesis

Corresponding Author: Dr Faramarz Memari, Assistant Professor of Neurotology

Corresponding Author's Institution: Ira University of Medical Sciences & Health Services

First Author: Faramarz Memari, Assistant Professor of Neurotology

Order of Authors: Faramarz Memari, Assistant Professor of Neurotology; Reza Mostafavi Tabatabaee , General practitioner; Hamid Borghei Razavi , General practitioner; Seyed-Mohammad Fereshtehnejad, General practitioner; Ahmad Daneshi, Assistant Professor of Department of ORL & HNS

Abstract: Background:
Resection of the petrous temporal bone to various degrees provides different levels of access to lesions of the posterior fossa. However, precise distances of petrosal bone are not still clearly described due to the numerous variations of them which may lead to serious complications during transpetrosal surgeries.
Objective:
Our objective was to evaluate different distances of temporal bone in order to assess their variations and the possible correlations between them. Subjects and Methods:
This anatomical study was performed on 60 temporal bones from 60 human cadavers in the years 2006 and 2007. All the bones contained an adequate portion of the petrous apex and attached fossa dura. Twelve landmarks were defined and 27 different distances were measured for each temporal bone using two-point caliper.
Results:
The less variation was observed in the distance between the origin of corda tympani and corda in pyramidal direction with the less variations in Z-score (2.95); whereas, the most variation was detected in the shortest horizontal distance between the sigmoid sinus and posterior wall of the external meatus (Z-score variation=6.71). There was a significant correlation between vertical intratemporal diameter of carotid in pyramidal direction and superior-inferior diameter of horizontal carotid canal (rPearson=0.500, $P<0.001$). Other significant correlations were also found between other distances.
Conclusion:
The variations of each distance were evaluated and many significant correlations were demonstrated between them which could potentially aid ENT specialists and neurosurgeons in order to approach more safely the fossas and anatomical landmarks during head and ear surgeries.

13 January 2009

Dear colleagues in ***European Archives of Oto-Rhino-Laryngology***,

First of all we wish to thank you for your comments. As you have requested**,** we have done some revisions in the article **"Transpetrosal Approach: an anatomical study of temporal bone"** as seen below**.** We have considered all these comments.

Here, we list all the comments & the changes and answers we have performed:

Reviewer #1:

- Language: Spelling is correct, but wording in several sentences suggests the authors are non-native English speakers. I suggest having the manuscript checked before publication.
  Language editing is performed in our revised manuscript and the changes are highlighted in red.

- Description of temporal bones: There is no description as to the age, left/right and male/female distribution of the temporal bones. Please provide a summary description.
  The temporal bones were from cadavers age 22 to 65. This was added in the subjects and methods section of the article. The left/right and male/female ratios were almost the same (1/1).

- Explain the term "Z-score" at the instant of its first occurrence in the manuscript.
  While evaluating the manuscript for revision, we thought it is more scientific to calculate and report the “Coefficient of Variation” or “CV” instead of Z-scores. Therefore, as you see in our revised manuscript, all Z-scores have been changed to CV. And consequently, some paragraphs of our “Results” have been also changed. In addition, this index (CV) is explained in “Methods” of the manuscript, too. And Table 2 is also changed.
  By the way, as you know CV is a known statistical index to compare the variations of different measurements with different ranges and even various units and is calculated as follows: *(100×standard deviation)/mean*

- It would be most useful to the reader to see a limited number of photographs. I suggest 2 or 3 photographs of a single temporal bone in various stages of preparation with a few pertinent landmarks, which are used in your study, clearly labelled.
  As requested, two photographs are added in our revised manuscript with footnotes.

- For the measurements, a calliper is used. Please state the resolution of the device used and the reproducibility of the measurement.
  A two-point caliper with 0.01 mm resolution was used. The measurement results were found to be reproducible even with different doctors measuring the same distance. (This is added to the article in red)

- You may also want to comment on the advantages and disadvantages when compared to other methods such as CT scans.
  The CT scan measurements does help, but they are done two dimensionally as opposed to these 3 dimensional measurements. Also the soft tissue borders and distances could not be very clear in the CT scans. (Added in the article in red)

- If the age range is broader than in the cited paper by Stieger et al, it would be most interesting to re-examine the notion that there is no significant growth in adulthood.
  As described above, these were all adult temporal bones aged between 22 to 65 and no children temporal bones were included in the study.

