A Morphometric Study of Normal Parietal and Coronal Suture's Width in Indian Infant Population by CT Imaging

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Abstract

Background: The skull of newborn normally consists of seven bones: the paired frontal, temporal, and parietal bones, and the single occipital bone, and six sutures including the paired coronal and lambdoid sutures, and the single sagittal and metopic sutures. The anatomical knowledge of the pediatric skull is a challenging task, and the stages of its development are not easily recalled by radiologists. *Materials and Methods:* The sagittal suture and bilateral coronal sutures were evaluated for 483 patients, ages 1 day to 395 days collected retrospectively from electronic medical records. Histograms as well as normality and boxplots were used to view the distribution of the data. *Results:* The average proximal suture widths for the sagittal and coronal sutures at zero months of age were 4.9 ± 0.13 and 2.45 ± 0.13 mm, respectively. From zero to 1 month of age, these sutures narrowed significantly to 2.3 ± 0.15 and 1.3 ± 0.13 mm, respectively. From 1 to 12 months of age, sutures narrowed gradually. The proximal coronal suture widths showed a significant reduction from 1 month to 12 months (1.3 ± 0.13 to 0.85 ± 0.12 mm). *Conclusions:* This study provides normal reference values for suture widths established by CT scan among a sample of Indian infant population and it may be used to assess the infant calvaria for suture diastasis.

Keywords: Newborn skull; Parietal suture; Coronal suture's width; CT scan.

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Introduction

The skull of newborn normally consists of seven bones: the paired frontal, temporal, and parietal bones, and the single occipital bone, and six sutures including the paired coronal and lambdoid sutures, and the single sagittal and metopic sutures.[1,2] The anatomical knowledge of the pediatric skull is a challenging task, and the stages of its development are not easily recalled by radiologists. This comes from the variable nature and changing appearances of sutures over the normal developmental period.[3] The large sutures are seen in all infants less than 12 months of age and toddlers (1–4 years) and persist into adulthood.[4] The sutures are fibrous type of joint that occurs only in the skull. The metopic suture, typically closes around 9–24 months; the sagittal suture, closes at around 22 years of age; the coronal suture closes at around 24 years; and the lambdoid suture close at around 26 years.[5,6]

In United States of America there has seen a recent rise in the number of emergency department visits from 352.8 to 390.5 per 1000 persons over the time span of 1997–2007.[7] This trend is also reflected in the pediatric population.[8] Pediatric head trauma is a common presentation for emergency department and acute care clinic visits in developed countries but in developing countries it may varies from congenital cause to infections.

Henderson and Sherman were the first to assess

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neonate sutures. They evaluated 100 neonate infants by radiography, demonstrating a large variation in the coronal and sagittal suture widths.[9] To assess sutural diastasis, Erasmie *et al.* recorded numerical data from CT imaging; however, it is insufficient in providing an assessment of the intracranial anatomy or pathology.[10] With advancement in sonography technology, sutural appearance and intracranial distances can be assessed to determine normality.[9] In the acute setting, however, sonography is not the preferred method of assessing the pediatric head due to variability between ultrasonographers, ultrasonographer availability,[11] and limited overall assessment of intracranial contents. In acute setting, a close evaluation of morphologic features of the suture is performed to asses for diastasis,[12] early closure[13] and fracture.

There in very little literature describing normal suture width among infants in Indian population and lack of normal standard values on CT, hence this study was taken to assist radiologist in diagnosing cranial suture abnormalities.

Materials and Methods

A review of CT imaging reports on the PACs (Picture Archiving and Communication System) identified patients with a normal CT of the head was performed; the study included head CTs conducted among patients 1 year of age or younger during September 2017 to May 2019 in government medical college, Jalgaon. The preterm infants and infants who had undergone cranial surgery were excluded from the study.

The width of each of the cranial sutures (sagittal, coronal) was measured. All measurements were made using the integrated calipers on the workstation software (GE Medical Systems), and had been performed with 2-slice CT scanner; with slice thickness of 5 mm and window width/level of 3000/550 HU. The study sample included 483 patients between 1 and 395 days of age (mean, 96 days). The CT data available included 966 sagittal suture evaluations and 1932 coronal suture evaluations.

