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Original Research Article

MORPHOMETRIC ANALYSIS OF THE DEVELOPING PEDIATRIC CERVICAL SPINE USING COMPUTED TOMOGRAPHY IN INDIAN POPULATION

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Abstract

Background: Anatomical measurements of the pediatric cervical spine changes during the period of growth from birth until fifteen years of age. During which the size and shape of the vertebrae undergoes morphological changes. These changes widely vary between individuals due to the ossification process and synchondroses. **Objective:** To assess the normal measurements of vertebra of cervical spine using computed tomography scan in pediatric population. **Materials and Methods**: CT based descriptive study was conducted in Department of orthopaedics and traumatology, department of radiology Government medical College hospital karur during the period of January 2019 to October 2019. **Results:** The dimensions of the cervical body including both typical and atypical vertebrae was found to increase up to 10 years of age thereafter it had a slow growth. In the sub-axial spine the height of the C3 vertebral body was greater than C4 and C5 but less compared to C6 and C7 in all age groups. The spinal canal diameter and the Torg ratio was found to decrease with age and as we go down the cervical region. **Conclusions:** The morphometric dimensions in this study would provide a reference range for C1 lateral mass, Odontoid process, C1 posterior arch, vertebral body (C2-C7) and Spinal canal diameter (C1-C7) in pediatric age group (0 to 15 years).

INTRODUCTION

Understanding of the developmental anatomy of the pediatric cervical spine facilitates the interpretation of its imaging and conceptualization of its biomechanical properties. It also provides a comprehensive understanding of pediatric cervical spine and surgical approach to deal with patients with deformity, anomalies, tumors and infection.

The understanding of pediatric spine growth is limited and remains incomplete. Knowing the embryology and ossification pattern of the spine helps us to know about any anomalies, unfused synchondrosis and fracture pattern.[1]

Morphometric analysis involves quantitative description of the anatomical structures. Morphometric measurements can be done on dry cervical vertebra, using plain radiography, computed tomography and magnetic resonance imaging. However by using computed tomography scan the bony parameters and anatomical characteristics are better analyzed and studied.[2]

Several previous studies have measured growth at single cervical segments or at the craniovertebral junction,[3] as well as the growth of surgically relevant anatomy such as pedicles and lateral masses. Other studies have analyzed growth of the sub axial vertebral bodies in patients between infancy and 10 years of age, reporting morphometric data according to age groups spanning 2 or 3 years.[4] A few studies have investigated alignment of the cervical spine in children as well. Although each of these studies has quantitatively defined some normal ranges for the pediatric cervical spine, no study has comprehensively reported normal measurements of the entire pediatric cervical spine with attention to segmental morphometric analysis of each cervical vertebral body.

Hence a detailed study regarding the growth pattern and changes that take place in the growth period of pediatric cervical spine from C1-C7 in our Indian population was emphasized and studied.

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MATERIALS AND METHODS

CT based descriptive study was conducted in Department of orthopaedics and traumatology, department of radiology Government medical College hospital karur during the period of January 2019 to October 2019

Study Population

All the patients who underwent cervical spine computed tomography as part of screening in traumatic injuries (involving brain, face, thorax or polytrauma) or soft tissue pathology of neck in children from birth –fifteen years of age were included in the study and approval from the institutional ethical committee was obtained before initiating the study.

Sample Size

Sixty children with normal cervical spine CT satisfying the selection criteria were included in the study.

Sample Size Calculation

Was estimated based on the cervical vertebrae transverse diameters (22.18 ± 2.52 mm) of the vertebral body from the study by Sandeep Saluja et al. Considering SD of 2.52, at 5% alpha error, 90% power and at 95% Confidence level sample size of 50 was obtained. Considering 20% Non-response rate a sample size of 50 + 10 = 60 subjects were included in the study.

Inclusion Criteria

Computed tomography of normal cervical spine of pediatric age group from birth - fifteen years of age.

