

Fetal Anatomy: Morphometry of Vertebral Canal and Spinal Cord of Cervical Region in Human Fetuses.

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ABSTRACT

Background: Fetal anatomy is now becoming popular with advancement in fetal surgery in-utero. The knowledge regarding the embryonic development of vertebral canal plays an important role in diagnosis of congenital anomalies as well as fetal surgeries of the vertebral canal. **Methods:** Sixty fetuses which were preserved in 10% formalin were divided into five groups according to the gestational age. Spinal cord was exposed by opening vertebral canal from behind by laminectomy. The parameters like length of cervical part of vertebral canal, transverse diameter of canal at different vertebral levels, transverse and antero-posterior diameter of spinal cord were measured. **Results:** All parameters of cervical vertebral canal i.e. length of vertebral canal, transverse diameters at different vertebral levels exhibited a stable but variable rate of growth with advancing gestational age. Similarly, the parameters of spinal cord, antero-posterior and transverse diameters of spinal cord at upper, middle and lower vertebral levels revealed similar growth pattern with increasing gestational age. **Conclusion:** These measurements prove to be helpful in deciding the age of the fetus, early diagnosis of congenital disease and in utero fetal surgeries.

Keywords: Cervical, Fetal, Morphometry, Spinal cord, Vertebral canal.

INTRODUCTION

With the advancement of new imaging techniques, sophisticated instruments and surgical procedures, it has now become possible to do in utero fetal surgeries. It is an emerging branch which requires lot of research work. In utero fetal surgery requires expertise in different branches like anatomy, pathology, radiology and surgery. In human fetuses, the most appropriate time for the fetal surgeries is in between 18th to 30th week of gestation.^[1] The early diagnosis of the fetal disorder play a key role in this emerging technique. Many congenital anomalies like cleft lip and palate, myelomeningocele, pleural effusion, congenital high airway obstruction syndrome and heart defects can be corrected in-utero.^[2] The area of foetal surgery remains an essential area of study, because there are several other disorders with a poor prognosis in neonatal life in which the theory of a fetal cure is attractive.

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The knowledge regarding the embryonic development of vertebral canal plays an important role in diagnosis of congenital anomalies as well as fetal surgeries of the vertebral canal.^[3] Initially cells of the mesodermal germ layer form a thin sheet of loosely woven tissue on each side of midline. By approximately the 17th day, cells close to midline proliferate and form a thickened plate of tissues known as paraxial mesoderm. More laterally, the mesoderm layer remains thin and is known as the lateral plate. Intermediate mesoderm

connects paraxial and lateral plate mesoderm. Paraxial mesoderm organizes into somites in occipital and caudal segments. Somites give rise to the myotome, sclerotome and dermatome which are all supporting tissues of the body. Vertebrae form from the sclerotome portion of the somite. During the fourth week, sclerotome cells migrate around the spinal cord and notochord to merge with the cells from opposing somites on the other side of the neural tube.^[4] Patterning of the shapes of vertebrae is regulated by HOX gene.^[5]

The vertebra of the immature skeleton consists of separate elements which unite to form single bone.^[6] Although fetal and newborn vertebral column bones are small, they are more massive than other parts of skeleton and therefore are highly resistant to decay. The bones of cervical vertebral column undergo considerable change in size but not in shape during the intra-uterine life.^[7,8]

In congenital anomalies of the cervical spine, neurological compromise from instability or stenosis may be prevented with early recognition and careful management of persons who are at risk. Congenital anomalies range in severity from those that are benign and asymptomatic to anomalies that can potentially cause fatal instabilities like Basilar impression, Occipitocervical synostosis, Odontoid anomalies and Klippel Feil syndrome.^[9,10]

The fetal axial skeleton is the center of interest by many scientists. Noback^[11] studied the complete developmental anatomy of fetal skeleton. Noback and Robertson^[12] detected the sequences of presence of ossification centers of the human skeleton during the first five gestational months. O'Rahilly et al^[13] studied the entire vertebral column at the end of the embryonic period.

Morphometric information specifically in relation to cervical spine and spinal cord were scanty

although clinically of great importance. So, the aim of the study is to know the morphometry of cervical part of spinal cord and vertebral canal at different gestational ages.