Among the selected patients, 251 were male and 232 female, with a disproportionate representation of the neonate cohorts as reflected by the low mean months of age (Table 1) but with similar histories across the age groups (Table 2). Age, in days, was abstracted from the radiologic information system. The age in weeks was calculated by dividing the provided days of life by 7, and the month of life was determined based on a 30-day average month, with the assigned month representing the last complete month of life. Patients were subsequently assigned into the following 6 age groups for analysis: 0, 1, 2, 3, 6, and 12 months.

Table 1: Patient demographics

Sr. No	Age group	Male	Female	Total
1.	0	64	72	136
2.	1	32	31	63
3.	2	30	49	79
4.	3	50	21	71
5.	6	45	22	67
6.	12	25	7	32

Table 2: Indication for CT Imaging Study

| Sr. No	Indications	0	1	2	3	6	12
1.	Infections	52	18	28	24	21	8
2.	Congenital anomalies	26	12	18	17	16	7
3.	Seizure	22	14	14	11	9	6
4.	ICSOL	11	6	8	7	8	6
5.	Trauma	9	6	5	6	7	2
6.	Others	16	7	6	6	6	3
	Total	**136**	**63**	**79**	**71**	**67**	**32**

CT Imaging Analysis

The sagittal suture and bilateral coronal sutures were evaluated on axial imaging by using a measurement selection point similar to Erasmie and Ringertz and electronic calipers measuring distances along the inner margin of the suture. The proximal sagital, right and left coronal suture width measurements were made in relation to the

anterior fontanelle. The distal sagittal and right and left coronal suture width measurements were made in relation to lamboid and sphenosquamous fontanelle respectively which was confirmed on cross-referenced lateral scout images, and reviewed by 2 senior radiologists.
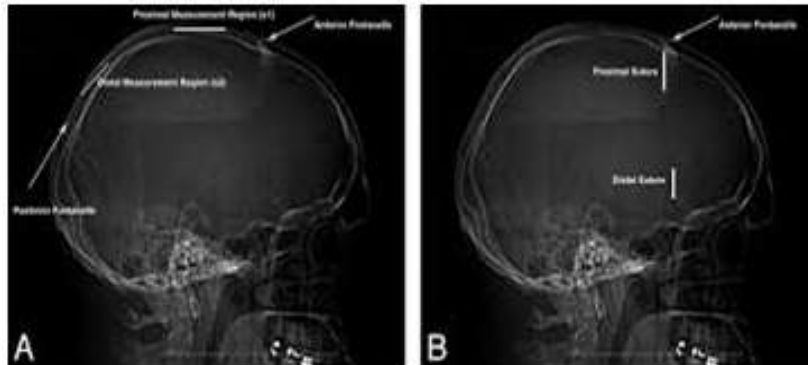
Fig 1: Suture evaluation. (A), Lateral image from CT scan of a young child demonstrating the location of proximal (s1) and distal (s2) sagittal suture measurements and were obtained at a minimum distance of 5 mm from the associated fontanelle. (B), Lateral image from CT scan of a young child demonstrating the location of proximal and distal measurements of coronal suture and were obtained at a minimum distance of 5 mm from the anterior fontanelle and the sphenosquamous suture

Results

Assessment of Sagittal Suture Width

The mean proximal sagittal suture width at 0 months of age was 4.93 ± 0.13 mm (Fig. 2; Table 3). In comparison to neonates, the mean proximal suture width of 1-month-olds was approximately half (2.38 ± 0.15 mm; $p < 0.001$). In comparison with 1-month-olds, infants 6 months of age had significantly narrower mean suture widths ($p < 0.001$) and likewise for infants 12 months of age compared with 1-month-olds ($p < 0.001$; Fig. 2 and Table 3). Other month-by-month comparison between 2, 3, 6, and 12 months did not reach significance.

