VASCULAR ANATOMICAL VARIANTS OF THE TEMPORAL BONE AS DEPICTED ON HIGH RESOLUTION TEMPORAL BONE CT SCANS DONE IN NAIROBI, KENYA

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ABSTRACT

Background: The temporal bone is the center of otology practice thus understanding its anatomy and variations is important for diagnosis, treatment and planning surgeries in ear pathology. Vascular variants may present with pulsatile tinnitus and pose high haemorrhagic risk during ear surgery.
Objective: To determine the patterns and prevalence of vascular anatomical variations in temporal bone anatomy as depicted on High Resolution Computed Tomography (HRCT) scans.
Design: A descriptive cross-sectional study.
Methodology: The study was carried out on 100 participants (182 radiologically normal temporal bones) who underwent HRCT of the temporal bone at the Kenyatta National Hospital and Plaza Imaging Solutions, both centres are located in Nairobi, Kenya.
Results: The age range was 2-74 years with a mean of 31.6±16.5 years and a male:female ratio of 1:1.1. The vascular variants noted included prominent sigmoid sinus (70.3%), lateral sigmoid sinus (22.5%), lateral internal carotid artery (12.6%), high jugular bulb (11.5%), anterior sigmoid sinus (8.8%), dehiscent jugular bulb (6.6%), anomalous transpetrous venous channel (1.6%) and petrosquamous sinus (1.1%). There were higher paediatric rates of lateral sigmoid sinus at 60% versus adults'16.6% (p= 0.001), sigmoid sinus dehiscence at 12% versus adults'10.2% (p= 0.02) and high jugular bulb at 16% versus adults' 10.8% (p=0.048). No gender predilection for anatomical variants was noted. Data analysis was conducted using SPSS version 22.
Conclusion: There was a high prevalence of vascular variants with significant disparity between age groups and individuals. These variants should be actively sought when reviewing patients' scans.

Key words: Vascular variants, Temporal bone, HRCT and prevalence

INTRODUCTION

Anatomical variations are the normal flexibilities or differences in topography and morphology of body structures usually of embryonic or genetic origin[1]. The variations clinically influence predisposition to certain illnesses, symptomatology, clinical findings, investigation findings and patient management especially in surgical procedures[2]. Vascular anatomical variants in the temporal bone may clinically simulate or result in pathology for example pulsatile tinnitus by aberrant Internal Carotid Artery (ICA) and sigmoid anomalies and otoscopic resemblance to glomus tumour or high haemorrhagic risk during ear operations by persistent stapedial artery and aberrant ICA[3-6]. There are significant differences in temporal bone by gender and age where by age, below 10.8 years, the temporal bone may be considered immature by bone density[7] thus paediatric-type and this immaturity may account for the higher prevalence of anatomical variants in the paediatric age group. This study aimed at determining the patterns and prevalence of vascular anatomical variations of the temporal bone in patients evaluated by temporal bone HRCT in two Nairobi based centres: Kenyatta National Hospital (KNH) and Plaza Imaging Solutions.

MATERIALS AND METHODS

Study procedure

This was a descriptive cross-sectional study conducted after approval by the local ethics and research committee. The study population consisted of patients independently referred by their physicians for HRCT of temporal bone to either study centre. The sample size of 100 participants was calculated using a World Health Organization formulae for the "safest choice" of prevalence as 50%[8]. Participants were recruited by convenience sampling. Their demographic data was entered into a data collection sheet. Their HRCTs were stored in a compact disc and subsequently evaluated by the principal researcher and one (the same) consultant radiologist. Temporal Bones (TBs) with pathology obscuring visualization of and/or erosion of major landmarks and anatomical features were excluded from the study but the normal contralateral ear was included as an unpaired TB thus 18 unpaired TBs and 82 paired TBs totaling 182 radiologically normal TBs were studied. The anatomical variations were recorded in the data collection sheet. The diagnostic criteria for the vascular anatomical variants are shown in Table 1.

Equipment

The CT scan machine at KNH was a Philips 16 slice Brilliance machine that took standard axial scans by helical technique (140kV, 250mA, rotation time of 0.75 seconds, section thickness of 0.6mm). The CT scan machine at Plaza Imaging Solutions was Aquilion One Toshiba 320 slice machine that took standard axial plane scans by helical technique (135kv, 200mA, rotation time of 1.5 seconds, slice thickness of 0.5mm). To standardize image evaluation, RadiAnt Dicom viewer version 5.5.0 was utilized.

