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Measurement of calvarial thickness in multidetector computed tomography

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Abstract

Objective: The purpose of the study was to measure the calvarial thickness by using Computed Tomography Scans to correlate with sex, age, right and left side.

Materials and methods: This quantitative, cross-sectional prospective study was performed in the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital. Imaging data were collected over the period of January to April 2022 with the total number of 122 individuals. The age and gender of the individuals were noted. The measurement was done in the sagittal and coronal reformatted images of CT scan of head with the help of axial sections and Volume Rendered Technique (VRT). Thickness of frontal, parietal and occipital bones were measured at two levels for each bone. Mean thickness of the skull vault was calculated by averaging all the values. Statistical analysis was carried out with the help of SPSS version 26 (IBM, Window OS, Free trial license) and Microsoft Excel version 2010 (32 bit OS). The quantitative data was analyzed using independent sample t-test and Karl Pearson's correlation.

Results: Mean thickness of calvarium was 5.81±0.59 mm. Our study found that the female calvarium was thicker than male counterparts (P=0.24). Though only frontal bone in female was significantly thicker than that of male counterparts at both upper and lower level (P = 0.04 and P = 0.03). There was increasing thickness of human calvarium with increasing age.

Conclusion: Most of the previous studies were focused on correlating calvarial thickness with respect to gender with controversial results. In this study, the valuable information regarding anatomical thickness of human calvarium with respect to age and gender among the Nepalese individuals was found. Results from our study are different from various published reports in other population.

Keywords: MDCT, Calvarium

Introduction

In the last few decades, computed tomography (CT) scans have revolutionized the imaging and diagnosis of calvarium. Calvarial thickness in humans can be measured with a computerized tomography scan (CT scan). This could aid in determining racial and gender differences in calvarial thickness in a population. The information collected from the calvarial thickness study in the human population may be beneficial to researchers, anatomists, anthropologists, surgeons, and surgical screw manufacturers. Measurement of calvarial thickness is also important in various disease conditions including hemolytic anemia like thalassemia where there is expansion of diploic space and increased calvarial thickness.

The cranial vault, also known as the calvarium, is the roof of the cranial cavity (brain box). The cranial vault consists of frontal, parietal, and occipital bones that form as a result of membrane ossification, hence the term "membranous bones". Because of their better acceptance in the donor site, membranous bones are commonly employed in bone grafting. Using a computerized tomography (CT) scan, surgeons should first measure the thickness of bone in the calvarium while examining the donor site [2].

Previous researches have attempted to assess cranial thickness, with mixed results regarding the relationship between cranial vault thickness with age and gender [1, 3, 4]. Similar types of studies were also done in Nepal but results were different from research done in other countries [5, 6]. We under-

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took this study to measure the calvarial thickness in Nepalese population.

Materials & methods

Data collection:

This was a prospective, quantitative, cross-sectional study conducted in the Department of Radiology and Imaging, Tribhuvan University Teaching Hospital (TUTH) for 3 months (January to April 2022). A purposive non-probability sampling technique was used in the sampling of the subjects. All the subjects who visited for a CT scan of the head region were included in the study. Measurement was performed on a CT scan of the head in the axial, coronal and sagittal sections.

Data collection method:

Data was collected from the measurement performed on a CT scan of the head region.

Duration of study

January 2022 to April 2022

Inclusion criteria:

- Those people are referred in radiology department for CT scan of head region with age of 18 and above.

Exclusion criteria:

- Any subject with pathology, fracture and post-operative changes of bone of measurements.
- Any subject with abnormally thickened calvaria

Methods of measurement

In this study, different measurements were taken in sagittal MPR of CT of head region. The measured line and distance are;

Frontal bone

Total length of frontal bone from bregma to nasion was measured in mid sagittal section and thickness was measured at upper (UF) and lower (LF) one third point of that measured length [Figure 1].

Parietal bone

Total length of midline of parietal bone was measured in mid sagittal section.Thickness of parietal bone was measured in coronal sections at 5 cm lateral to anterior (RAP, LAP) and posterior (RPP, LPP) one third point of that measured length of parietal bone [Figure 2].

For occipital bone

Total length of occipital bone from lambda to external occipital protuberance was measured in mid sagittal section. Thickness was measured at upper (UO) and lower (LO) one third point of that measured length [Figure 3].