Exclusion Criteria

1. Congenital anomalies of spine.
2. Spinal cord injury.
3. Bone and ligamentous injury.
4. Tumors and infections.
5. Children above 15 years of age

Methodology

Computed Tomography (CT) scans of the subjects having normal cervical spine which was performed as part of screening of other pathologies were taken. All the scans was performed using 128 slice CT scanner with 2mm intervals (OPTIMA). Measurements was done using Radiant Dicom software. All the measurements was performed by a single observer in the study. The mid sagittal images was used to study the posterior arch height of C1, odontoid height, spinal canal diameter from C1-C7, vertebral body anterior posterior diameter and height from C2-C7 and the axial views were used to study the C1 lateral mass anterior posterior diameter, the width of lateral mass and transverse diameter of sub axial spine. The subjects were divided into three age groups: Group 1 is 0-5 years, Group 2 is 6-10 years and Group 3 is 11-15 years of age based on the notion that the pediatric cervical spine matures at around 9 years of age and to know the growth pattern before and after maturity we included children up to 15 years of age[1,5]. The various measurements taken are given below.

Statistical Analysis: Data was entered into Microsoft excel data sheet and was analyzed using SPSS 22 version software. Categorical data was represented in the form of Frequencies and proportions. Continuous data was represented as mean and standard deviation. Independent t test was used as test of significance to identify the mean difference between two quantitative variables. ANOVA (Analysis of Variance) was the test of significance to identify the mean difference between more than two groups for quantitative data. p value (Probability that the result is true) of <0.05 was considered as statistically significant after assuming all the rules of statistical tests.

RESULTS

In the study 36.7% were in the age group <5 years, 31.7% were in the age group 6 to 10 years and >10 Years respectively. In the study majority of subjects were males 65% and 35% were females.

In the study there was no significant association between gender and age distribution. In group 1 male subjects constituted to 68.2% and females 31.8%, in group 2 and group 3 males and females were 63.2% and 36.8% respectively.

The mean posterior arch height was 5.2mm in group 1, 7.6mm in group 2 and 7.8mm in group 3. The mean spinal canal diameter was 17.0mm in group 1, 20.5mm in group 2 and 20.9mm in group 3. The lateral mass on the right side had a mean anterior posterior diameter of 15.1mm in group 1, 20.1mm in group 2 and 19.1mm in group 3. The mean transverse diameter was 7.7mm in group 1, 9.6mm in group 2 and 11.2mm in group 3. The mean height was 6.4mm in group 1, 10.2mm in group 2 and 10.2mm in group 3. The left side lateral mass had a mean anterior posterior diameter of 15.2mm in group 1, 20.1mm in group 2 and 19.5mm in group 3. The mean transverse diameter was 7.6mm in group 1, 9.7mm in group 2 and 11.1mm in group 3. The mean height was 6.5mm in group 1, 10.2mm in group 2 and 10.1mm in group 3. In the study significant difference was observed in all the C1 parameters between three age groups. It can be observed that with increase in age there was significant increase in all the parameters except for right and left anterior posterior diameter (APD), left height (HT). [Table 1]

The mean height of the vertebral body was 6.8mm in group 1, 9.1mm in group 2 and 9.6mm in group 3. The mean anterior posterior diameter was 7.7mm in group 1, 10.2mm in group 2 and 11.7mm in group 3. The mean spinal canal diameter was 14.5mm in group1, 17.9mm in group 2 and 17.3mm in group 3. The mean dens height was 9.9mm in group 1, 16.4mm in group 2 and 19.3mm in group 3. In the study significant difference was observed in all the C2 parameters between three age groups. It can be observed that with increase in age there was

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significant increase in all the parameters except for SCD. [Table 2]

The mean height was 5.2mm in group 1, 7mm in group 2 and 8.7mm in group 3. The mean anterior posterior diameter was 8.1mm in group 1, 11.5mm in group 2 and 11.8mm in group 3. The mean transverse diameter was 15.3mm in group 1, 19mm in group 2 and 20mm in group 3. The mean spinal canal diameter was 12.6mm in group 1, 16mm in group 2 and 15.1mm in group 3. The TORG Ratio was 1.6, 1.4 and 1.3 in group 1, 2 and 3 respectively. In the study significant difference was observed in all the C3 parameters between three age groups. It can be observed that with increase in age there was significant increase in all the parameters except for SCD and TORG Ratio. [Table 3]

The mean height was 5mm in group 1, 6.9mm in group 2 and 8.6mm in group 3. The mean anterior posterior diameter was 8.2mm in group 1, 11.5mm in group 2 and 11.8mm in group 3. The mean transverse diameter was 15.4mm in group 1, 20mm in group 2 and 20.6mm in group 3. The mean spinal canal diameter was 12.1mm in group 1, 15.8mm in group 2 and 14.7mm in group 3. The TORG Ratio was 1.5, 1.4 and 1.9 in group 1, 2 and 3 respectively. In the study significant difference was observed in all the C4 parameters between three age groups except for TORG Ratio. It can be observed that with increase in age there was significant increase in all the parameters except for SCD. [Table 4]