Table 1: Diagnostic criteria for vascular variants

	Vascular anatomical variations	Description on HRCT
1.	Aberrant ICA	An internal carotid artery that is laterally displaced into the middle ear cavity and no carotid canal, best seen in axial view
2.	Lateral ICA	An internal carotid artery with a dehiscent lateral bone cover, adjacent to the middle ear cavity, in at least one axial and one coronal view (orthogonal plane)
3.	Persistent stapedius artery	Soft tissue density at the cochlear promontory with expansion of the tympanic facial canal, obliteration of the stapes obturator foramen and the absence of the foramen spinosum in axial view
4.	Anterior Sigmoid Sinus (ASS)	Sigmoid sinus whose anterior sigmoid plate is ≤9mm from the posterior EAC bony wall when seen in axial view
5.	Lateral Sigmoid Sinus (LSS)	Sigmoid sinus that is laterally placed compared to the contralateral side or the lateral distance to the outer cortex is less than the thickness of the cranium taken at the ipsilateral occipitomastoid suture in axial view at the level of EAC
6.	Prominent Sigmoid Sinus (PSS)	Sigmoid with a significant lateral indentation on the sigmoid plate relative to the contralateral sigmoid or ≥33.3% protrusion of the sigmoid sinus diameter into the mastoid seen in axial view at EAC level
7.	Sigmoid sinus dehiscence	A defect in the bony sigmoid plate with direct exposure of the sigmoid sinus to the mastoid airspaces
8.	High Jugular Bulb (HJB)	A jugular bulb that is seen at the same level as the IAC in axial or coronal view
9.	Dehiscent jugular bulb	The absence of bony covering on the jugular bulb with its direct exposure to the middle ear cavity when seen in axial and coronal views
10.	Sigmoid diverticulum	Isolated sigmoid projection into the mastoid aircells through sigmoid sinus dehiscence
11.	Large mastoid emissary vein	A prominent mastoid emissary vein with its width being ≥33.3% of the ipsilateral sigmoid diameter in axial view
12.	Petrosquamous sinus	An aberrant vascular channel seen as a linear hypodensity in a bony canal from the mastoid roof draining to the sigmoid sinus and running in an anteroposterior direction

Abbreviations: EAC = External Auditory Canal; ICA = Internal Carotid Artery

Data analysis

Data analysis was performed using IBM SPSS statistical software (Version 22) and correlations analyzed using Fisher's exact test.

Study limitations

The clinical indications for the HRCTs were not captured thus minimal direct clinicoradiological correlations could be deduced.

RESULTS

Temporal bone HRCT scans of 100 participants (182 normal temporal bones) were examined as 82 paired TBs and 18 unpaired TBs.

Demography

The participants' ages ranged from 2-74 years. The mean age was 31.8±16.5 years. The males were 7 (47%) and females 53 (53%). The paediatric group (≤11 years) consisted of 14 participants (14% of study group) where 25 TBs were evaluated. The comparative demographics by age, gender and central tendencies are contrasted in Table 2.

Table 2: Age and gender of participants

Tendencies ➡ / Group ⬇	Study size	Range (years)	Mean age	Median age	Mode	M:F
Paediatric group	14(14%)	2-10	6.4	7.5	2	1.3:1
Adult group	86(86%)	12-74	35.9	36	48	1:1.2
Overall group	100(100%)	2-74	31.8	32	48	1:1.1

Variant anatomy of temporal bone

The overall vascular variants observed included Prominent Sigmoid Sinus (PSS) at 70.3%, Lateral Sigmoid Sinus (LSS) 22.5%, Lateral ICA 12.6%, High Jugular Bulb (HJB) 11.5%, Anterior Sigmoid Sinus (ASS) 8.8%, dehiscent jugular bulb 6.6%, anomalous transpetrous venous channel 1.6% and petrosquamous sinus 1.1%. No aberrant ICA, persistent stapedial artery or jugular diverticulum were observed.