Reviewer#2:

- Photographs would have helped?
  Photographs added as above.

We tried to consider all your comments as you wanted us. It is really pleasure to see our manuscript accepted in your journal. By the way, all the changes are printed in red in our revised manuscript.

It will be very kind of you to let us know about the result. We are looking forward to see our article published in your journal.

Best wishes,

Faramarz Memari
Reza Mostafavi Tabatabaee
Hamid Borghei Razavi
Seyed-Mohammad Fereshtehnejad
Ahmad Daneshi

* Title Page

Transpetrosal Approach: an anatomical study of temporal bone

Authors:
Faramarz Memari MD[1*]
Reza Mostafavi Tabatabaee MD[2]
Hamid Borghei MD[2]
Seyed-Mohammad Fereshtehnejad MD[2]
Ahmad Daneshi MD[3]

1. Assistant Professor and chief of Otology/Neurotology, ENT Research Center and Department, Rasool-e-Akram Medical Center, Iran University of Medical Sciences and Health Services (IUMS), Tehran, Iran. (* Corresponding author)
   Email: dr_faramarz_memari@yahoo.com
   Tel: +989121965135
2. General practitioner, Iran University of Medical Sciences and Health Services (IUMS), Tehran, Iran.
3. Assistant Professor and Chairman of Department of ORL & HNS, ENT Research Center and Department, Rasool-e-Akram Medical Center, Iran University of Medical Sciences and Health Services (IUMS), Tehran, Iran.

Transpetrosal Approach: an anatomical study of temporal bone

ABSRTACT

Background:
Resection of the petrous temporal bone to various degrees provides different levels of access to lesions of the posterior fossa. However, precise distances of petrosal bone are not still clearly described due to the numerous variations which may lead to serious complications during transpetrosal surgeries.
Objective:
Our objective was to evaluate different distances of temporal bone landmarks in order to assess their variations and the possible correlations between them.
Subjects and Methods:
This anatomical study was performed on 60 temporal bones from 60 human cadavers in the years 2006 and 2007. All the bones contained an adequate portion of the petrous apex and attached fossa dura. Twelve landmarks were defined and 27 different distances were measured for each temporal bone using two-point caliper.
Results:
The less variation was observed in the superoinferior diameter of horizontal carotid canal with the less coefficient of variation (CV) of 9.29; whereas, the most variation was detected in the inferior (axial) plane of posterior semicircular canal to superior plane of jugular bulb (CV=57.65). There was a significant correlation between vertical intratemporal diameter of carotid in pyramidal direction and superior-inferior diameter of horizontal carotid canal ($r_{Pearson}=0.500$, $P<0.001$). Other significant correlations were also found between other distances.
Conclusion:
The variations of different distances and landmarks were evaluated and many significant correlations were demonstrated between them which could potentially aid ENT specialists and neurosurgeons in order to approach anatomical landmarks and cranial fossas more safely during otologic and neurotologic surgeries. It could also help the design of middle ear prosthesis.

Keywords.
Transpetrosal Approach; Temporal bone; Anatomical landmark; Middle ear prosthesis

Introduction

Resection of petrous temporal bone provides different levels of access to lesions of the posterior and middle cranial fossa. Although their nomenclature can be confusing, the numerous variants of the transpetrosal approaches can be classified broadly into anterior and posterior groups.(1) The posterior transpetrosal approaches include the retrolabyrinthine, translabyrinthine, and transcochlear, whereas the ones in the anterior group are extensions of the basic middle fossa approach. The translabyrinthine and transcochlear approaches are dependent on and are progressions of the retrolabyrinthine exposure. Both the anterior and posterior approaches have the potential of exposing the cerebellopontine angle and the petroclival region. The posterior approaches are based on the standard mastoidectomy and involve resection of the petrous bone to various degrees. This Results in progressively increased exposure anteriorly, but comes at the expense of hearing in the translabyrinthine approach and of hearing and facial strength in the transcochlear approach. In contrast, the middle fossa approaches spare the lateral petrous bone and involve resection of the medial petrous bone to various degrees. Middle fossa approach is designed to preserve hearing. Extensions of the middle fossa approach involve resection of bone within the Kawase rhomboid and division of the tentorium to provide exposure of the posterior fossa. (2)

On the other hand, precise distances of different petrous bone landmarks are not still clearly described due to their wide range of variations. This lack of exact understanding of relations within the temporal bone may lead to serious complications during overall temporal bone surgeries and especially transpetrosal approaches.