The mean distal sagittal suture width at 0 months of age was 4.67 ± 0.31 mm (Fig. 2). In comparison to neonates, the mean distal sagittal suture width of 1-month-olds was approximately 45% narrower (2.46 ± 0.17 mm; $p < 0.001$). Compared with 1-month-olds, the mean suture width of the 3-month olds was significantly narrower as was that of 6-month-olds and 12-month-olds ($p < 0.0001$). The decrease in suture width did not continue to reach statistical significance for other month-by-month comparison with the exception of 2 months and 12 months ($p < 0.028$; Fig. 2 and Table 3).
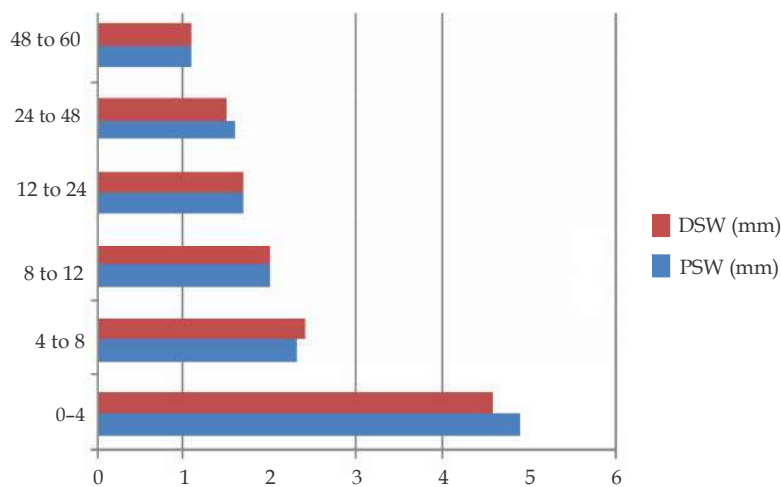
Fig 2: Sagittal suture width. Age variation of the proximal and distal sagittal suture width over a 1-year period. Data are represented as means _ SE (n _ 27–156).

Table 3: Sagittal suture width measurements

| Age group (wk)	PSW (mm)	DSW (mm)
0 to 4	4.9	4.6
4 to 8	2.3	2.4
8 to 12	2	2
12 to 24	1.7	1.7
24 to 48	1.6	1.5
48 to 60	1.1	1.1

Assessment of Coronal Suture Width

The right and left coronal sutures closed at the same rate as reflected by mean widths that were statistically indistinguishable from each other at all time points measured (Table 4 and Fig. 3). In contrast, there was significant difference between mean proximal coronal suture width at 0 months of age and 1 month of age, 2.47 ± 0.13 and 1.37± 0.13 mm, respectively ($p < 0.001$). Unlike the sagittal suture, there was no significant reduction in the mean proximal coronal suture width between 1 and 12 months of age (1.37 ± 0.13 versus 0.84 ± 0.12 mm; Fig. 3). The mean distal coronal suture width at zero months of age was 1.52 ± 0.02 mm (Fig. 4). By the first month of age, the mean distal suture width had decreased significantly to 1.18 ± 0.09 mm ($p < 0.001$). There was no statistically significant reduction in the suture width between 1 and 3 months of age. The large number of coronal CT evaluations supported findings of statistical significance by 12 months of age versus 1, 2, 3, and 6 months ($p < 0.001$, 0.002, 0.001, and 0.031, respectively).