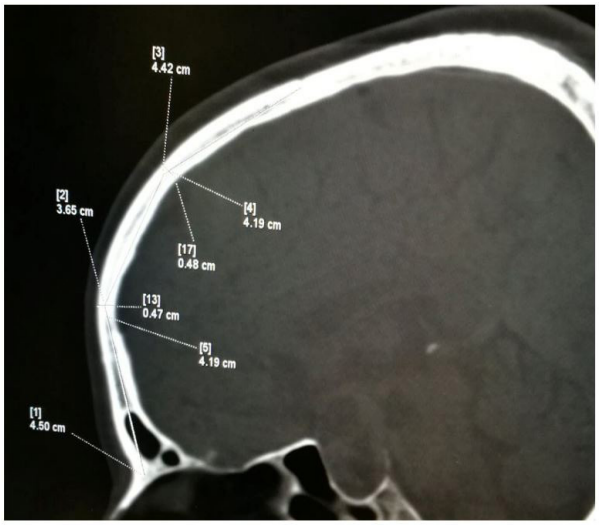

Figure 1: *Measuring the thickness of frontal bone in sagittal plane.*

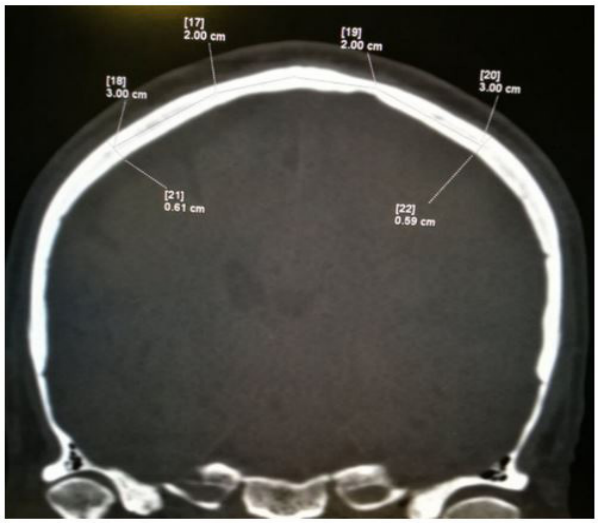

Figure 2: *Measuring the thickness of parietal bone in coronal section.*

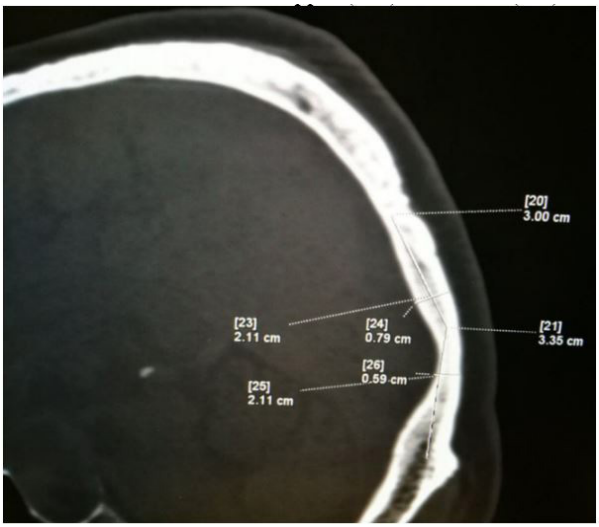

Figure 3: *Measuring the thickness of occipital bone in sagittal section.*

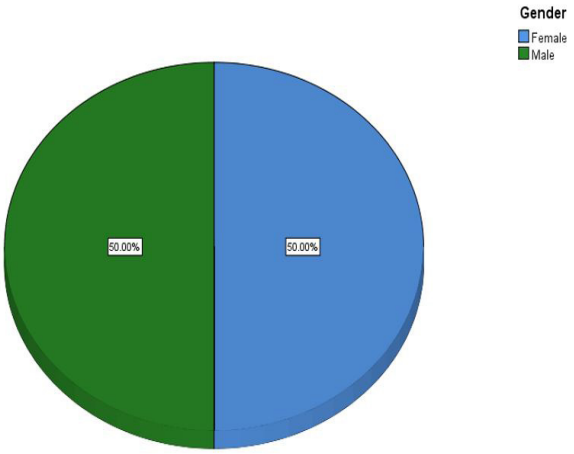

Figure 4: *Pie Diagram Showing the Distribution of Total Sample Size According to Sex.*

