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Original Article

Radiology Section

Demonstration of Normal Development of Corpus Callosum in Infancy by Magnetic Resonance Imaging

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ABSTRACT

Introduction: Corpus Callosum (CC) is the major anatomical and functional commissure which transmits information across two cerebral hemispheres. It is assessed by looking at its morphology on midsagittal sequence of Magnetic Resonance Imaging (MRI). Physiological variations and diseases alter the structure of CC. It undergoes structural changes throughout the infancy which should be taken into account for better evaluation. Hence, the normal reference biometric data of CC on MRI in infants is needed. There are very limited data of normal reference range of thickness of CC especially in infants.

Aim: To establish the normal standards for the CC in first year of life using MRI.

Materials and Methods: It was a retrospective observational study conducted in the year 2019-2020 in which the MRI images of 100 patients aged 4 days to 12 months with seizures and trauma were reviewed to evaluate CC. Children with abnormalities on MRI were excluded from the study. The thickness of subregions of the CC (genu, body, splenium) and the length were measured. Age related changes in the size of the subregions of the CC was assessed. Data was entered in Microsoft Excel sheet and statistical analysis was done using SPSS software.

Results: In the age group of less than two months, the width of genu, body, isthmus and splenium was 5 mm, 2 mm, 1.52 and 3.45 mm, respectively. The length of CC was 47.24 mm. As the age of children increased, there was increase in width of genu, body, splenium, isthmus and length of CC. At the age group of 11-12 months the width of genu, body, isthmus and splenium was 9.10 mm, 4.90 mm, 2.29 mm and 8.64 mm respectively. The length of CC was 60.57 mm. The study reveals that there is a progressive change in dimension of CC with advancement of age.

Conclusion: There is a considerable change in the appearance of CC during infancy, knowledge of which is useful in differentiating between normal and abnormal brain.

Keywords: Cerebral hemispheres, Genu, Splenium

INTRODUCTION

Corpus callosum is the major anatomical and functional commissure which transmits information across two cerebral hemispheres and callosal fibers have a special topographic organisation [1]. The parts of CC are rostrum, genu, body, isthmus and splenium. CC is affected in various neurologic and systemic diseases including congenital diseases, white matter disease, tumours and vascular anomalies [2,3]. Various developmental anomalies, hypoxic and ischaemic events damage the CC causing thinning of CC [4]. Usually, CC is assessed by looking at its morphology on midsagittal sequence of MRI. Physiological variations and diseases alter the structure of CC, making the morphological analysis of CC on MRI difficult. In addition to this, CC undergoes structural changes throughout the infancy which should be taken into account for better evaluation. Previously many studies have provided the biometric standard reference data of CC in childhood and adulthood as well as gender related differences in the subregions of CC [1,5-7]. However, very limited literature is available for the reference charts for measurement of CC in infants. Hence, the present study was done to provide the reference biometric data of CC on MRI in infants.

MATERIALS AND METHODS

It was a retrospective observational study conducted in the year 2019-2020. Ethical clearance was taken from Institutional Ethics Committee (IEC/2019-20/37). The indications for MRI were convulsive disorder, trauma, macrocephaly etc. All the included MRI cases did not show any structural or anatomical abnormalities. Infants with abnormal MRI like changes of hypoxic ischaemic encephalopathy, encephalitis, tumours were excluded from the study.

Based on the previous studies [8,9], data indicate that age and length of CC positively correlate in adults with correlation coefficient of 0.32. Assuming similar correlation, to estimate the true value of correlation coefficient in infants with error of 0.18 with 95% confidence a minimum of 97 infants was required. Hence to round off, a total of 100 infants aged from 4 days to 12 months, who underwent MRI of brain from January 2019 to August 2019 were included in the study. Sample size was calculated using the formula: where, $Z_{1-\alpha/2}$ (1.96) Table value for 95% confidence, r (0.32) anticipated correlation coefficient and d (0.18) is error.