Also, nowadays different designs of various middle ear prosthesis are being introduced. Having the exact knowledge of anatomical landmarks within the temporal bones and their distances could help the design of such prosthesis.

Although there have been studies of the transpetrosal approaches, they do not provide definite information on different relations and distances and how to prevent injury to the cochlea, facial nerve and the labyrinth,etc. In the present study, the aim was to define certain anatomical landmarks and provide the operator with the anatomical knowledge and practical information so that he or she can approach different areas of the temporal bone, the internal auditory canal (IAC) and petroclival region safely and protect the vital structures around it. The operator not only should know the constant landmarks but also should know by how much certain distances between these landmarks may vary. These vital structures include the cochlea, superior, lateral and posterior semicircular canals, facial nerve, jugular bulb and anteriorly, the internal carotid artery (ICA). He also has to avoid inadvertent injury to the sigmoid sinus and the dura. Defining these anatomical landmarks and their distances will also help the surgeon in performing Otologic procedures such as petrosectomy (partial, subtotal or total), facial nerve decompression procedures, resection of intratemporal and jugular foramen and skull base tumors such as Glomus Jugulare tumors schwannoma and neurofibromas, resection of acoustic neuromas, etc.

Subjects & methods

This anatomical cross-sectional study was performed in Ear, Nose and Throat (ENT) research center of Iran University of medical sciences in the years 2006 and 2007. Sixty temporal bones were obtained for this study from 60 adult human cadavers (age between 25 to 65). All the bones contained an adequate portion of the petrous apex and attached dura. Twelve landmarks were defined and 27 different distances were measured for each temporal bone using two-point caliper (MITOTOYO, Japan) with 0.01 mm resolution (table 1). The measurement results were found to be reproducible even with different doctors measuring the same distance. The advantage of these measurements over CT scan is the fact that these are all 3 dimensional measurements.

After drilling the cortical bone of the squamous part and exposure of the mastoid bowl, the cortical thickness of temporal bone (A) and the distance between Henle 's spur to the posterior annulus of tympanic membrane and the shortest distance between the sigmoid sinus and posterior wall of EAC in horizontal plane (distances B and C) were measured. Then complete cortical mastoidectomy was performed. The tegmen and posterior fossa dural plate were identified and the sigmoid sinus was skeletonized. The bone posterior to EAC was drilled until a thin transparent cortical thickness was left. The shortest distance between the sigmoid sinus and posterior wall of EAC in horizontal plane and the shortest distance between sigmoid sinus and posterior wall of EAC (distances D and E) were measured.

The dome of lateral semicircular canal was identified. The endolymphatic sac and duct were identified just anterior to the sigmoid sinus and the posterior fossa dura and inferior to the Donaldson's line. Anteriorly, the facial nerve is identified in its vertical segment but left covered with a thin layer of bone for protection against inadvertent burr trauma. The distance between Junction of sigmoid sinus dura and posterior fossa dura to inferior and superior half of mastoid part of facial nerve and also the length of the facial nerve at the second genu just inferior to the lateral semicircular canal to stylomastoid foramen (distances K, L, and M) were measured. Then the most anterior part of the endolymphatic duct to facial nerve and Henle 's spur to the dome of lateral semicircular canal (distances F and G) were measured.

In the next step, the semicircular canals were unroofed from the lateral side in order to measure the distances between the junction of dura of sigmoid sinus and posterior fossa dura and semicircular canals as well as the shortest distance between middle fossa dura and the dome of superior semicircular canal (H, I, J, and O). Drilling the posterior wall of EAC, corda tympani was exposed. Distance between the origin of corda tympani from the bifurcation of facial nerve to corda adjacent to the pyramidal process (N) was measured. Exposing the middle ear by extracting TM and ossicles, the vertical distance between cochleariform process and middle fossa dura (p) was measured.