There were higher paediatric rates of LSS at 60% versus adults' 16.6% (p= 0.001), sigmoid sinus dehiscence at 12% versus adults'10.2% (p= 0.02) and HJB at 16% versus adults' 10.8% (p=0.048). The overall prevalence and age contrasted prevalence of variants are summarized in Tables 3 and 4.

Table 3: Summary of overal vascular variations in temporal bone HRCTs

Variations		Rt n=89 (48.9%)	Lt n=93 (51.1%)	Total n=182 (100%)	Comments
1.	Aberrant ICA	00	00	00	1 case LICA protrusion
2.	Lateral ICA	13	10	23(12.6%)	
3.	Persistent stapedius rtery	00	00	00	
4.	Anterior sigmoid sinus	6	10	16(8.8%	
5.	Lateral sigmoid sinus	21	20	41(22.5%)	
6.	Prominent sigmoid sinus	68	60	128(70.3%)	3 cases sigmoid diverticula
7.	Sigmoid sinus dehiscence	12	7	19(10.4%)	
8.	High jugular bulb	14	7	21(11.5%)	
9.	Dehiscent jugular bulb	7	5	12(6.6%)	
10.	Jugular diverticulum	00	00	00	
	Mastoid type				
	Hans 1	10	13	23(12.6%)	
	Hans 2	19	11	30(16.6%)	
	Hans 3	12	13	25(13.7%)	
	Hans 4	40	47	87(47.8%)	
11.	Sclerosed	8	9	17(9.3%)	
12.	Petrosquamous sinus	1	1	2(1.1%)	

Table 4: Prevalence of vascular variation by age groups

Variations		Paediatric group n=25(100%)	Adult group n=157(100%)	Overall group n=182(100%)	P-value
1.	Aberrant ICA	00	00	00	-
2.	Lateral ICA	00	23(14.6%)	23(12.6%)	0.54
3.	Persistent stapedius rtery	00	00	00	-
4.	Anterior sigmoid sinus	4(16%)	14(1.6%	16(8.8%	0.27
5.	Lateral sigmoid sinus	15(60%)	26(16.6%)	41(22.5%)	0.001
6.	Prominent sigmoid sinus	17(68%)	111(70.7%)	128(70.3%)	0.62
7.	Sigmoid sinus dehiscence	3(12%)	16(10.4%)	19(10.4%)	0.02
8.	High jugular bulb	4(16%)	17(10.8%)	21(11.5%)	0.048
9.	Dehiscent jugular bulb	00	12(7.6%)	12(6.6%)	1.00
10.	Jugular diverticulum	00	00	00	-
11.	Mastoid type				
	Hans 1	7(28%)	16(10.2%)	23(12.6%)	0.11
	Hans 2	6(24%)	24(15.9%)	30(16.6%)	0.31
	Hans 3	3(12%)	22(14.0%)	25(13.7%)	1.00
	Hans 4	7(28%)	80(50.9%)	87(47.8%)	0.35
	Sclerosed	2(8%)	15(9.6%)	17(9.3%)	1.00
12.	Petrosquamous sinus	1(4%)	1(0.6%)	2(1.1%)	0.14

Lateral ICA was the only arterial variant observed in this study with a prevalence of 12.6% and 38.5% bilaterality. Lateral Sigmoid Sinus (LSS) prevalence was 22.5%, sigmoid sinus dehiscence was 10.4% and Anterior Sigmoid Sinus (ASS) was the least common sigmoid variation at 8.8%. Large emissary vein was noted in 5.5% TBs with no bilaterality (Figure 1).

Figure 1: Axial views of sigmoid dehiscence (white hollow arrows)-A/B and sigmoid diverticula (white solid arrows)-C/D/E

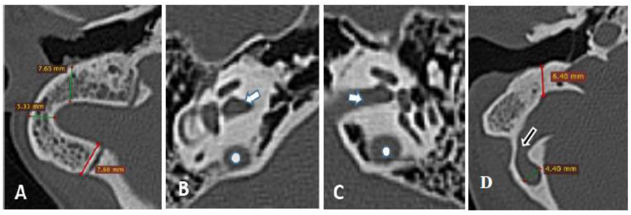

Figure 2: Axial views of concurrent ASS/ LSS/ PSS-A, bilateral HJB-B/C (white spots- jugular bulb / white solid arrows- IAC both seen at the same level) and Rt ASS/LSS with a large emissary vein-D (white hollow arrow)

Subarcuate canal was seen in 122/182 (67.0%) of TBs with 71.4% bilaterality. The subarcuate canals that were prominent totaled 13/122 (10.7%). Jugular foramen symmetry was also assessed in the 82 paired TBs (Figure 3). Asymmetrical jugular foramen was seen in 33/82 (40.2%) of paired TBs against n=49/82 (59.8%) with symmetrical foramina.