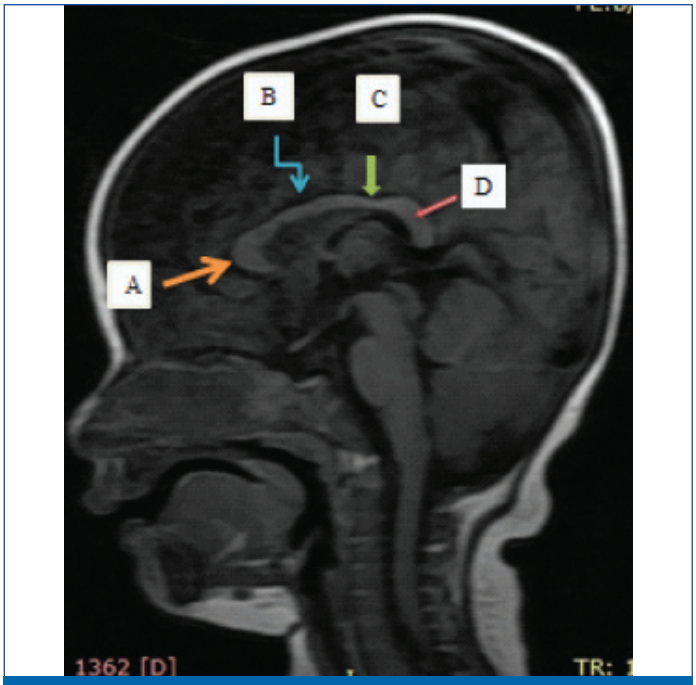
$$N \geq \frac{(Z_{1-\alpha/2})^2 (1-r^2)^2 + 1+6r^2}{d^2}$$

$$N \geq \frac{1.96^2 (1-0.32^2)^2 + 1 + 6(0.32^2)}{0.18^2} = 97$$

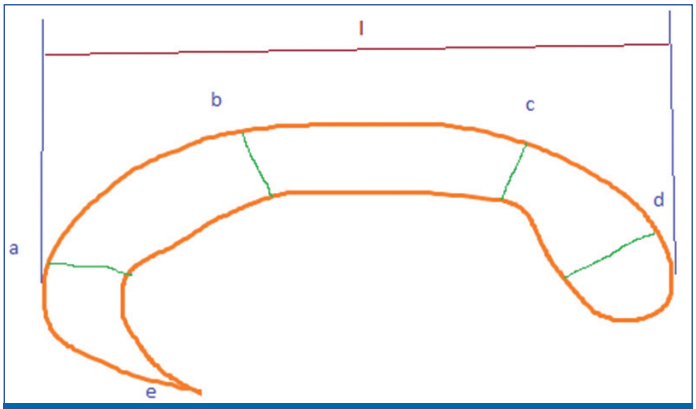
MRI was performed on 1.5 T units (GE, Signa Hdx). Midline sagittal T1 sections [Table/Fig-1] were obtained. The parameters for MRI were TE-20 msec, TR-400-600 msec, Sections thickness 5 mm and 128×256 matrix. All biometric data were acquired on digital image. Thickness of CC was measured as described by Gupta T et al., at genu, splenium, body and isthmus [Table/Fig-2] [10]. Length of CC was measured from anterior most aspect of genu to posterior most part of splenium.

STATISTICAL ANALYSIS

Data was entered in Microsoft Excel sheet and statistical analysis was done using Statistical Package for the Social Sciences (SPSS) Software version 21.0. The quantitative data was expressed as mean and Standard Deviation and the qualitative data was expressed as percentage.



[Table/Fig-1]: Midsagittal T1 weighted MRI of 11-month-old infant showing parts of corpus callosum. A- genu of corpus callosum, B-body, C-isthmus and D- splenium of corpus callosum.



[Table/Fig-2]: Diagram showing the method of measurement of thickness of various subparts of corpus callosum. Thickness was measured of: a) genu; b) body; c) splenium; d) denotes isthmus of corpus callosum; e) represents rostrum. Length of corpus callosum was measured from anterior tip of the genu to posterior tip of splenium, shown as length (l).