Next the facial nerve in tympanic cavity and geniculate ganglion were exposed. Distance between posterior plane of geniculate ganglion and vertical plane of cochleariform process, vertical distance between geniculate ganglion and middle fossa dura, length of facial nerve from pyramidal bend to the geniculate ganglion, and anterior plane of superior semicircular canal to posterior plane of geniculate ganglion were measured (Q, R, S, and u). Drilling a trough along the inferior edge of the vestibule, the jugular bulb is identified. Then inferior (axial) plane of posterior semicircular canal to superior plane of jugular bulb (T) was measured. Exposing the cochlea and carotid canal by drilling anterior part of the medial wall of tympanic cavity, diameter of vertical intratemporal carotid canal at the level of pyramidal process, closest distance between carotid canal and cochleariform process, anterior plane of the cochlea to posterior plane of vertical carotid canal, posterior plane of carotid canal at the junction of the vertical and horizontal parts to the middle fossa dura, inferior (axial) plane of the cochlea to the superior plane of jugular bulb in hypotympanum, and superoinferior diameter of horizontal carotid canal (V, W, X, Y, Z, AA) were also measured.(2, 3, 4)

Data were analyzed using SPSS v.13 software. In descriptive analysis, frequency ratios, mean and standard deviation (SD) were reported. Moreover, the coefficients of variations (CV) were calculated for each distance in order to evaluate and compare the variation of each distance with the others. The higher the CV was the more the variation of the distance was. Pearson correlation was used to evaluate the associations between the distances. All *P*-values were calculated two-tailed and $P<0.05$ was considered significant.

By the way, this study was approved by the ethical committee of Iran University of Medical Sciences & Health Services.

Results

The results of all measurements with their ranges and the CV's are summarized in tables 2. Among all 27 distances, the less variation was observed in superoinferior diameter of horizontal carotid canal with the less coefficient of variation (CV) of 9.29. In addition, the "M" distance which is representative for the superiormost point of the mastoid portion of the facial nerve to stylomastoid foramen was the next less variable distance (CV=9.77); whereas, the most variation was detected in the inferior (axial) plane of posterior semicircular canal to superior plane of jugular bulb (CV=57.65), the shortest distance between middle fossa dura and dome of superior semicircular canal (CV=49.97) and inferior (axial) plane of the cochlea to superior plane of jugular bulb in hypotympanum (CV=42.78), respectively.

A drilled temporal bone and its different anatomical landmarks are shown in Pictures 1 and 2. Statistical correlations between all 27 distances are shown in Tables 3a-c. There was a significant correlation between diameter of vertical intratemporal carotid canal and superoinferior diameter of horizontal carotid canal ($r_{Pearson}=0.500$, $P<0.001$); and between the most anterior part of the endolymphatic sac to the facial nerve and inferior (axial) plane of posterior semicircular canal to superior plane of jugular bulb ($r_{Pearson}=0.489$, $P=0.021$) meaning that when the jugular bulb was high, there was a high probability that the facial nerve was also closer to the endolymphatic sac and vice versa. Also there was a significant reverse correlation between measurement "C" (the most lateral anterior part of the EAC to the annulus of tympanic membrane) and measurement "U" (the distance between anterior plane of superior semicircular canal to the posterior plane of geniculate ganglion) [$r_{Pearson}= -0.446$, $P<0.001$], this means that when the EAC is longer anteriorly, there is a high chance that the geniculate ganglion will be closer to the superior semisircular canal. There was also reverse correlation between measurement "N" (Origin of corda tympani to corda adjacent to the pyramid) and measurement "Z" (Inferior [axial] plane of the cochlea to superior plane of jugular bulb in hypotympanum ($r_{Pearson}=-0.474$, $P=0.019$), i.e. when the jugular bulb is high in hypotympanum, the corda tympani is shorter in its vertical length. The most significant direct and reverse correlations are listed in Tables 3a-c.

Moreover, distance K and L that is Junction of sigmoid sinus dura and posterior fossa dura to the inferior and superior halves of mastoid portion of facial nerve were significantly correlated with the distance M which is the superiormost point of the mastoid portion of the facial nerve to stylomastoid foramen (r Pearson=0.486, $P<0.01$ and r Pearson=0.535, $P<0.001$, respectively). In the other words, the distance between sigmoid sinus and facial nerve is correlated directly to the length of facial nerve.