The mean height was 5mm in group 1, 6.9mm in group 2 and 8.7mm in group 3. The mean anterior posterior diameter was 8.5mm in group 1, 11.6mm in group 2 and 11.8mm in group 3. The mean transverse diameter was 15.7mm in group 1, 20.6mm in group 2 and 22mm in group 3. The mean spinal canal diameter was 12.2mm in group 1, 15.6mm in group 2 and 14.4mm in group 3. The TORG Ratio was 1.5, 1.3 and 1.2 in group 1, 2 and 3 respectively. In the study significant difference was observed in all the C5 parameters between three age groups. It can be observed that with increase in age there was significant increase in all the parameters except for SCD and TORG Ratio. [Table 5]

The mean height was 5.4mm in group 1, 7.4mm in group 2 and 9mm in group 3. The mean anterior posterior diameter was 8.7mm in group 1, 11.8mm in group 2 and 12.1mm in group 3. The mean transverse diameter was 16.4mm in group 1, 22.3mm in group 2 and 24mm in group 3. The mean spinal canal diameter was 12mm in group 1, 15.4mm in group 2 and 14.3mm in group 3. The TORG Ratio was 1.4, 1.3 and 1.2 in group 1, 2 and 3 respectively. In the study significant difference was observed in all the C6 parameters between three age groups. It can be observed that with increase in age there was significant increase in all the parameters except for SCD. [Table 6]

The mean height was 6.2mm in group 1, 7.8mm in group 2 and 10mm in group 3. The mean anterior posterior diameter was 8.9mm in group 1, 12.1mm in group 2 and 12.5mm in group 3. The mean transverse diameter was 17.6mm in group 1, 23.7mm in group 2 and 26.8mm in group 3. The mean spinal canal diameter was 11.9mm in group 1, 14.6mm in group 2 and 13.9mm in group 3. The TORG Ratio was 1.4, 1.2 and 1.1 in group 1, 2 and 3 respectively. In the study significant difference was observed in all the C7 parameters between three age groups. It can be observed that with increase in age there was significant increase in all the parameters except for SCD. [Table 7]

Table 1: Comparison of C1 parameters with respect to Age distribution

C1			Group					
			<5 years		6 to 10 years		> 10 years	
			Mean	SD	Mean	SD	Mean	SD
PAH			5.2	1.3	7.6	1.4	7.8	1.5
SCD			17.0	3.2	20.5	1.4	20.9	1.6
Lateral Mass	Right Side	APD	15.1	3.8	20.1	1.3	19.1	1.9
		TD	7.7	1.5	9.6	.5	11.2	1.5
		HT	6.4	1.6	10.2	1.2	10.2	1.6
	Left side	APD	15.2	3.7	20.1	1.7	19.5	1.9
		TD	7.6	1.6	9.7	.6	11.1	1.6
		HT	6.5	1.8	10.2	1.0	10.1	1.6

Table 2: Comparison of C2 parameters with respect to Age distribution

C2	Group					
	<5 years		6 to 10 years		> 10 years	
	Mean	SD	Mean	SD	Mean	SD
HT	6.8	1.4	9.1	1.1	9.6	2.3
APD	7.7	1.7	10.2	.6	11.7	2.3
SCD	14.5	2.4	17.9	.9	17.3	1.3
DENS HT	9.9	2.9	16.4	3.6	19.3	2.9

Table 3: Comparison of C3 parameters with respect to Age distribution

C3	Group					
	<5 years		6 to 10 years		> 10 years	
	Mean	SD	Mean	SD	Mean	SD

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HT	5.2	1.0	7.0	.9	8.7	2.0
APD	8.1	1.9	11.5	1.0	11.8	2.1
TD	15.3	5.1	19.0	1.1	20.0	2.0
SCD	12.6	1.8	16.0	1.4	15.1	1.1
TORG R	1.6	.4	1.4	.2	1.3	.2

Table 4: Comparison of C4 parameters with respect to Age distribution

C4	Group					
	<5 years		6 to 10 years		> 10 years	
	Mean	SD	Mean	SD	Mean	SD
HT	5.0	1.1	6.9	.7	8.6	2.0
APD	8.2	1.9	11.5	1.1	11.8	2.1
TD	15.4	5.0	20.0	1.2	20.6	1.9
SCD	12.1	1.9	15.8	1.5	14.7	1.1
TORG R	1.5	.3	1.4	.2	1.9	2.7