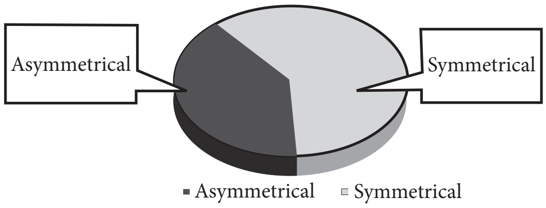

Figure 3: Jugular foramen symmetry

Aberrant soft tissue density, possibly an anomalous venous channel, was observed in three TBs as noted in Figure 4 . The channel was medial to the superior semicircular canal running in an anteroposterior course to drain into the superior petrosal sinus.

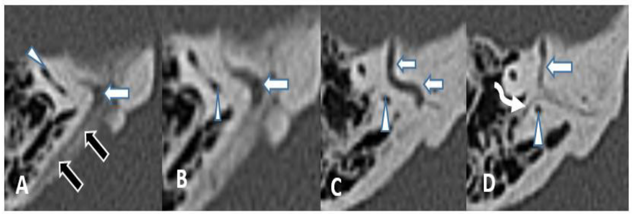

Figure 4: Anomalous venous channel (white solid arrow) from middle cranial fossa to the superior petrosal sinus is seen craniocaudally from A-D. Superior petrosal sinus (white hollow arrows, superior semicircular canal (white arrow head) and subarcuate canal (curved white arrow) are seen

Mastoid pneumatization was classified as sclerosed (9.3%) and pneumatized, where pneumatization was graded according to Han's classification[9]. The classes were Hans 1= poor pneumatization (12.6%), 2= moderate pneumatization (16.5%), Hans 3= good pneumatization (13.7%) and Hans 4= very good pneumatization (47.8%) (Figure 5).

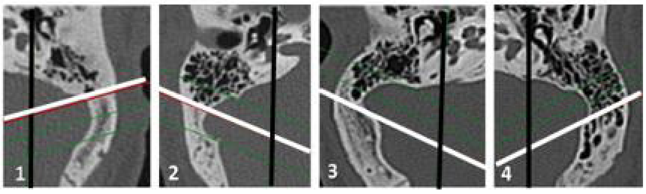

Figure 5: Scans showing mastoid pneumatization Hans types 1-4 respectively (axial cut at level of incudomalleor joint with black lines in the anteroposterior plane while white and green lines are at 40-45^0 consistent with Hans classification)

On correlations, Hans 4 mastoid pneumatization was significantly associated with PSS (p= 0.001) while sclerosed mastoid was associated with both ASS (p= <0.04) and LSS (p= <0.005). LSS was associated with both sclerosed and lower mastoid pneumatization (Hans 1 and 2) than higher mastoid pneumatization (p=<0.005).

DISCUSSION

Arterial variants in the temporal bone especially the aberrant internal carotid artery and persistent stapedial artery are extremely rare. These variants were not observed in this study and several others[6,10,11]. Lateral ICA was noted to be the highest occurring arterial variant with a prevalence of 12.6% in this study and 2-3.4% in others[6,12]. Injury to the lateral ICA and other arterial variants can result in catastrophic intraoperative haemorrhage[6] thus a cautious low threshold for diagnosis is recommended.