Additionally, distance D (the shortest distance between the sigmoid sinus and posterior wall of EAC in horizontal plane) was also directly correlated with the distance L (distance between junction of sigmoid sinus dura and posterior fossa dura to superior half of mastoid portion of facial nerve) [r Pearson=0.338, P=0.010].

Discussion

Transpetrosal approach has overcome the limitations associated with traditional transcranial exposure of the posterior, middle and anterior cranial fossas. The combination of transpetrosal procedures with other approaches has provided many options for obtaining wide surgical exposure of the petroclival region and posterior fossa. Nevertheless, the improved access to the posterior, middle and anterior cranial fossas through the transpetrosal route comes at the price of increased morbidity. The variations of the transpetrosal approaches are numerous, and the resulting nomenclature can be quite confusing. Frequently, these variations overlap with one another and have minor distinguishing nuances (1, 6). On the other hand, the complex anatomy of the region necessitates thorough study if transpetrosal surgery is to be performed with minimal patient morbidity. The Otologic surgeon and neurosurgeon must master the temporal bone and petrous bone microscopic anatomy before attempting these procedures.

Otologists have to deal with the detailed microscopic anatomy of the Temporal Bone on everyday basis. Depending on the nature of the Otologic/Neurotologic procedure, there is always a need during surgery to identify the important landmarks on the temporal bone progressively and one by one from "known" to "unknown" anatomy, estimating the location of different important landmarks before actually being able to visualize them. Review of high resolution computerized tomography scans helps the surgeon to become more aware of the relative location of temporal bone landmarks and the relationship between them in a particular patient. However the CT studies are done two dimensionally. Also, the soft tissue borders and distances could not be very clear in the CT scans.

Several times during an otologic procedure, the surgeon will have to try finding an otologic landmark using the already known or already exposed landmarks. Knowing the distances between different important anatomical landmarks within the temporal bone will help the surgeon going from "known" to "unknown anatomy and positively identify the important landmarks during surgery and thus avoiding injury to them.

There are numerous instances; for example, during Glomus tumor surgery, knowing the distance beween the cochlea and the carotid canal or the distance beween the cochlea and the jugular bulb will be helpful in determining the surgical plan or proceeding during surgery, Or during petrosectomies or decompression of the facial nerve at the geniculate ganglion, knowing the distance between the geniculate ganglion and the cochleariform process or the geniculate ganglion and the middle fossa dura could be helpful. Knowing the distance between the sigmoid sinus and the semicircular canals will help the surgeon avoid injury to the semicircular canals during endolymphatic sac decompression or during translabyrinthine acoustic neuroma removal, knowing the distance between the posterior semicircular canal and the cochlea to the jugular bulb will help identify the bulb positively and avoid injury to it. Even during a routine mastoid surgery knowing the distance between the facial nerve and the sigmoid sinus or the facial nerve and the semicircular canals will help to identify one of these landmarks after identifying the other.

Today, various middle ear prosthesis are in the process of design and improvement. Having the exact knowledge of anatomical landmarks within the temporal bones and their distances could help improve the design of such prosthesis.

To the best of our knowledge, there are few published studies evaluating these 27 distances and the correlations between them. Stieger et al (7) in 2006 performed an anatomical study on 10 cadavers to generate anatomical data on the human middle ear and adjacent structures to serve as a base for the development and optimization of new implantable hearing aid transducers. They presented a statistical description of 24 distances in the adult human middle ear which may limit or influence the design of middle ear transducers. Significant inter-individual differences but no significant differences for gender, side, age or degree of pneumatization of the mastoid were found and they concluded that the method employed in their study using standard CT scans could also be used preoperatively to rule out exclusion criteria (7).

Sincoff et al in 2007 (8) declared that the posterior transpetrosal approach and the transcrusal variant provide a lateral operative corridor to lesions of the upper and middle clivus. They also added that the transcrusal variant provides increased exposure and operative freedom similar to that provided by the transcochlear approach while minimizing cranial nerve morbidity (8).

Gong et al in another study in year 2005 (9) performed a surgical anatomic study on 10 adult cadaver heads fixed in 10% formalin and 10 dry skulls. Ten cadaver heads were examined by bone-window CT scan pre and post-operation in their study. They concluded that for the subtemporal transpetrosal ridge approach (STA), the important structures include Vein of Labbe, petrous bone and brain stem ventral space. The important data include the drilling space of the petrous ridge. They suggested to replace the combined approach with STA to diminish the morbidity and mortality (9).

