Computerized tomography assessment of calvarial wall thickness in different gender and age in neurosurgical practice- A single centre study

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Abstract
Introduction: Computed tomography (CT) scan has revolutionized the imaging and is gold standard in diagnosis of calvarium thickness. This could help in identifying the racial and the gender variations in calvarial thickness in a population.[1] It is helpful for neuroendoscopic procedures to assess size of burrhole in relation to site.
Objective of our study: To identify the gender and age variations of calvarial thickness in a given population.
To assess the thickness of the various parts of the skull i.e frontal, parietal and occipital bones by computed tomography
Materials and Methods: A total of 166 cases, with 71 males and 95 females were selected for the study after meeting inclusion criteria. Thickness of the calvaria was measured over bone windows obtained from computed tomography of brain.
Results: We found the superior occipital bone to be thicker in females than males, and inferior occipital bone thicker in males than females which was statistically significant in our study. The overall thickness of the other part of the skull is thicker in females compared to males and right frontal and left parietal is thicker in both the gender but is statistically non- significant.
Conclusion: In our study, overall calvarial thickness is greater in females, but in superior occipital region, female skull is thicker and in inferior occipital region, male skull is thicker which is statistically significant and also showed that there is no correlation with age and sides of the skull. Our interpretation did not correlate with the older literature, who interpreted that male skull wall is thicker than females.

Keywords: Computed tomography, Calvarium thickness, Frontal bone, Parietal bone, Occipital bone.

Introduction
Computed tomography (CT) scan has revolutionized the imaging and is gold standard in diagnosis of calvarium thickness. This could help in identifying the racial and the gender variations in calvarial thickness in a population.[1] It is helpful for neuroendoscopic procedures to assess size of burrhole in relation to site. It helps to know the possible area prone for fractures in the skull. It is helpful in reconstructive plastic surgeries as skull is a frequently used site of bone graft harvest and for otorhinolaryngologists for placing hearing implants. The data obtained about calvarial thickness study in human population may be useful for researchers, anatomists, anthropologists, surgeons and manufacturers of surgical screws.[2]

Aims and Objectives of the study
1. To identify the gender and age variations of calvarial thickness in a given population.
2. To assess the thickness of the various parts of the skull i.e frontal, parietal and occipital bones by computed tomography.

Materials and Methods
Source of data
1. All patients getting CT brain under neurosurgery in KLE hospital, Belagavi would be taken as subjects for this study.
2. The primary data for this study would be the CT brain of the patients.

Method of collection of data
The CT brain have been carried out for patients having CNS complaints at KLE hospital Belagavi:

Its a single centre prospective study, which we studied 200 cases, out of which 166 cases, with 71 males and 95 females were selected for the study after meeting inclusion criteria. CT scan head for these cases was done, after excluding cases like brain tumours, fracture skull.

Thickness of the skull were measured on 64 slice CT scanner with 2.5 mm thickness.

The three parts of skull frontal, parietal and occipital bones were used for measurement.
1. The frontal bone was measured 2cms anterior to coronal suture bilaterally 2cms lateral to midline.
2. The parietal bone was measured between the coronal and lambdoid suture bilaterally 2cms lateral to midline.
3. The occipital bone was measured at two sites (1. Midway between inion and lambda 2. Midway between inion and opisthion)

Temporal bone measurement was not taken since it has no diploe and chances of error are high with the measurement done on conventional CT scan.