RESULTS

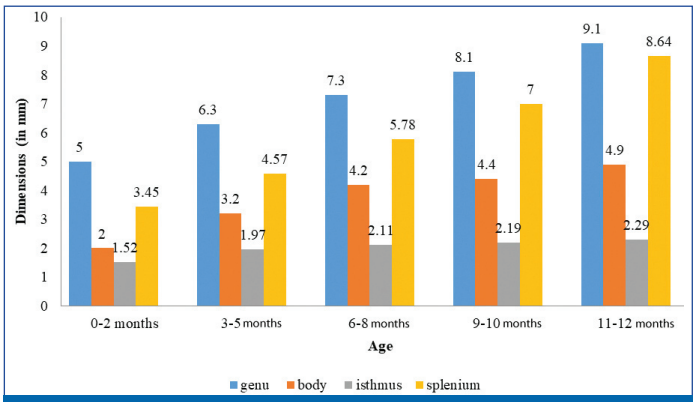
The study included 100 infants, of which 55 were males and 45 were females. The age of the infants ranged between 4 days to 12 months with maximum infants in 11 to 12 months age group [Table/Fig-3].

Age	Total	Male	Female
0-2 months	9	3	6
3-5 months	14	9	5
6-8 months	20	13	7
9-10 months	26	11	15
11-12 months	31	19	12
Total	100	55	45
Percentage		55%	45%

[Table/Fig-3]: Showing the distribution of patients according to age and gender.

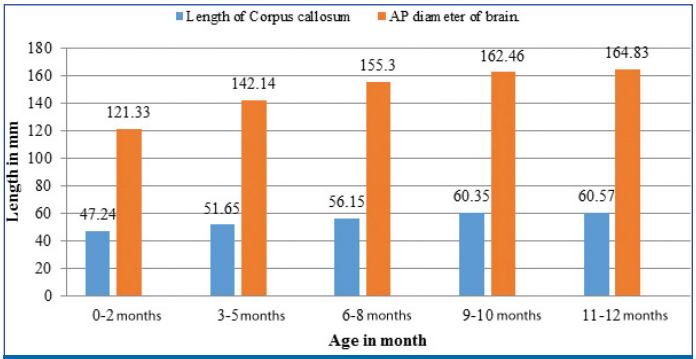
CC in neonatal brain was seen as a thin and flat structure. The mean measurements of genu, body, isthmus, splenium and length of CC in neonates were 5 mm, 2 mm, 1.52 mm, 3.45 mm and 47.24 mm, respectively. By 6 to 8 months, the measurements were found to increase to 7.3 mm, 4.2 mm, 2.11 mm, 5.78 mm and 56.15 mm, respectively. Measurements in 11-12-month-old brain were 9.10 mm, 4.90 mm, 2.29 mm, 8.64 mm and 60.57 mm [Table/Fig-4,5].

Different parts of CC showed gradual increase in their dimensions with increasing age [Table/Fig-4]. However, some morphological changes were observed in the structure of CC by 5-6 months of age. The bulbous enlargements which were not seen in the neonatal brain gradually showed their presence during this period. The thickness of genu which was comparatively smaller to splenium in infancy was found to grow to reach a size almost equal to or more than that of splenium by the end of 12 months [Table/Fig-4,5].



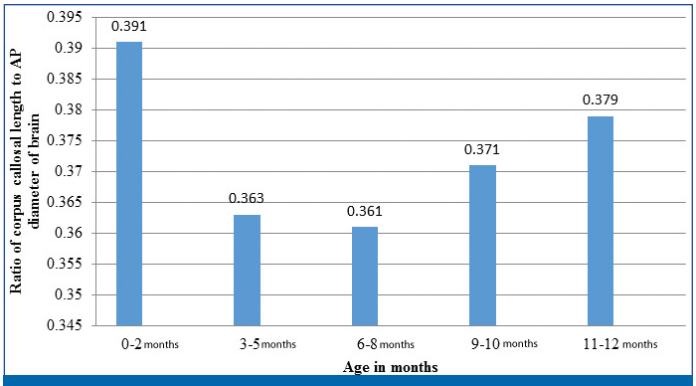
[Table/Fig-4]: Mean measurements of genu, body, isthmus and splenium in different age groups. In this table a gradual increase can be seen in the dimensions of genu, body, isthmus and splenium with progressing age. However, the rate of increase appeared to be different for different structures with least for isthmus and maximum for splenium of CC.