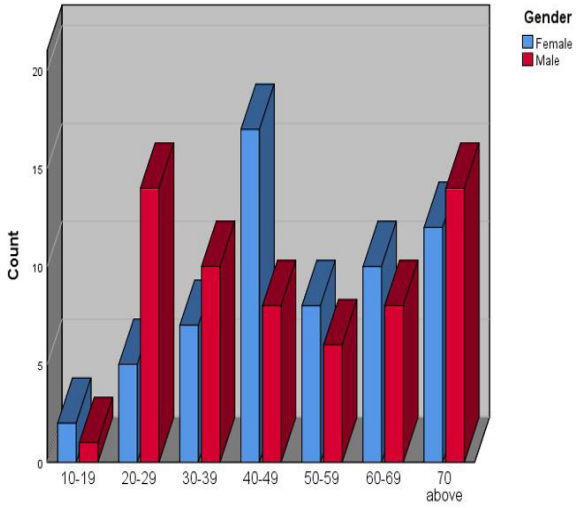

Figure 5: *Bar Diagram of the Distribution of Sample Size According to Age Group.*

Table 1: *Distribution of mean, SD, and Range of the total sample (n = 122).*

Parameters	Mean ±SD	Range	Total mean±SD
UF(mm)	5.72 ± 0.77	3.90 - 7.20	5.81±0.59 mm
LF(mm)	5.86 ± 0.77	4.20- 7.40	
UO(mm)	6.71 ± 0.58	5.40 - 8.00	
LO(mm)	6.59 ± 0.57	5.30 - 7.70	
RAP(mm)	5.14 ± 0.60	3.80 - 6.60	
LAP(mm)	5.11 ± 0.62	3.70 - 6.60	
RPP(mm)	5.69 ± 0.65	4.40 - 8.00	
LPP(mm)	5.65 ± 0.65	4.30 - 7.70	

Data collection tool:

CT scan was performed on 128 slice MDCT scanner (Seimens Somatom Defination As+, TUTH, Biomedical equipment no: 1001915) and data collection and measurement was done in Syngo Via workstation with resolution of 3 megapixel.

Statistical Analysis

Statistical analysis was carried out with the help of SPSS version 26 (IBM, Window OS, Free trial license) and Microsoft Excel version 2010 (32 bit OS). The quantitative value for thickness of UF, LF, UO, LO, RAP, LAP, RPP, and LPP were analyzed using Shapiro Wilk test for normal distribution. Data were presented as mean, range and SD for all variables. Patient's age, gender, UF, LF, UO, LO, RAP, LAP, RPP, and LPP were recorded. The tested quantitative data was analyzed using independent sample t-test with gender and Karl Pearson's correlation with age. A 95% confidence interval was taken and $p<0.05$ was considered to be statistically significant.

Table 3: *Distribution of P-value of parietal bone at anterior and posterior regions in males and females separately.*

Parameters	P value	
	male	female
AP	0.89	0.73
PP	0.94	0.51

Result

Data was collected from 122 subjects, 61 (50%) males and 61 (50%) females with the age from 18 to 100 years [Figure 4, 5]. The mean age of the patients was 50.34±19.41 years.

The mean values of the thickness of frontal bone at upper (UF) and lower (LF) regions of the total sample were found to be 5.72±0.77 mm and 5.86±0.77 mm respectively. The mean values of the thickness of occipital bone at upper (UO) and lower (LO) regions of the total sample were found to be 6.71±0.58 mm and 6.59±0.57 mm respectively. The mean values of thickness of right and left parietal bone at anterior regions (RAP, LAP) of total sample were 5.14±0.60 and 5.11±0.62 mm respectively. Similarly, Mean values of thickness of right and left parietal bones at posterior regions (RPP, LPP) of the total sample were found to be 5.69±0.65 mm and 5.65±0.65 respectively. The mean value of thickness of calvarium was found to

Table 2: *Distribution of Mean Value, SD, Range, and P-value in male (n_1 = 61) and females (n_2 = 61).*