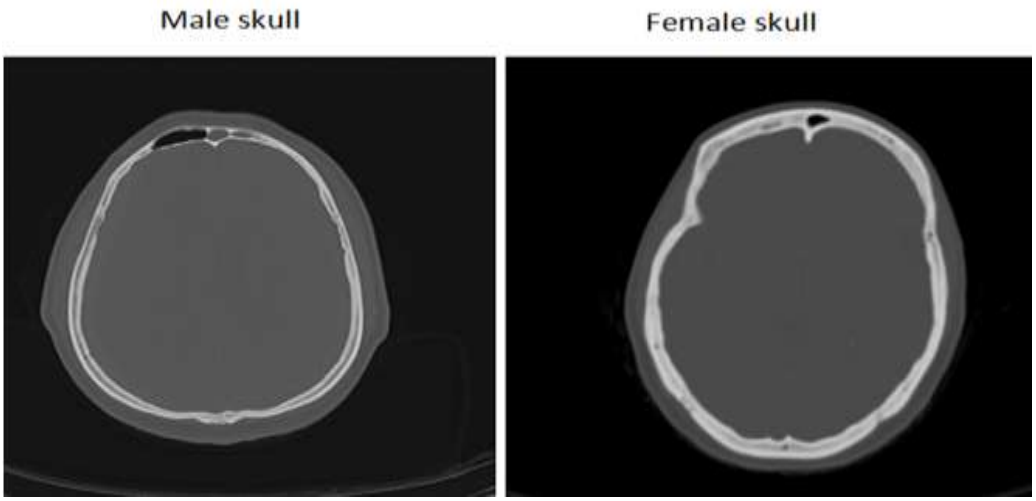

Fig. 1: Comparison of male and female skull

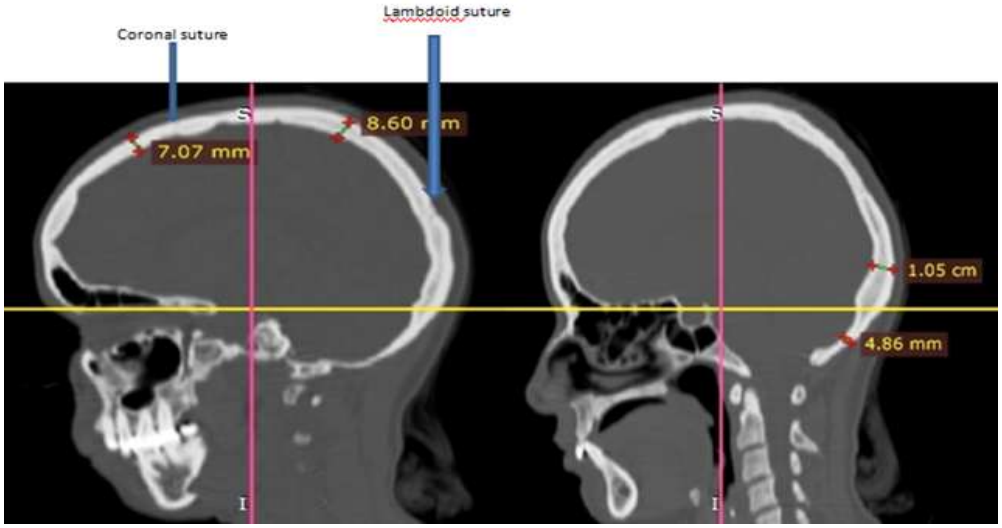

Fig. 2: Measurements of skull at frontal, Parietal, superior and inferior occipital region.

Inclusion Criteria

1. All patients presented with CNS complaints.

Exclusion Criteria

1. Skull fractures
2. CNS tumours

Results

Our study group had 166 cases with 71 males and 95 females, with mean age for males was 46yrs and females was 48 yrs. We did not find any difference in the thickness of the frontal bone and parietal bone in both the gender. But we found the superior occipital bone to be thicker in females than males, and inferior occipital bone thicker in males than females which was statistically significant in our study. The overall thickness of the other part of the skull is thicker in females compared to males and right frontal and left parietal is thicker in both the gender but is statistically non significant.

Statistical analysis

Done by student's unpaired t test and Karl pearson test for correlation study.

Table 1: No. of patients selected.

Sex	Number	Percentage
Female	71	42.77
Male	95	57.23
Total	166	100.00

Table 2: Karl pearson's correlation coefficients with age and the thickness.

