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Original Article

A morphometric study of predictors for sexual dimorphism of cervical part of vertebral column in human foetuses

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ABSTRACT

Introduction: Foetal anatomy is the evolving specialty in the modern era. The first reason behind this is the advancement of a new field of in-utero foetal surgery and second reason is that it is related to medico-legal importance.

Methods: According to the gestational age 30 foetuses were divided into two groups. Each group comprised of 10 male and 5 female foetuses with gestational age <25 and >25 weeks respectively, corresponding with 2nd and 3rd trimesters of pregnancy. Spinal cord was exposed by opening vertebral canal from behind by laminectomy. Transverse diameter of cervical vertebral canal and height of cervical vertebral body were measured at C3 to C7 vertebral levels. The aim of the study was to find the reference values of transverse diameter of vertebral canal and height of bodies of vertebrae at different cervical vertebral level and to appreciate whether it spectacles sexual dimorphism or not. Another aim was to decide which parameter (Transverse diameter of vertebral canal or height of the body of cervical vertebrae) of the vertebrae is the better indicator of sexual dimorphism.

Results: Sexual difference at different vertebral levels was observed in only third trimester. The values of transverse diameter were more in females and height of the vertebral bodies in males at all levels of cervical vertebrae. The Cohen's Kappa coefficient for transverse diameter of cervical vertebral canal is 0.6 whereas of height of the body of cervical vertebrae is 0.2.

Discussion: Both transverse diameter and height of cervical vertebrae (C3–C7) shows sexual dimorphism in third trimester. Between these two parameters, transverse diameter the vertebral canal of the cervical region proves to be a better indicator of gender.

1. Introduction

Embryology has fascinated many researchers and is still considered as thirty eight weeks miracle in the womb of a woman. Foetal anatomy is the evolving specialty in itself. There are two reasons behind this evolution.

First reason is the advancement of a new field of in-utero foetal surgery which involves the repair of congenital anomalies before birth, thus providing a better quality of life to a newborn. In-utero surgery necessitates a multidisciplinary team with proficiency in anatomy, physiology, pathology, radiology as well as other medical areas.[1] This is due to improvement in highly erudite surgical instruments and imaging techniques making corrective surgeries possible before birth. The timely diagnosis of foetal ailments like myelo-meningocele, Occipito-cervical synostosis, Klippel Feil syndrome, Hemi vertebrae, Transitional vertebrae etc that may be irreparable in the neonate can be prevented by in-utero surgery.[2] 18–30 weeks is considered as the most suitable time for performing foetal surgeries.[1] In inherited abnormalities of the cervical spine, neurological aberrations can be prevented with early appreciation and vigilant management of persons who are at jeopardy. These abnormalities may range from benign and asymptomatic to anomalies that can potentially cause fatal uncertainties.[3] The foetal surgery remains an imperative area of study, because there are several other illnesses with a poor prognosis in neonatal life in which the idea of a foetal remedy is attractive.

Second reason for studying foetal anatomy is related to medico-legal importance. The study of the morphology of central nervous system is of great clinical importance due to its involvement in grievances and anomalies.[4] Besides this, sexual dimorphism of the vertebral canal will prove to be helpful in dealing with cases of female foeticide. Morphometric readings of skeleton often helped in determining the age and sex of foetuses and therefore of great medico-legal importance.[5]

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Thorough information signifying configuration of growth of spinal canal and cord in cervical region of human foetuses was deficient in literature. Additionally scanty references accessible were centered on imaging techniques posing options of errors.[6–9] Direct measurements in foetal specimens will offer precise readings and therefore better insight to our knowledge.

The aim of the study was to find the reference values of the dimensions of canal at different cervical vertebral level and to appreciate whether it spectacles sexual dimorphism or not. Another aim of the study was to decide which parameter (Transverse diameter of the cervical vertebral canal or height of the body of the cervical vertebrae) is the better indicator of sexual dimorphism.