In our study, we have evaluated 27 distances of temporal bone in order to assess their variations and the possible correlations between them during the transpetrosal approach.

Conclusion

Our data set describes the adult human temporal bone anatomy quantitatively. The variations of each distance were evaluated and many significant correlations were demonstrated between them which could potentially aid Otolaryngologists and neurosurgeons in surgery of the petrous bone and approaching the cranial fossas more safely by positively identifying these landmarks and thus avoiding injuring them and also might help the design of various middle ear prosthesis.

More studies are needed in this area, especially studies comparing the HRCT and 3 dimensional CT scan findings with the actual measurements within the temporal bone itself.

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Table 1

Table 1. Descriptive characteristics of all 27 distances.

	Distance
A	**The thickness of the mastoid cortex**
B	**Henle 's spur to the posterior annulus of tympanic membrane**
C	**The lateral most part of the EAC to the anterior annulus of tympanic membrane**
D	**The shortest distance between the sigmoid sinus and posterior wall of EAC in horizontal plane**
E	**The shortest distance between sigmoid sinus and posterior wall of EAC (in any plane)**
F	**The most anterior part of the endolymphatic sac to facial nerve**
G	**Henle 's spur to the dome of lateral semicircular canal**
H	**Junction of sigmoid sinus dura and posterior fossa dura to the posterior plane of posterior semicircular canal**
I	**Junction of sigmoid sinus dura and posterior fossa dura to the posterior plane of common crus**
J	**Junction of sigmoid sinus dura and posterior fossa dura to posterior plane of lateral semicircular canal**
K	**Junction of sigmoid sinus dura and posterior fossa dura to inferior half of mastoid portion of facial nerve**
L	**Junction of sigmoid sinus dura and posterior fossa dura to superior half of mastoid portion of facial nerve**
M	**The superiormost point of the mastoid portion of the facial nerve to stylomastoid foramen**
N	**Origin of corda tympani to corda adjacent to the pyramidal process**
O	**The shortest distance between middle fossa dura and dome of superior semicircular canal**
P	**Vertical distance between cochleariform process and middle fossa dura**
Q	**Posterior plane of geniculate ganglion to vertical plane of cochleariform process**
R	**Vertical distance between geniculate ganglion and middle fossa dura**
S	**Facial nerve from 2nd genu to the geniculate ganglion**
T	**Inferior (axial) plane of posterior semicircular canal to superior plane of jugular bulb**
U	**Anterior plane of superior semicircular canal to posterior plane of geniculate ganglion**
V	**Diameter of vertical intratemporal carotid canal at the level of pyramidal process**
W	**Closest distance between carotid canal and cochleariform process**
X	**Anterior plane of the cochlea to posterior plane of vertical carotid canal**
Y	**Posterior plane of carotid canal at the junction of the vertical and horizontal parts to middle fossa dura**
Z	**Inferior (axial) plane of the cochlea to superior plane of jugular bulb in hypotympanum**
AA	**Superoinferior diameter of horizontal carotid canal**

Table 2

Table 2. Descriptive characteristics of all 27 distances from A to AA.

	Minimum	Maximum	Mean	Std. Deviation	CV[a]
A	1.50	4.70	2.3632	.55560	23.51
B	11.22	17.94	15.6536	1.54097	9.84
C	11.20	18.30	15.0763	1.65092	10.95
D	7.34	23.68	10.3084	2.43408	23.61
E	5.60	12.82	9.0031	1.55872	17.31
F	3.00	7.10	4.8627	1.01410	20.85
G	12.00	18.52	15.5863	1.65297	10.61
H	1.20	5.60	3.7797	1.16919	30.93
I	2.02	7.20	5.4543	1.31388	24.09
J	3.54	8.60	6.3885	1.25376	19.63
K	3.50	9.60	6.7821	1.51869	22.39
L	5.00	10.30	7.4557	1.53094	20.53
M	12.40	17.92	15.5475	1.51919	9.77
N	2.00	5.20	3.5481	1.08631	30.62
O	.30	5.20	2.1510	1.07496	49.97
P	4.02	11.00	6.1307	1.23340	20.12
Q	.60	2.58	1.5369	.48233	31.38
R	1.02	5.18	2.6067	.86137	33.04
S	3.04	14.68	8.9000	2.45677	27.60
T	.00	9.30	3.3841	1.95083	57.65
U	2.17	6.40	4.1086	1.24236	30.24
V	3.80	6.48	5.0249	.84137	16.74
W	2.00	8.24	5.6740	1.53354	27.03
X	1.00	2.46	1.7340	.41273	23.80
Y	1.00	3.52	2.1928	.76834	35.04
Z	1.00	7.20	4.0698	1.74111	42.78
AA	5.30	7.70	6.3728	.59191	9.29