Mean value of CC and Anteroposterior (AP) diameter of brain showed linear increase in growth. The rate of growth was seen to decrease after nine months of age [Table/Fig-5].



[Table/Fig-5]: Mean values of corpus callosal length and AP diameter of brain in different age groups.

Corpus callosal length to brain AP diameter ratio was maximum in the infant brain which was seen to decline by 3-5 months of age and later it showed an increasing trend. However, the ratio was found to be within the range of 0.34 to 0.40 [Table/Fig-6].



[Table/Fig-6]: Corpus callosal length to brain AP diameter ratio in different age groups. AP: Anteroposterior

DISCUSSION

Formation of CC occurs between 8-20 weeks of gestation [11] in an anteroposterior direction. The genu forms first followed by body, splenium and the rostrum forms at the end. Between 8 and 16 weeks,

the bed for ingrowth of callossal fibres is formed. The callosal fibres begin to cross by 12 weeks, to begin with genu and fibres of rostrum completes the crossing lastly by 18-20 weeks. The fibers of CC are topographically arranged with genu and rostrum formed by prefrontal cortex, body via primary motor and sensory cortex and splenium via parieto-temporal and occipital fibers [12]. Diseases affecting different parts of brain affect respective subregions of CC. Hence, there is a need of biometric data of the subregions of CC. Although CC attains the adult configuration by 20 weeks, it is much smaller in size and grows considerably in subsequent weeks.

CC has a different appearance in neonate as compared to the adult. The adult morphology evolves over first eight months of age. The first postnatal change occurs at genu which shows substantial thickening at second and third months. The bulbous enlargement of genu is related to development of interhemispheric connections of the precentral and postcentral gyri. These areas, which are involved with basic motor and sensory functions, develop in early life [13].

The process in myelination can be seen in CC as a relative increase in signal intensity that progresses from posterior CC towards the genu, the splenium attains high signal intensity by four months and genu by the end of six months. The hyperintense signal intensity of different parts of CC attains homogeneity by the end of eight months. These findings correspond to occipital to frontal pattern of myelination within the brain. The rate of growth of corpus callosal length was comparatively lesser to the rate of other parts of CC. The ratio of CC to anteroposterior diameter of brain was found to be within a narrow range throughout the study population in all groups. From the data obtained, the growth of CC showed a progressive pattern with advancing age which is comparable to study done by Barkowich AJ and Kjos BO [9]. The CC to AP diameter of brain ratio was found to be within the range of 0.34 to 0.40 which is similar to the study done by Barkowich AJ and Kjos BO [9]. The different events occurring during growth of CC were found to correspond to developmental milestone of normal child.

Many previous studies have showed that length of CC increased with increasing age [14-17]. Few studies have provided normative data of CC predominantly in adults [1,15-17]. One study has shown developmental changes in CC in infancy and early adulthood [18]. Few studies [17,19] have focused on gender related differences in the dimensions of different parts of the CC. According to the study done by Mohammadi MR et al., the anteroposterior length and vertical dimension of the CC, the length of genu and splenium were larger in males than in females, but these differences were not significant [12]. The anteroposterior and vertical lengths of the brain were significantly larger in males than in females ($p<0.05$).

Limitation(s)

The research was done predominantly in infants and not studied the gender related variation in the thickness of subregions of CC. CC is a three-dimensional structure and the evaluation of the development of CC by volume measurements will provide more accurate dimensions according to the ages. However, the current study did not focus on the volume measurements and this is another limitation of the present study.

CONCLUSION(S)

There was a considerable change in the appearance of CC during the first year of life and the growth of CC occurs in an orderly manner. The knowledge of evolution of CC is helpful in differentiating between normal and abnormal brain.

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