2. Material and method

Thirty dead foetal bodies encompassing equal males and females were preserved in formalin in Department of Anatomy. Human foetuses were obtained from department of Obstetrics and Gynaecology Teerthankar Mhaveer Medical College & Research Centre, Moradabad, after signing Material Transfer Agreement (MTA). Ethical clearance was obtained from Institutional Ethics Committee. The criterion given by Streeter in 1920[10] was used for deciding the gestational age which was based on the measurement of length of foetal foot. Measurement from the tip of the second toe to the midpoint of heel was considered as foot length. External genitalia were taken into attention to decide the sex of foetuses. In this study, according to the gestational age 30 foetuses were divided into two groups. Each group comprises of 10male and 5 female foetuses with gestational age <25 and >25 weeks respectively, corresponding with 2nd and 3rd trimesters of pregnancy. Spinal cord was exposed by opening vertebral canal from behind by laminectomy, a method popularly used by surgeons given by Raoof[11] in 2001. On the back of foetus a vertical cutaneous incision was given extending from external occipital protuberance (EOP) superiorly to natal cleft (NC) inferiorly (Fig. 1). Three transverse incisions were made: One at the superior end, second at the middle and third at the inferior end of vertical incision. Skin flaps were redirected on either sides of midline to uncover the fasciae over erector spinae. Underlying fasciae and muscles were excised to bare the back of vertebral column. Scissors were applied in sacral hiatus on both sides of midline and vertebral canal was untied by laminectomy till it extended to the posterior arch of atlas (Fig. 2). A vertical nick was made in the dura mater along with arachnoid mater in the lumbar region and continued

Fig. 1. Dorsal aspect of foetus with midline vertical incision extending from external occipital protuberance to natal cleft.

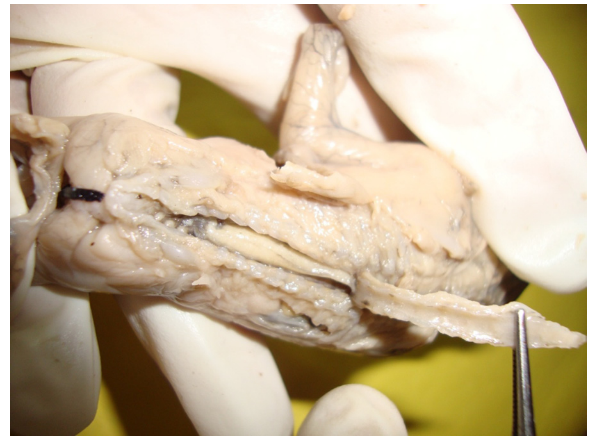

Fig. 2. Laminectomy performed in lower part and posterior wall of vertebral canal raised to expose lower spinal cord.

upward upto level of atlas.Spinal cord was exposed by cutting and removing the dura-arachnoid together throughout its length. All the nerve roots were severed to free the spinal cord from vertebral canal. Spinal cord was detached after making an incision at its superior end at the level of atlas. Transverse diameter of cervical vertebral canal and height of cervical vertebral body were measured at C3 to C7 vertebral levels using Vernier Calipers (mm) (Fig. 3).

Sexual dimorphism was studied by analysing the readings in both the genders by using Student's '*t*' test and the p value <0.001 was considered as significant. The Cohen's Kappa (κ) coefficient was calculated to measure the level of agreement and thus identify which is the better parameter (transverse diameter/height) for sexual dimorphism.

$\kappa = \Pr(a) - \Pr(e)/1 - \Pr(e)$

Where,

κ = Kappa coefficient

Pr (a) = Relative observed agreement among raters

Pr (e) = Hypothetical probability of chance agreement

$\Pr(e) = 1/N^2 \sum nk_1 nk_2$ where N = Number of items, Cohen's kappa measures the agreement between two raters nk_1 and nk_2.

Interpretation of value of κ,

<0.2 = Poor agreement

0.2–0.5 = Moderate agreement

0.6–1 = Good agreement.

3. Result

The transverse diameter of cervical vertebrae at different vertebral levels (C3–C7) are more in third trimester as compared to second trimester exhibiting a steady but variable rate of growth with advancing gestational age. Besides this, the statistically

Fig. 3. Exposed vertebral canal showing cervical vertebrae from C1 to C7 level.

Table 1
Comparison of the transverse diameters of cervical vertebrae in both genders in 2nd and 3rd trimesters.