[a] Coefficient of variation

Table 3a

Table 3-a. Evaluation of the correlation between different distances

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
A		.029 .826	-.045 .732	.077 .570	.037 .785	.073 .745	.062 .640	-.057 .669	-.007 .956	.114 .390	.016 .908	.185 .164	**.289** **.025***	-.025 .902
B			**.384** **.003***	.091 .505	**.319** **.016***	.368 .092	.065 .626	.130 .335	.015 .913	.196 .141	**-.280** **.035***	-.247 .063	-.219 .096	-.025 .902
C				.085 .530	-.023 .862	.241 .280	.130 .321	-.066 .620	.178 .181	.041 .760	-.042 .754	.053 .691	.084 .525	.102 .612
D					**.525** **<0.001***	-.083 .713	.189 .159	.185 .172	-.060 .659	.041 .763	**.323** **.014***	**.338** **.010***	-.063 .642	-.393 .052
E						.252 .258	.008 .950	.073 .590	-.059 .661	.161 .229	.105 .436	.135 .313	-.197 .139	-.248 .232
F							.360 .099	.164 .466	-.209 .362	.132 .557	-.012 .959	-.124 .583	.136 .547	.148 .664
G								.210 .114	.031 .815	.041 .760	.188 .158	.224 .091	**.276** **.033***	.078 .697
H									**.530** **<0.001***	**.442** **.001***	.120 .374	.075 .580	.061 .651	**.431** **.028***
I										**.461** **<0.001***	.219 .102	**.278** **.036***	.226 .088	.255 .209
J											.030 .821	.055 .680	.050 .707	.194 .341
K												**.704** **<0.001***	**.486** **<0.001***	.112 .584
L													**.535** **<0.001***	.086 .683
M														.118 .557
N														

Table 3b

Table 3-b. Evaluation of the correlation between different distances

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
A	-.192	-.605	-.179	-.074	-.049	**.291**	-.177	.186	-.181	.067	-.241	-.097	-.060
	.141	.619	.174	.575	.714	**0.027***	.181	.182	.195	.631	.092	.488	.669
B	-.070	-.045	.165	-.247	-.012	-.113	-.075	.169	.096	.080	-.095	**.294**	.151
	.597	.734	.217	.059	.931	.402	.576	.231	.500	.573	.514	**.035***	.285
C	-.063	.170	.050	-.233	.128	.52	**-.446**	-.051	-.097	.141	-.209	.246	.036
	.633	.193	.709	.073	.337	.698	**<0.001***	.719	.488	.314	.144	.076	.800
D	**.369**	.108	.159	-.006	**.273**	-.089	-.040	.028	.093	-.250	-.053	-.070	-.013
	.005*	.426	.241	.967	**.044***	.513	.769	.847	.515	.076	.717	.622	.926
E	.120	.107	.112	.099	.034	-.166	-.089	-.040	-.082	-.180	-.189	-.015	-.039
	.368	.423	.409	.459	.805	.217	.512	.780	.569	.207	.193	.914	.784
F	-.214	-.070	-.297	-.308	.121	**.489**	-.034	-.122	-.183	-.172	-.205	-.159	-.020
	.339	.756	.180	.164	.591	**.021***	.881	.598	.428	.455	.387	.492	.932
G	**.255**	.176	-.044	-.140	.149	-.042	-.210	-.202	-.224	-.064	.037	-.134	-.007
	.049*	.178	.743	.285	.265	.752	.110	.148	.107	.651	.801	.338	.961
H	**.269**	.114	.200	.088	-.086	-.016	**.271**	.243	.103	.062	.132	-.112	.096
	.041*	.396	.137	.510	.529	.907	**.041***	.086	.470	.667	.366	.429	.498
I	.097	.060	.011	-.026	-.228	-.012	.008	.148	-.107	**.284**	.027	.065	.080
	.467	.653	.937	.844	.091	.932	.953	.299	.457	**.043***	.856	.647	.571
J	-.062	.018	.138	-.024	**-.340**	-.160	.054	.072	**-.283**	-.010	.053	.125	.060
	.643	.892	.301	.858	**.010***	.230	.690	.610	**.042***	.946	.715	.373	.670
K	.145	.109	-.053	.224	.256	.033	-.104	.035	.020	.042	-.065	-.125	**.287**
	.277	.416	.694	.092	.057	.805	.440	.805	.888	.766	.654	.374	**.037***
L	.111	.142	-.163	-.086	.076	-.005	-.214	.098	-.125	.009	-.271	-.210	**.274**
	.408	.287	.225		.577	.970	.110	.495	.383	.947	.060	.135	**.049***
M	.047	-.029	-.235	-.194	.111	.143	-.080	.166	-.140	.017	-.251	-.003	.123
	.723	.828	.073	.138	.407	.283	.549	.234	.317	.904	.079	.983	.381
N	-.202	-.171	-.194	-.005	-.035	.158	.047	-.074	.251	.026	.254	**-.474**	.198
	.313	.394	.333	.979	.864	.440	.815	.726	.226	.903	.231	**0.019***	.342