Parameters	Mean ± SD		Range		P value
	Male	Female	Male	Female	
UF	5.58 ± 0.85	5.86±0.67	3.90 - 7.20	4.50 - 7.20	0.04
LF	5.71 ± 0.82	6.00±0.69	4.20 - 7.20	4.50 - 7.40	0.03
UO	6.69 ± 0.62	6.74±0.54	5.50 - 8.00	5.40 - 7.90	0.63
LO	6.54 ± 0.61	6.65±0.52	5.30 - 7.70	5.60 - 7.70	0.26
RAP	5.10 ± 0.64	5.17±0.55	3.80 - 6.60	4.10 - 6.40	0.51
LAP	5.08±0.64	5.14±0.60	3.70 - 6.40	4.10 - 6.60	0.64
RPP	5.64±0.67	5.74±0.63	4.40 - 6.90	4.60 - 8.00	0.37
LPP	5.63±0.69	5.67±0.62	4.30 - 6.40	4.40 - 7.70	0.73

Table 4: *Correlation of calvarial thickness with age.*

Parameters	Male		Female	
	r	P value	r	P value
UF	0.83	<0.001	0.73	<0.001
LF	0.98	<0.001	0.94	<0.001
UO	0.74	<0.001	0.68	<0.001
LO	0.72	<0.001	0.77	<0.001
RAP	0.89	<0.001	0.75	<0.001
LAP	0.84	<0.001	0.78	<0.001
RPP	0.87	<0.001	0.77	<0.001
LPP	0.88	<0.001	0.79	<0.001

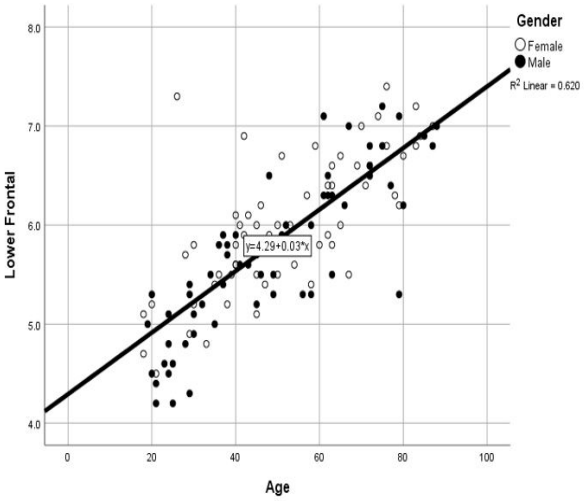

Figure 7: *Scatter plot between age and lower frontal in male and female.*

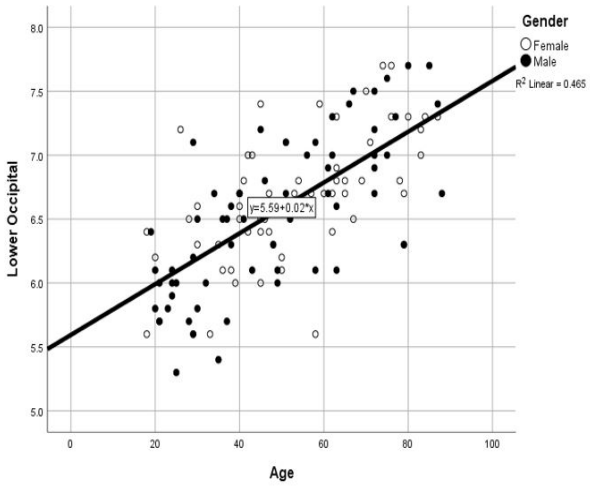

Figure 9: *Scatter plot between age and lower occipital in male and female.*

be 5.81±0.59 mm [Table 1].

The mean values of thickness of frontal bone at upper (UF) and lower (LF) regions were found to be 5.58±0.85 mm and 5.71±0.82 mm respectively in males and 5.86±0.67 mm and 6.00±0.69 mm respectively in females. The mean values of thickness of occipital bone at upper (UO) and lower (LO) regions were found to be 6.69±0.62 mm and 6.54±0.61 mm respectively in males and 6.74±0.54 mm and 6.65±0.52 mm respectively in females. The mean values of thickness of right and left parietal bones at anterior (RAP, LAP) region were found to be 5.10±0.64 mm and 5.08±0.64 mm respectively in