Table 4: Coronal Suture Width Measurements

Age group (wk)	RPC (mm)	RDC (mm)	LPC (mm)	LDC (mm)
0	2.5	1.5	2.4	1.5
1	1.3	1.1	1.3	1.1
2	1.2	0.9	1.2	0.9
3	1.1	1.0	1.1	1.0
6	1.1	0.8	1.0	0.8
12	0.8	0.5	0.9	0.5
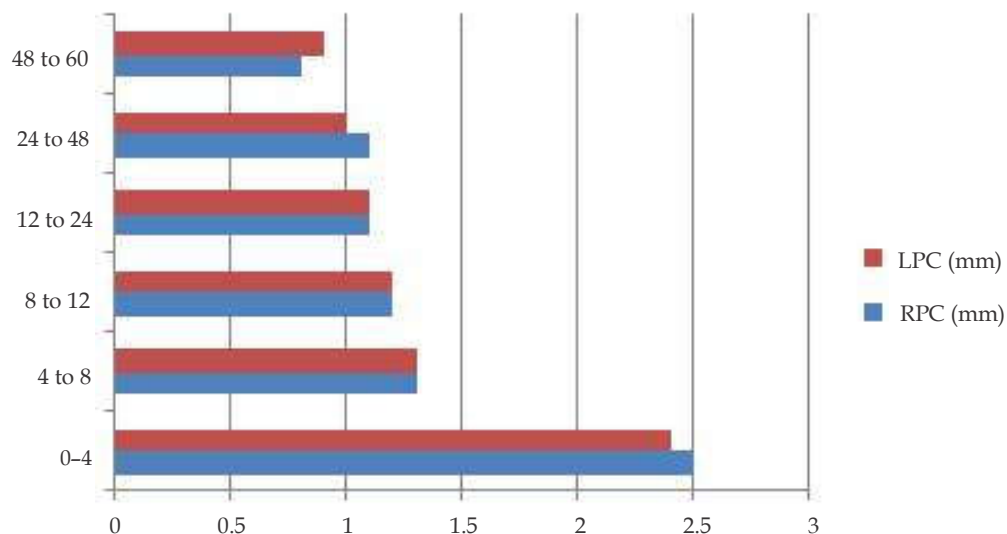
Fig 3: Comparison of the right and left proximal coronal suture widths over a 1-year-period. At each time point, there was no difference between the right and left coronal suture. Data are represented as means _ SE (n _ 27–156).
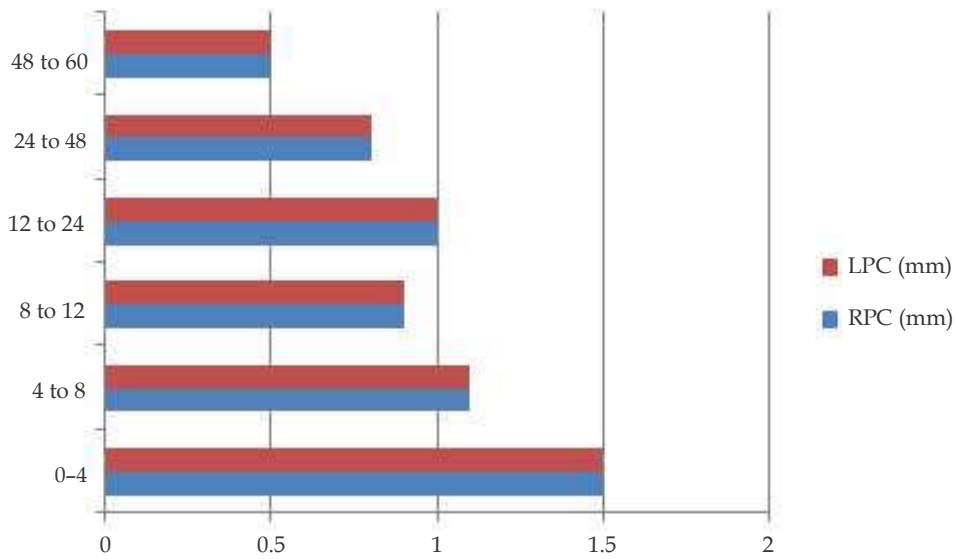
Fig 4: Comparison of the right and distal (B) coronal suture widths over a 1-year-period. At each time point, there was no difference between the right and left coronal suture. Data are represented as means _ SE (n _ 27–156).

Discussion

Nowdays, the matter of using emergency departments for paediatric evaluation has been raised leading to increasing number of neonates and infants undergo CT imaging of head for various reasons. Therefore essential information about normal suture width in infants can be helpful in the assessment of CT scan prevent the concern of sutural fracture.

This study expands on the evaluation of suture initially discussed by Mitchell. Our data portray a CT table of sagittal and coronal suture width throughout first year of life. Infections and congenital anomalies are the main reason for undergoing CT imaging of head in the infants in our study.

Mitchell *et al.*[9] studied and reported the appearance of coronal and sagittal suture in normal infants on CT scan. They calculated the width of cranial sutures on CT scan in 483 patients between 1 and 395 days of age. They found that the proximal and distal suture widths for the sagittal suture was 5, 2.4, 1.1 mm and 4.6, 2.6, 1.1 mm at zero, first, and 12 months of age, respectively. They reported a significant difference between mean proximal sagittal suture width at 0 months with 1 month of age, and 1 month with 12 months of age. Similar to the mentioned study, the mean proximal and distal sagittal suture widths in our study was 2.3 for infants <2 months of age, but at 12 months of age it was 1.1 mm. Also, similar to Mitchell *et al.*[7] results,