Table 5: Comparison of C5 parameters with respect to Age distribution

C5	Group					
	<5 years		6 to 10 years		> 10 years	
	Mean	SD	Mean	SD	Mean	SD
HT	5.0	1.0	6.9	.5	8.7	1.8
APD	8.5	1.9	11.6	1.0	11.8	2.0
TD	15.7	4.8	20.6	1.4	22.0	1.7
SCD	12.2	1.8	15.6	1.5	14.4	1.1
TORG R	1.5	.3	1.3	.1	1.2	.2

Table 6: Comparison of C6 parameters with respect to Age distribution

C6	Group					
	<5 years		6 to 10 years		> 10 years	
	Mean	SD	Mean	SD	Mean	SD
HT	5.4	1.1	7.4	.8	9.0	2.1
APD	8.7	1.9	11.8	1.0	12.1	2.0
TD	16.4	5.1	22.3	1.0	24.0	2.3
SCD	12.0	1.8	15.4	1.5	14.3	1.1
TORG R	1.4	.3	1.3	.1	1.2	.2

Table 7: Comparison of C7 parameters with respect to Age distribution

C7	Group					
	<5 years		6 to 10 years		> 10 years	
	Mean	SD	Mean	SD	Mean	SD
HT	6.2	1.4	7.8	.9	10.0	2.2
APD	8.9	2.0	12.1	1.1	12.5	1.7
TD	17.6	5.2	23.7	5.3	26.8	2.3
SCD	11.9	1.8	14.6	3.3	13.9	1.0
TORG R	1.4	.3	1.2	.1	1.1	.2

DISCUSSION

Morphology of cervical spine have been studied in both adults and pediatrics, but only few studies have been performed in pediatric population. In analyzing the review of literature studies were based on the pedicles and few were in respect to body and spinal canal. In this study different parameters were studied from C1-C7, giving a normal range that would describe the growth pattern and relative changes which would take place from birth until they attain adulthood.

Our study population was segregated into three groups. Group 1 children aged 0 – 5 years which constituted for 36.7%. Group 2 children aged 6 – 10 years constituting 31.7% and Group 3 with children aged 11 – 15 years constituting 31.7%. Majority of the subjects were males (65%). *A researcher* who have analyzed the sub axial spine had included children less than 10 years, as the pediatric cervical spine matures by 8-9 years of age,[6,7] however to observe any changes in the dimension and the growth thereafter we included children less than 15 years of age.

C1 (ATLAS)

Cervical spine C1 Atlas has been subjected to various measurements such as the posterior arch height (PAH), spinal canal diameter (SCD) and lateral mass dimensions (which includes the anterior posterior diameter, width and the height) and analyzed.

The mean PAH in group 1was 5.2mm, group 2 was 7.6mm and in group 3 was 7.8 mm, these parameters showed gradual increase in height up to 10 years of age and thereafter had a slow growth. The mean height in all age groups was more in females (mean 7.1mm) than in males (mean 6.7). *Researcher* in his study measured the posterior arch height, width and length for screw placement where the mean PAH was 6.35mm in children less than 13

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years of age.[8] In other study by *chamoun et* ***al***.[9] while analyzing lateral mass screw placement in children they had found the mean PAH in children as 6.3mm. *Lee et* al,[7] in his other study had a mean PAH of 7.1mm in children less than 7 years.

The mean spinal canal diameter at C1 in group1 (17.0mm), group 2 (20.5mm) and group 3 (20.9mm) showed a gradual increase in the diameter with age upto 10 years and later the growth was slow and there was no significant difference between males and females. Lee at el in his other study of morphometry of pediatric cervical spine at cranio-vertrebral junction showed the the mean SCD in children less than 7 years was 16.2mm.1 in a study by using lateral radiographs showed that the spinal canal diameter at C1 was between 15mm and 20mm. 10 However spierings et al showed that spinal canal diameter less than 13mm measured from posterior aspect of dens to anterior surface of the posterior arch of atlas is associated with neurological problems.