Table 3c

Table 3-c. Evaluation of the correlation between different distances

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
O		.034 .797	.153 .248	-.106 .419	-.036 .789	-.207 .119	.079 .553	-.036 .801	.046 .744	-.250 .071	.151 .295	-.160 .252	.002 .987
P			-.049 .714	.122 .354	.244 .065	.014 .917	-.135 .306	.006 .965	-.045 .751	.078 .578	.119 .409	.018 .896	**.334** **.015***
Q				.202 .125	-.107 .424	-.244 .067	.079 .550	-.056 .692	.078 .580	.035 .802	.132 .362	.091 .515	.055 .697
R					.018 .895	-.175 .190	.030 .821	-.217 .119	.225 .105	.166 .236	**.308** **.030***	-.054 .703	-.111 .428
S						.253 .060	.029 .830	.074 .597	.126 .369	.011 .940	.138 .338	.151 .281	.088 .537
T							-.011 .934	.050 .729	.057 .691	.047 .745	-.055 .709	.041 .775	.032 .822
U								.263 .057	**.369** **.007***	-.200 .152	**.341** **.015***	-.064 .648	.119 .395
V									.179 .200	.049 .726	**.333** **.018***	.096 .498	**.500** **<0.001***
W										.050 .722	.070 .629	-.052 .716	.224 .110
X											.027 .851	.093 .510	.013 .925
Y												.033 .819	-.107 .458
Z													-.054 .703
AA													

Picture 1

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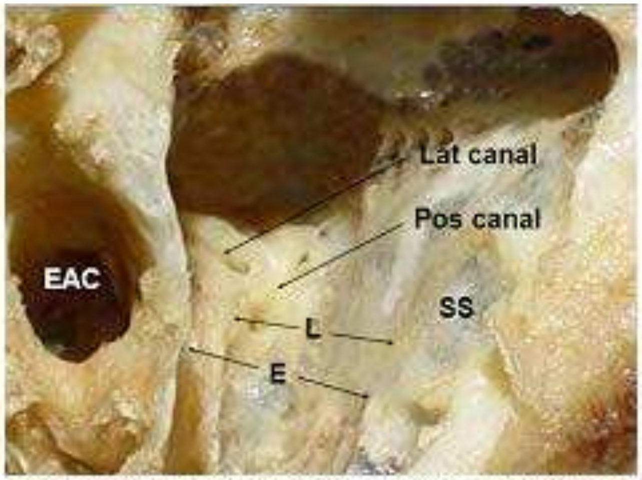

Picture 1: Temporal bone showing the External auditory canal (EAC), Lateral semicircular canal (opened), Posterior semicircular canal (opened), Sigmoid sinus (SS), Measurement L (Junction of sigmoid sinus dura and posterior fossa dura to superior half of mastoid portion of facial nerve) and measurement E (The shortest distance between sigmoid sinus and posterior wall of EAC in any plane)

Picture 2

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Picture 2: Larger view showing different anatomical landmarks within a drilled temporal bone