Between	r Value	p Value	Inference
AGE-RF	0.0954	0.2213	NS
AGE-LF	0.0653	0.4031	NS
AGE-RP	0.0205	0.7936	NS
AGE-LP	0.0066	0.9328	NS
AGE-SO	0.1870	0.0157	NS
AGE-IO	0.0687	0.3792	NS
RF-LF	0.8520	<0.0001	HS
RF-RP	0.4950	<0.0001	HS
RF-LP	0.4910	<0.0001	HS
RF-SO	-0.0973	0.2126	NS
RF-IO	0.2690	0.0005	HS
LF-RP	0.4640	<0.0001	HS
LF-LP	0.4550	<0.0001	HS
LF-SO	-0.0803	0.3036	NS
LF-IO	0.2270	0.0033	VS
RP-LP	0.8100	<0.0001	HS
RP-SO	0.0751	0.3361	NS
RP-IO	0.4090	<0.0001	HS
LP-SO	0.1053	0.1770	NS
LP-IO	0.3800	<0.0001	HS
SO-IO	0.0948	0.2242	NS

Table 3: Comparison of different region of the skull in Females

RF		**LF**			
Mean	**S.D.**	**MEAN**	**S.D.**	**p Value**	**Inference**
7.81	2.37	7.78	2.38	0.9270	NS
RP		**LP**		**LF**	
Mean	**S.D.**	**Mean**	**S.D.**	**p Value**	**Inference**
8.02	2.04	7.68	1.84	0.4023	NS

Table 4: Comparison of different region of the skull in Males.

RF					
Mean	**S.D.**			**p Value**	**Inference**
7.69	1.89			0.9997	NS
RP		**LP**			
Mean	**S.D.**	**Mean**	**S.D.**	**p Value**	**Inference**
8.06	1.80	8.20	1.66	0.56	NS

Table 5: Comparison between males and female skull.

	Female		**Male**			
	Mean	**S.D.**	**Mean**	**S.D.**	**p Value**	**Inference**
AGE	48.80	17.47	46.16	17.61	0.3382	NS
RF	7.81	2.37	7.69	1.89	0.7108	NS
LF	7.78	2.38	7.68	1.84	0.7746	NS
RP	8.02	2.04	8.06	1.80	0.9011	NS
LP	8.29	1.82	8.20	1.66	0.7352	NS
SO	8.79	1.57	7.55	1.88	<0.0001	HS
IO	5.22	1.74	6.40	1.83	<0.0001	HS

Discussion

The skull is a complex component of the skeletal system whose main function is to protect the brain. It is comprised of 22 bones, eight of which form the neurocranium and are connected by synarthrodial joints called sutures. These sutures are gradually obliterated by fusion of the adjoining bones; fusion begins on the inner surface of the skull between the ages of 30 and 40 years; and on the outer surface between 40 and 50 years.

The cranial bones consist of: (a) An outer table of compact bone which is thick, resilient and tough; (b) an inner table of compact bone which is thin and brittle; and (c) the diploe which consists of spongy bone filled with red marrow, in between the two tables. The skull bones derive their blood supply mostly from the meningeal arteries from inside and very little from the arteries of the scalp.[3]

Prof. B D Chaurasia in his textbook of human anatomy has described about the characteristic features of the male and female skull and has stated that male skull wall is thicker than the female skull wall.

Table 6: Difference between male and female skull.[3]

	Males	**Females**
Weight	Heavier	Light
Size	Larger	Smaller
Walls	Thick	Thin
Vault	Rounded	More prominent

In previous articles, studies have been done by many authors like McElhaney et al. in 1970 on cadavers and primates to evaluate the physical and mechanical properties of the skull. A study done by Moss et al in 2009 said that skull flexure is thought to play a critical role in the mechanical load on the brain from blast impact conditions where the pressure wave generates flexural ripples in the skull and researches have found the flexural properties of the skull to be highly dependent on skull thickness. [4]

The thickness of the layers of the skull, as well as bone mechanical properties, microstructure, and geometry determine the deformation of the skull during an impact was stated by Ruan & Prasad in 2001. [5]

A study done by Niels Lynnerup et al measured the thickness of the human cranial diploe in relation to age, sex and general body build and inferred that males overall have a thicker diploe, albeit this difference is statistically significant only in the frontal region. Neither cranial diploeic thickness nor cranial total thickness is statistically significantly associated with the sex, weight or stature of an individuals.[6] Contrary to this study Hatipoglu HG et al has inferred sexual dimorphism in all craniometric data and observed positive correlation between body mass index and diploeic thickness.[12]

Sowell and colleagues evaluated the change in brain tissue density with age and discovered the most significant gray matter density loss occurs in the frontal and parietal regions and due to the regional loss in gray matter density and increase in cerebrospinal fluid (CSF) below these frontal and parietal bone which cause increased thickness in this area.