There was also no significant difference between the right and left lateral mass, however the APD and height increased with age up to 10 years of age but the width was found to gradually increase in all age groups. These changes indicate that maximum growth occurred before the age of 10, except for the width which showed a linear growth in all age groups. Lee et al in his study while analyzing screw placement at cranio-vertberal region in children showed that the mean lateral mass width of C1 was 9.6mm compared to our study which was 9.5mm. In the literature measurements of the lateral mass (anterior posterior diameter and height) were taken to find the trajectories of screw placement and none for the growth.[1]

C2 (AXIS)

In our study of the axis vertebrae the mean height of the vertebral body excluding the dens, the anterior posterior diameter and the dens height were measured. These parameters showed a gradual increase with age up to 10 years thereafter the growth process was slow.

In our study we had a mean odontoid height of 9.9mm, 16.4mm and 19.4mm in group 1, 2 and 3 respectively. Lee et al in his study had a mean dens height of 10.7, 13.5 and 16.2mm in children of less than 2years, 3-5 years and 5-7 years respectively. However, the mean dens height in our study was 15.3mm in females as compared to males which was 14.9mm, showing that the rate of growth of dens was higher in female subjects.[1]

The mean height of C2 vertebral body in our study was 6.8mm, 9.1mm and 9.6mm in group 1, 2 and 3 respectively. In the study by lee et al the mean vertebral body height of C2 was 7mm, 8mm and 8.7mm in children between age groups of 0-2 years, 3-5years and 5-7 years respectively. The rate of growth in our subjects was similar as compared to there study.[1]

The mean anterior posterior diameter (APD) of C2 vertebral body in our study groups was 7.7mm, 10.2mm and 11.7mm. Lee et al7 in his study had a mean of 9.9mm, 11.1mm and 12mm in children of age groups between 0-2years, 3-5years and 5-7 years respectively. The APD in our study was less than the study by lee et al due to ethnicity and physical factors.

SUB AXIAL SPINE (C3 - C7)

In our study of the sub axial spine the vertebral body height at each level was gradually increasing in size with age, but however the C3 height was more than C4 and C5 but less than C6 and C7. The vertebral body height was compared with other studies as shown in the table 18.

The changes in the height in our study was similar to the study by Lee et al, except the growth in C4 and C5 was less than C3 which may be due to ethnicity and physical factors.[3]

The Anterior posterior diameter and the transverse diameter gradually increased with age and as we go down the lower cervical region. But after the age of 10 the growth was slower. Compared with the study of Lee et al,[5] which was similar to their study is shown in the table 19.

The AP dimensions increased approximately by 3.5mm (3.3- 3.7mm) throughout the age groups in all subaxial spine compared to Lee et al which was 3.4mm. The growth of AP diameter was larger than the growth of the height and was larger in boys than girls.[3]

In the literature many reports have been described about the spinal canal diameter (SCD) from cadaveric study, lateral radiographs, CT and magnetic resonance imaging, which were mostly on adult population and few on pediatric patients.

The pattern of change in SCD on lateral radiographs can be divided into four categories: the straight type, in which SCAP decreased gradually from C1 to C7, the V type, in which the SCAP was minimized at the middle cervical level, the W type, in which the SCAP was minimized at two cervical levels, and all other types. In our study the spinal canal diameter was found to decrease as we go down the cervical canal describing a straight type of pattern change.[11]

The ratio of the sagittal diameter of the cervical canal to that of vertebral body was first proposed by Pavlov et al [Pavlov ratio or Torg ratio (TR)] as an indicator of the degree of developmental canal narrowing. However Lim and Wong insisted that TR is not a consistent and reliable method to confirm cervical canal stenosis, a TR less than 0.80 has generally been known to be a strong predictor for the induction of symptomatic change in the adult population. In our study the TR was found to decrease as we go down the cervical canal and with age. Showing that there is increase in AP diameter and decrease in SCD as we go down the cervical canal which is evident from our study. In another study from teenagers to adults showed that the canal body ratio decreases with age.[12]

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CONCLUSION

The morphometric dimensions in this study would provide a reference range for C1 lateral mass, Odontoid process, C1 posterior arch, vertebral body (C2-C7) and Spinal canal diameter (C1-C7) in pediatric age group (0 to 15 years).

These reference values would help in understanding the growth pattern and for planning surgery and selecting appropriate implants. The dimensions of the cervical body including both typical and atypical vertebrae was found to increase up to 10 years of age thereafter it had a slow growth. In the sub-axial spine the height of the C3 vertebral body was greater than C4 and C5 but less compared to C6 and C7 in all age groups. The spinal canal diameter and the Torg ratio was found to decrease with age and as we go down the cervical region.

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