we found a significant difference between mean sagittal suture width at <2 months and 12 months of age. The right and left proximal coronal suture widths in Mitchell *et al.*, study was 2.5, 1.3, 0.8 mm and 1.5, 1.1, 0.5 mm at zero, first, and 12 months of age, respectively. The mean right proximal and left coronal suture width in our study was 1.3 and 0.8 at <2 and 12 months of age, which was similar to the mentioned study for 1 month of age and was higher for 12 months of age. They reported a significant difference between mean suture width at 0 months and 1 months of age, but they did not find a significant reduction in the mean suture width between 1 and 12 months of age. The right and left distal coronal suture widths in Mitchell *et al.*, study was 2.4, 1.3, 0.8 mm and 1.5, 1.1, 0.5mm at zero, first, and 12 months of age, respectively. The mean left proximal and left coronal suture width in our study was 1.1 and 0.5 at <2 and 12 months of age, which was similar to the mentioned study for 1 months of age and was higher for 12 months of age. They reported a significant difference between mean suture width at 0 month and 1 month of age, but they did not find a significant reduction in the mean suture width between 1 and 12 months of age. Our findings as well as Mitchell *et al.* study provided appropriate information about coronal and sagittal suture widths in infants lower than 12 months of age based on CT scans for assessments of infants' skull.[9]

Riahinezhad M *et al.*[14] studied the evaluation of sutures widths by CT scans in infants throughout

the first year of life. They calculated the average width of the coronal suture was 2.37 mm at age of <2 months, narrowing significantly to 1.67 mm by 12 months of age. The average width of the sagittal suture was 2.76 mm at age <2 month, narrowing significantly to 1.63 mm at 12 months. Also, the coronal suture in male infants was significantly larger than female infants but other sutures are similar in size between males and females. In sub-group analyzes, a significant relation was found between sutures widths and age among male infants; but in female students this relation was not statistically significant.

In another previous study, the researchers report the appearance of cranial sutures in 53 infants younger than 1 year on MRI scans.[15] They reported that the mean coronal suture widths in their studied infants was 1.2 mm; being 1.4 mm for sagittal suture, and 1.3 mm for lambdoid suture. These findings are different from that find in our study, the sutures widths in the present study were higher than the mentioned study at a lower age but are nearly comparable at a higher age of about 12 months. The difference between both studies can be explained by the difference in assessment method; we reported our results base on CT scans, while in the mentioned study, the findings were based on MIR scans.

In a study by Soboleski et al.,[11] 50 infants aged between 0 and 5 months undergoing brain sonography were assessed to examine the cranial suture width of the coronal, sagittal, and lambdoid sutures.[10] They reported that the mean coronal, sagittal, and lambdoid suture widths were 0.89, 0.93, and 0.96, respectively. Also, they reported that sutures widths were not correlated with age in their studied population. Unlike the mentioned study, we found a significant negative correlation between age and suture widths in infants under 1 year, also the mean of all sutures widths in our study are higher than that reported in the previously mentioned study. The differences between these findings can by due to different sample sizes (50 infants in Soboleski et al. study versus 302 infants in the present study) and assessment method (sonography in Soboleski et al. study and CT scans in our study).

Our study has limitations that should be noted. First, premature infants may have been included in the sample population. It is possible that the inclusion of premature infants may distort the measurements of cranial sutures at 0 and 1 month of age but probably did not affect results of the

older age groups. Second, there was a slight male predominance in the study population, so we did not separate the patients by sex. Few anthropologic studies have noted a slight increase in suture width in the adult male population to that of the adult female population;[16] however, an equivalent number of studies did not reach the same conclusion.[17] Third, less number of patients were in a higher age group in our study, and this might have reduced the potential of the study to evaluate the differences between mean suture widths in infants with respect to age groups.

In summary, it is the first study design to derive suture widths on CT in Indian population of infants by the most common technology used today. In the first year of life CT measurements of mean suture widths decrease rapidly. During the first month of life there occurs considerable closure for all cranial sutural measurement followed by gradual decrease in width during the remainder of the first year of life. Based on these data, we elaborated the normal values for the coronal and sagittal sutures width on CT during the first year of life. The suture widths noted by month here provide a quick and reliable means of assessing a patient's suture width against normal values for CT to the radiologists.

Conclusion

The present study provides data about normal suture widths in infants during the first of life by CT scans and the importance of the distinction between normal sutural anatomy and abnormalities, shows the necessity of further studies to evaluate sutures widths and closes in infants under 1 year based on CT scans as the frequent methods to assess infants' head problems. This study provides normal reference values for suture widths established by CT scan among a sample of Indian infant population and it may be used to assess the infant calvaria for suture diastasis.

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