The sigmoid sinus, jugular bulb and mastoid emissary vein comprise the most significant venous structures in the temporal bone. The ASS prevalence was 8.8% and fell within the range of 1.1-34% prevalence by other studies[6,10-13]. The LSS prevalence of 22.5% resonates with ranges by others studies, 8.3- 28% [6,13]. Anteriorly and laterally placed sigmoid sinus significantly increase the difficulty of mastoidectomy, risk of haemorrhage and the overall operative time especially if concurrent with other variants for example low lying tegmen[6,15]. Sigmoid sinus dehiscence was noted in 10.4% TBs differing from Koesling's 1%[13]. HJB prevalence was 11.5% which was in tandem with prevalence of 6-32% given by other studies[6,12,13]. Jugular bulb dehiscence was noted in 6.6% of TBs which is slightly higher than the 1- 4% prevalence reported in other studies[6,10,11,13]. HJB and jugular bulb dehiscence have been associated with significant haemorrhage during middle ear exploration and manipulation and can similarly be confused for a glomus tumour radiologically and during otoscopy especially in jugular diverticulum[4,5,6].

The mastoid emissary veins are usually <1mm but higher mean sizes have been reported[15,16]. In this study, the prevalence of large emissary vein was 5.5% without bilaterality and the veins ranged 2.3- 4.7mm in diameter where all the sizes were ≥33.3% of the ipsilateral sigmoid sinus diameter. Large mastoid emissary veins may result in significant venous haemorrhage in extended mastoidectomies and retrosigmoid approach procedures[17]. Mastoid emissary can also be a source of retrograde infection from the neck to the sigmoid, transverse, superior petrosal and even to the cavernous sinus[17].

Jugular foramen was asymmetrical in 40.2% of paired TBs resonating with Koesling's 42% prevalence but contrasting Tomura's 4%[10,13]. Asymmetrical jugular foramen could be a normal variant but it could also indicate lesions causing expansion of the foramen for example glomus jugulare or schwannomas. No lesion was noted as the cause of jugular foramen asymmetry in this study. Subarcuate canal was noted in 67.0% of TBs whereas Koesling noted it in 93% of cases[13]. Subarcuate canal is also called the petromastoid canal and runs from the medial anteromedial margin of the cephalad petrous and passes between the limbs of the superior semicircular canal. It was very prominent in 10.7% of cases and could easily be mistaken for a temporal bone fracture[5].

Petrosquamous sinus (Figure 6) was observed in 1.1% of TBs that was similar to Koesling's low prevalence of 1.4% but significantly differed from Pawel's 6.9% observation[6,13]. This sinus denotes the persistence of embryonic vascular channel, possibly the lateral capital vein, that runs in an anteroposterior direction usually on the bony roof of the mastoid cavity and drains into the sigmoid sinus[6,18]. It is directly associated with mastoidectomy related bleeding which could be profuse and confused for sigmoid sinus bleeding[6,18].

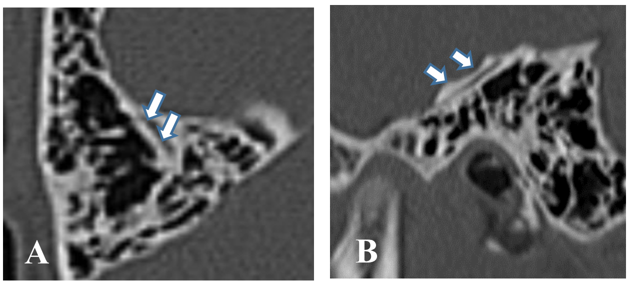

Figure 6: Petrosquamous sinus in axial- A and sagittal- B views

Several anomalous and aberrant venous channels in the temporal bone have been described[19,20]. These have been attributed to persistence of embryonic vasculature especially of the lateral capital vein also called the primary head sinus[19,22]. The anomalous channel seen unilateraly in 3 cases (1.6% of TBs) were consistently anterior to the superior semicircular canal thus may be an aberrance, persistent lateral capital vein or a transpetrous vein[18,20].

CONCLUSION AND RECOMMENDATION

There is a high prevalence rate of vascular temporal bone variations in this study. This may suggests a reciprocal predisposition to surgical complications or suggestive symptomatology. The differences in the prevalence rates of the vascular variants between this study and others, may imply that vascular variants differ based on geographical region and may have a genetic element. It is prudent for the otolaryngologists and radiologists to actively seek these variations on a case by case basis during temporal bone HRCT evaluation to reduce pitfalls in diagnosis of ear pathology, planning and undertaking otologic procedures.

Declaration of interest: The authors report no conflicts of interest.

Ethical approval: Ethical approval was given by KNH/UoN Ethics and Research Committee.

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