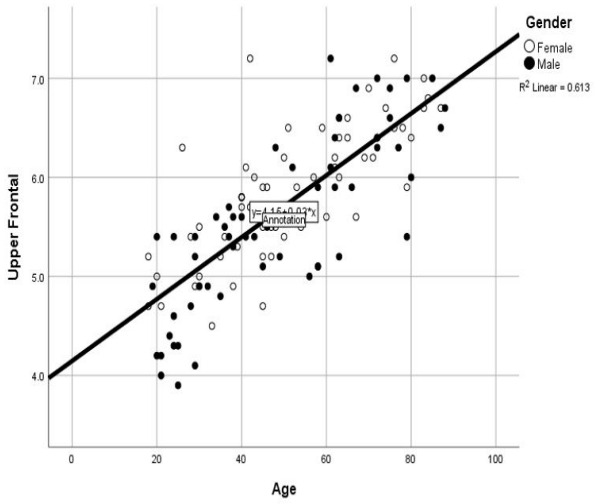

Figure 6: *Scatter plot between age and upper frontal in male and female.*

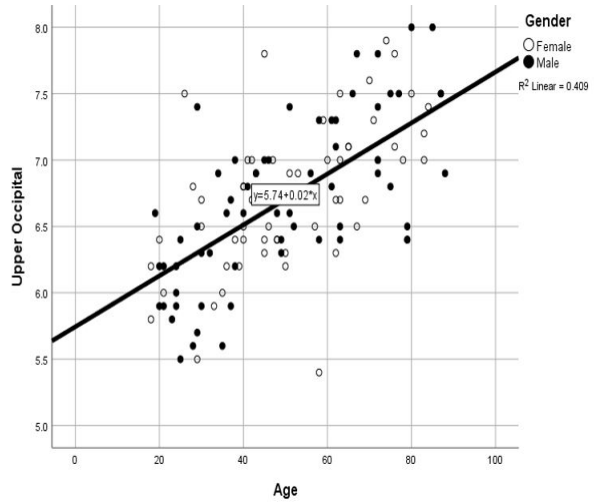

Figure 8: *Scatter plot between age and upper occipital in male and female.*

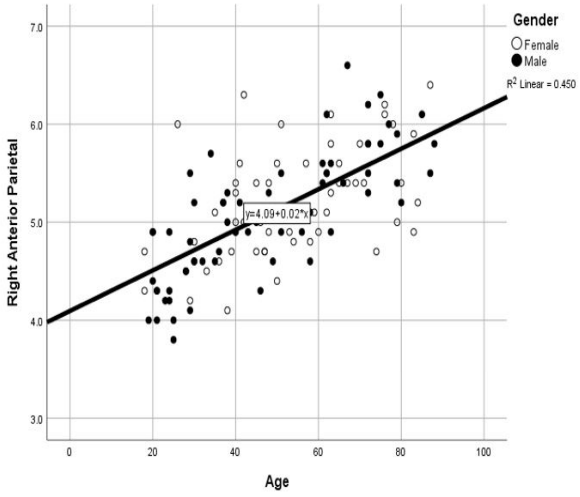

Figure 10: *Scatter plot between age and right anterior parietal in male and female.*

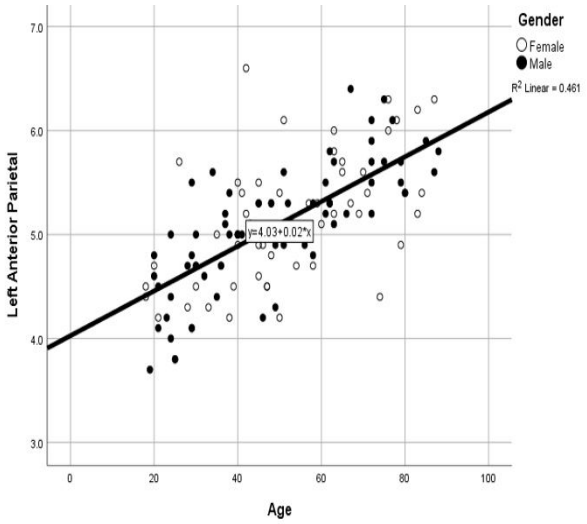

Figure 11: *Scatter plot between age and left anterior parietal in male and female.*