MATERIALS AND METHODS

Sixty human fetuses were studied which were already fixed in 10% formalin. Approval was taken from the ethical committee for doing the morphometric study of the fetuses preserved in the museum. The age of the fetus was decided with the help of correlation of fetal foot length and gestational age as documented by Streeter, 1920. The fetuses under consideration were divided into five groups on the basis of their determined gestational age as follows.

Table 1: Sub-grouping of the fetuses.

Groups	Age (weeks)	No. of males	No. of females	Total
I	<17	6	6	12
II	17-20	6	6	12
III	21-25	6	6	12
IV	26-30	6	6	12
V	>30	6	6	12

Spinal cord was exposed by opening vertebral canal from behind by laminectomy, a method popularly used by surgeons.^[14] One midline vertical incision and three horizontal incisions were made as shown in Figure 1.



Figure 1: One midline vertical and three horizontal incisions.

Following parameters were measured after exposing the spinal cord and vertebral canal.

- 1) Length of cervical part of vertebral canal (from upper border of anterior arch of C-1 to lower border of posterior surface of body of C-7).
- 2) Transverse diameter of cervical part of vertebral canal at different vertebral levels.
- 3) Antero-posterior diameters at the upper end, middle and lower end of cervical part of spinal

cord, i.e., at C-1, C-4 and C-7 vertebral levels respectively.

4) Transverse diameters at the upper end, middle and lower end of cervical part of spinal cord, i.e., at C-1, C-4 and C-7 vertebral levels respectively.

RESULTS

Length of cervical vertebral canal increased from 18.2mm in group I fetuses to 34.12mm in group V. Statistically significant increase ($p < 0.05$) was observed in groups III, IV and V fetuses [Figure 2].

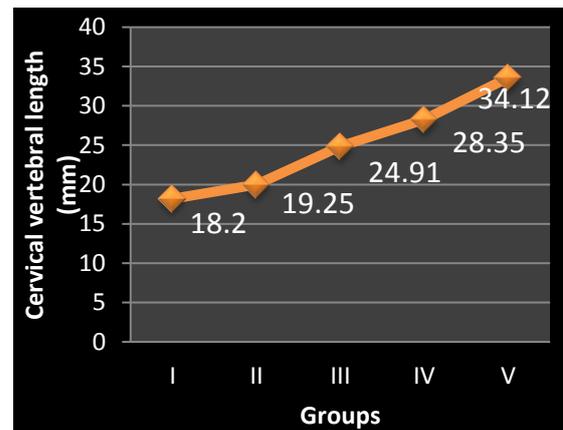


Figure 2: Length (mm) of cervical part of vertebral canal at different gestational ages.

In Table 2, the transverse diameter of vertebral canal at different vertebral levels shows a significant increase in parameter in group III, IV and V ($p < 0.05$). No significant increase in diameter is seen in group I and II.

In Table 3, the antero-posterior diameter of spinal cord at different vertebral levels shows a significant increase in parameter in group III, IV and V ($p < 0.05$). No significant increase in diameter is seen in group I and II.

In Table 4, the transverse diameter of spinal cord at different vertebral levels shows a significant increase in parameter in group III, IV and V ($p < 0.05$). No significant increase in diameter is seen in group I and II.

DISCUSSION

Various morphological studies are done on vertebral canal and spinal cord from time to time both during embryonic and post-embryonic periods. Ghazi and Gholami³ stated that allometric growth of the spinal cord is seen in relation to the vertebral column during embryonic and post-embryonic life in the sheep. Direct measurements were made by using callipers.

Table 2: Transverse diameter of vertebral canal at different vertebral levels.

Vertebral level	Group I	Group II	Group III	Group IV	Group V
C1	3.21 ± 0.03	4.1 ± 0.05	5.79 ± 0.04*	6.79 ± 0.05*	7.8 ± 0.04*
C2	4.48 ± 0.06	4.5 ± 0.05	5.62 ± 0.01*	6.49 ± 0.03*	7.56 ± 0.02*
C3	4.31 ± 0.42	4.61 ± 0.04	5.78 ± 0.06*	6.62 ± 0.07*	7.8 ± 0.04*
C4	4.32 ± 0.23	4.66 ± 0.04	5.62 ± 0.03*	6.79 ± 0.02*	7.51 ± 0.03*
C5	3.24 ± 0.22	4.41 ± 0.17	6.31 ± 0.05*	7.21 ± 0.09*	7.96 ± 0.04*
C6	4.06 ± 0.16	4.51 ± 0.03	5.42 ± 0.16*	6.77 ± 0.13*	7.99 ± 0.15*
C7	4.14 ± 0.29	4.62 ± 0.16	5.89 ± 0.13*	6.82 ± 0.06*	7.93 ± 0.07*

*p<0.05

Table 3: Antero-posterior diameter of spinal cord at different vertebral levels.