Hormonal status of the body also contributes to the mineralization and remodelling of the skull. The four main hormones that contribute to osteoclastic bone resorption and remodeling include calcitonin, parathyroid hormone, vitamin D3, and estrogen.Estrogen levels in females are known to decrease with age, also increasing the amount of bone resorption. With these known compounding age-dependent changes, it would be expected that the aging population, particularly females, would display some degree of reduction in cortical thickness.

Several authors have recorded a slight increase in cranial thickness with age and have related the frontal bone thickness increase to hyperostosis of frontalis interna. However other authors found that age-related increase in thickness, may be a result of inconsistencies in the radiologic examination.[1] It is assumed that hyperostosis frontalis interna is caused by a prolonged oestrogen production in females.[8]

Computed tomography (CT) scan has revolutionized the imaging study of living human body and has become the gold standard for evaluating any anatomical and pathological features in the body. Now a days CT has been much useful mean for the study of calvarial thickness on living subjects. One of the important advantage of using CT for the study of calvarial thickness on living subjects is one can assess any gender and racial variation. In addition to effect of nutritional, occupational and geographical factors on calvarial development and thickness can be studied.[7] The measurement of the human skull based on CT images results are of great importance and value in the fields of anatomy, clinical medicine, biomechanics study and neurosurgery like head injury analysis etc.[1] The total skull bone thickness is the total thickness of diploe and the external and internal tables. Numerous studies have used different radiological tests for assessment of cranial thickness like A-mode ultrasound, CT and MRI.

A study done by Elizabeth M. Lillie et al about skull table thickness measured by clinical CT and validation with microCT, found an average cortical thickness error of 0.078 ± 0.58 mm was observed with 91.3% of the error contained within the clinical CT scanner resolution.[4]

Fowzia Farzana et al did a study of CT assessment of skull thickness which showed the anterior third of the parietal bone has a more calvarial thickness on the right side than on the left side in both males and females. However, the female calvarium has a significantly thicker calvarium at the posterior third parietal; anterior and middle third occipital bones when compared to male counterparts showing a sexual dimorphism.[1]

Gerhard et al carried-out thickness mapping of the Occipital bone on CT-data and concluded that information about the thickness of cranial bones are not only of great medical interest, particularly for pre-operative surgical planning, but can be useful for investigations of fossil hominid material.[9]

Ross MD et al investigated skull thickness of Black and White races and found that White women have the thickest and White men the thinnest skulls. The skulls of women were statistically significant thicker than those of men in both ethnic groups.[10]

Ross AH et al has carried out research on cranial thickness in females and males with an objective to examine sex and age variation in cranial thickness in a White sample among Americans. He observed an increase in cranial thickness with age and there was no statistical difference in calvarial thickness between male and female.[11]

Hwang K et al have studied thickness mapping of the parietal bone in adult patients and inferred that the parietal bone tended to be thicker towards the Lamda point than at the coronal suture area.[13]

Daniel Novakovie et al have studied calvarial thickness for in a total of 195 temporal bones. In his study mean calvarial thickness was greatest at +1 cm above external auditory canal level i.e.6.3mm. So Such data can be useful for surgeons to plan for different burr holes at different positions and for cranioplasties.[14]

In our study overall thickness is greater in females than males, and right frontal and left parietal thickness is greater in both the gender but not statistically significant. Our study showed superior occipital bone thickness is greater in females and inferior occipital bone thickness is greater in females and is statistically significant and also inferred that there is no statistical correlation between age and the thickness of the skull.

Conclusion

In our study, overall calvarial thickness is greater in females, but in superior occipital region, female skull is thicker and in inferior occipital region, male skull is thicker which is statistically significant and also showed that there is no correlation with age and sides of the skull. Our interpretation did not correlate with the older literature, who interpreted that male skull wall is thicker than females. The goal of our study was to look for approximate thickness at various regions of the skull so that it is helpful for the neurosurgical perspective.

Conflict of Interest: None.

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