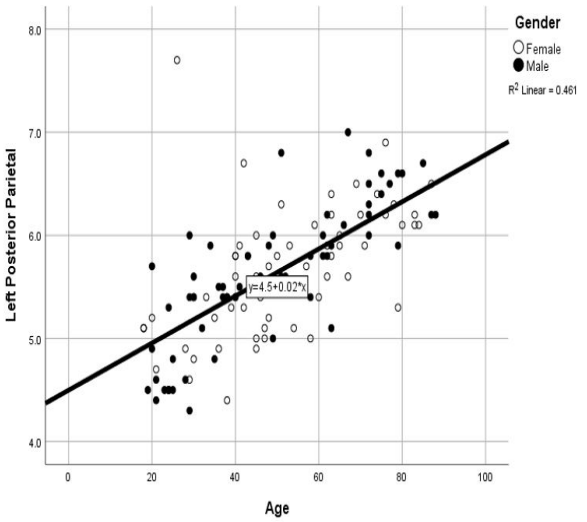

Figure 13: *Scatter plot between age and left posterior parietal in male and female.*

males and 5.17±0.55 mm and 5.14±0.60 mm respectively in females. Similarly, Mean values of thickness of right and left parietal bones at posterior (RPP, LPP) regions were found to be 5.64±0.67 mm and 5.63±0.69 mm respectively in males and 5.74±0.63 mm and 5.67±0.62 mm respectively in females.

After using independent sample t test, it was found that there was significant difference between male and female with thickness of frontal bone at upper and lower region at P value of 0.04 and 0.03 respectively. However, there was no significant difference between male and female with thickness of occipital bone at upper and lower occipital bone at P value of 0.63 and 0.26 respectively. Similarly, there was no significant difference between male and female with thickness of parietal bone right and left side anteriorly and also right and left side posteriorly at P value of 0.51, 0.64, 0.37 and 0.73 respectively [Table 2].

From independent sample t test, there was no statistically significant difference between thicknesses of right and left parietal bone at anterior (AP) and posterior (PP) region in both male and female [Table 3].

Correlation of calvarial thickness with age

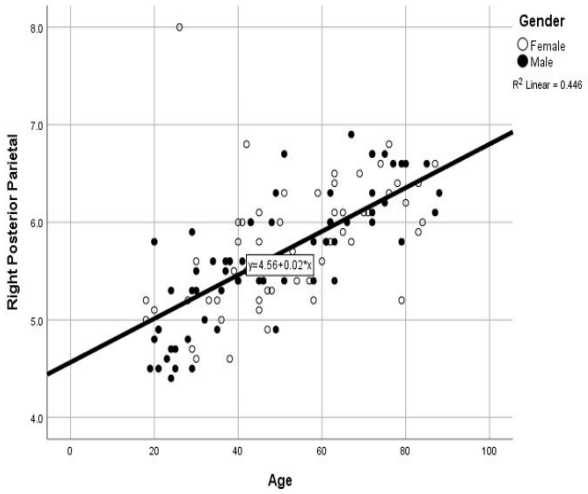

Figure 12: *Scatter plot between age and right posterior parietal in male and female.*

From the Karl Pearson's correlation, There was high correlation between age and thickness of frontal bone at upper region in both male (r= 0.83) and female (r=0.73) which was statistically significant at p value of <0.001 [Table 4] [Fig. 6].

From the Karl Pearson's correlation, There was very strong correlation between age and thickness of frontal bone at upper region in both male (r= 0.98) and female (r=0.94) which was statistically significant at p value of <0.001 [Table 4] [Fig. 7].

From the Karl Pearson's correlation, There was high correlation between age and thickness of occipital bone at upper region in both male (r= 0.74) and female (r=0.68) which was statistically significant at p value of <0.001 [Table 4] [Fig. 8].

From the Karl Pearson's correlation, There was high correlation between age and thickness of occipital bone at lower region in both male (r= 0.72) and female (r=0.77) which was statistically significant at p value of <0.001 [Table 4] [Figure 9].

From the Karl Pearson's correlation, There was high correlation between age and thickness of right parietal bone at anterior region in both male (r= 0.89) and female (r=0.75) which was statistically significant at p value of <0.001 [Table 4] [Figure 10].