Vertebral level	Group I	Group II	Group III	Group IV	Group V
C1	1.9 ± 0.2	1.99 ± 0.19	2.41 ± 0.04*	3.48 ± 0.31*	4.41 ± 0.12*
C4	1.82 ± 0.37	2.35 ± 0.05	3.16 ± 0.29*	3.99 ± 0.04*	4.83 ± 0.09*
C7	1.58 ± 0.05	1.69 ± 0.07	2.32 ± 0.18*	3.1 ± 0.21*	4.29 ± 0.06*

*p<0.05

Table 4: Transverse diameter of spinal cord at different vertebral levels.

Vertebral level	Group I	Group II	Group III	Group IV	Group V
C1	2.66 ± 0.11	2.86 ± 0.19	3.81 ± 0.14*	4.54 ± 0.17*	5.6 ± 0.05*
C4	2.39 ± 0.26	2.89 ± 0.11	3.89 ± 0.12*	4.92 ± 0.03*	5.91 ± 0.12*
C7	1.62 ± 0.14	2.11 ± 0.09	3.11 ± 0.16*	3.9 ± 0.14*	4.85 ± 0.15*

*p<0.05

O'Higgins et al^[4] used computer and optical instruments for studying the comparative anatomy of vertebral canal in mice and men. Joris et al^[5] executed comparison between the anatomy of spinal cord of human and porcine by Computed Tomography. Hifney et al^[6] exhibited association between the vertebral column and spinal cord in Equus asinus. Sakla^[7] did measureable study on post-embryonic growth of the spinal cord and the vertebral column of the albino mouse. Bradley^[8] enumerate the variances between normal and abnormal cervical canal by myelography.

Holsheimer et al^[9] defined MRI valuation of normal location of spinal cord in spinal canal at C4, C6, T5, T6, T11, and T12 in adult human. Stroman¹⁰ assessed neuronal functions by performing MRI on spinal cord of adult humans. The sagittal diameter of dural sac was measured by Nakstad^[15] from C2-6 in adult humans. Bradley^[8] enumerated the differences between typical and atypical cervical canal by using myelography. Murone^[16] and Oon^[17] highlighted the significance of sagittal diameters of the cervical spinal canal in adult humans.

Various researchers studied the morphology of vertebral canal and spinal cord by using radiological techniques. Sherman et al^[18] and Fang et al^[19] used Magnetic resonance imaging to study the normal cervical spinal cord in adult human. Different parameters of spinal cord in cadavers were analyzed by Kameyama et al.^[20] Suzuki and Shimamura^[21] also used the same technique to do morphological analysis of cervical part of spinal cord.

One interesting fact about the transverse diameters of vertebral canal at all seven cervical vertebral levels showed continuous growth in all the groups,

but statistical significant growth was seen in last three groups. Similar pattern of growth was seen in Sharma et al.^[22]

All the parameters considered in the present study showed steady increase with increase in gestational age and therefore could be used for determination of the same. Vertebral parameter, eg. length of cervical vertebral canal, transverse diameters of cervical spinal canal were of special interest due to medico legal importance. This was because of fact that although fetal vertebral column bones were small, they were more massive than other parts of skeleton and therefore was highly resistant to decay.^[23]

CONCLUSION

All parameters of cervical vertebral canal i.e. length of vertebral canal, transverse diameters at different vertebral levels exhibited a stable but variable rate of growth with advancing gestational age. Similarly, the parameters of spinal cord, antero-posterior and transverse diameters of spinal cord at upper, middle and lower vertebral levels revealed similar growth pattern with increasing gestational age.

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How to cite this article: Arora M. Fetal Anatomy: Morphometry of Vertebral Canal and Spinal Cord of Cervical Region in Human Fetuses. *Ann. Int. Med. Den. Res.* 2016;2(3):128-31.

Source of Support: Nil, **Conflict of Interest:** None declared