From the Karl Pearson's correlation, There was high correlation between age and thickness of left parietal bone at anterior region in both male (r= 0.84) and female (r=0.78) which was statistically significant at p value of <0.001 [Table 4] [Figure 11].

From the Karl Pearson's correlation, There was high correlation between age and thickness of right parietal bone at posterior region in both male (r= 0.87) and female (r=0.77) which was statistically significant at p value of <0.001 [Table 4] [Figure 12].

From the Karl Pearson's correlation, There was high correlation between age and thickness of left parietal bone at posterior region in both male(r= 0.88) and female(r=0.79) which was statistically significant at p value of <0.001 [Table 4] [Figure 13].

Discussion

Computed tomography (CT) scan has revolutionized the im-

aging study of living human body and has become the gold standard for evaluating any anatomical and pathological features in the body. One of important advantage of using CT for the study of calvarial thickness on living subjects is one can access any gender and racial variation. In addition to effect of nutritional, occupational and geographical factors on calvarial development and thickness can be studied. The measurement of the human skull based on CT images results are of great practical value in the fields of anatomy, clinical medicine, biomechanics study and head injury analysis.

In our study, conducted among 122 individuals, the mean thicknesses of the UF, LF, UO, LO, RAP, LAP, RPP and LPP were found to be 5.72±0.77 mm, 5.86±0.77 mm, 6.71±0.58 mm, 6.59±0.57 mm, 5.14±0.60 mm, 5.11±0.62 mm, 5.69±0.65 mm, and 5.65±0.65 mm respectively in entire participants. And mean thickness of calvarium was 5.81±0.59 mm.

We found mean thicknesses of frontal bone at upper and lower regions were 5.58±0.85 mm and 5.71±0.82 mm respectively in males and 5.86±0.67 mm and 6.00±0.69 mm respectively in females. Thickness of frontal bone at upper and lower region of female was found to be significantly thicker than male counterparts. It concurs with the finding of the study done by authors [1, 4, 5]. They all found that there was no significant difference between thickness of frontal bone between male and female.

Mean thicknesses of the right and left parietal bone at anterior region in our study were found to be 5.10±0.64 mm, and 5.08±0.64 mm respectively in males whereas 5.17±0.55 mm, and 5.14±0.60 mm respectively in females. Similarly, Mean thicknesses of the right and left parietal bone at posterior region were found to be 5.64±0.67 mm and 5.63±0.69 mm respectively in males whereas 5.74±0.63 mm and 5.67±0.62 mm respectively in females. We found that there was no statistically difference between thickness of right and left parietal bone in both male and female. Similar results were seen in studies [4, 5]. The study found similar results only at posterior one third region but there was significantly thicker parietal bone at anterior region on right side than on left side in both males and females [1].

We found that there was no significant difference in thickness of parietal bone between males and females. Similar results were seen in study [4, 5]. But a study performed found similar results only at anterior region and there was significantly thicker calvarium of parietal bone at posterior region in female counterparts than male counterparts [1].

In our study, mean thicknesses of the occipital bone at upper and lower regions were 6.69±0.62 mm and 6.54±0.61 mm respectively in males and 6.74±0.54 mm and 6.65±0.52 mm respectively in females. There was no statistically significant difference in thickness of occipital bone between males and females. Similarly, there was no statistically significant difference between thickness of occipital bone between males and females [5]. But study performed there was significantly thicker occipital bone at upper and middle region in female with compared to male counterparts and there was no significant difference between thickness of occipital bone lower region between both sexes [1]. And also found that thickness of occipital bone at upper region of female counterparts was greater than male counterparts which was statistically significant and occipital bone at lower region of male counterparts was significantly greater than female counterparts [4].

There was positive correlation between age and calvarial thickness in both male and female in our study. Similar result was seen in the study [3].

Different results of our study with compared to other studies may be due to the geographical variation, thickness measurement at different anatomical level than other's study or may be due to associate with use of different computer software for thickness measurement.

Conclusion

MDCT is considered as a gold standard for evaluating any anatomical and pathological features in the body. Overall thickness of frontal, parietal, and occipital bones were greater in female than male but only frontal bone was found significantly thicker in female than male. Right parietal bone at posterior region was thicker with compared to the left parietal bone at posterior region in female, which was statistically significant. There was positive correlation between age and human calvarial thickness. Further study including large number of individuals need to be done for better correlational study.

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