Vertebral level	Gestational period	No. of males	Mean ± S.D.	No. of females	Mean ± S.D.	T value	P value
C-3	Second trimester	10	4.8 ± 0.9	5	4.7 ± 0.8	0.9	Insignificant
	Third trimester	10	5.6 ± 0.6	5	7.2 ± 0.2	5.4	<0.001
C-4	Second trimester	10	4.8 ± 1.1	5	5.1 ± 0.8	0.6	Insignificant
	Third trimester	10	6 ± 0.4	5	7.2 ± 0.2	5.5	<0.001
C-5	Second trimester	10	4.6 ± 1.2	5	4.7 ± 0.9	0.9	Insignificant
	Third trimester	10	6.2 ± 0.4	5	7.5 ± 0.1	2.6	<0.001
C-6	Second trimester	10	4.8 ± 1.2	5	4.8 ± 0.8	0.9	Insignificant
	Third trimester	10	6.3 ± 0.3	5	7.5 ± 0.1	2.7	<0.001
C-7	Second trimester	10	4.8 ± 1.4	5	4.8 ± 0.9	0.9	Insignificant
	Third trimester	10	6.3 ± 0.3	5	7.6 ± 0.2	6.6	<0.001

significant (<0.001) sexual difference at different levels was observed in only third trimester [Table 1]. In contrast to other parameters of the body, the values of transverse diameter of vertebrae at all levels in third trimester are more females as equated with males [Fig. 4].

The heights of cervical vertebrae at different vertebral levels (C3–C7) are more in third trimester as compared to second trimester showing steady and variable rate of growth similar to transverse diameter. Besides this, the statistically significant (<0.001) sexual difference at different levels was observed in only third trimester [Table 2]. The values of height of vertebrae at all levels in third trimester are more in males as related with females [Fig. 5].

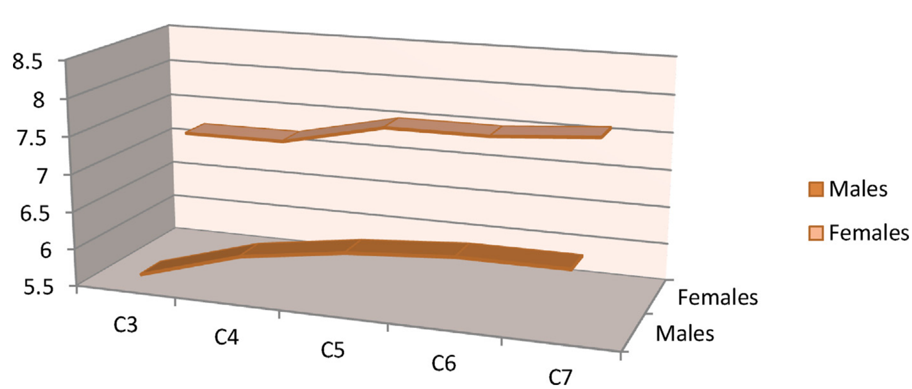

Fig. 4. Comparison of transverse diameter at different cervical vertebrae level in both groups in third trimester.

Table 2
Comparison of the heights of cervical vertebral bodies in both genders in 2nd and 3rd trimesters.

Vertebral level	Gestational period	No. of males	Mean ± S.D.	No. of females	Mean ± S.D.	T value	P value
C-3	Second trimester	10	3 ± 0.6	5	3.3 ± 0.5	0.3	Insignificant
	Third trimester	10	4.6 ± 0.4	5	3.3 ± 0.2	5.83	<0.001
C-4	Second trimester	10	3.1 ± 0.6	5	3.2 ± 0.4	0.7	Insignificant
	Third trimester	10	5.3 ± 0.4	5	3.7 ± 0.5	6.4	<0.001
C-5	Second trimester	10	3.1 ± 0.9	5	3.3 ± 0.7	0.6	Insignificant
	Third trimester	10	5.1 ± 0.6	5	3.3 ± 0.3	9.1	<0.001
C-6	Second trimester	10	3.1 ± 0.7	5	3.2 ± 0.6	0.9	Insignificant
	Third trimester	10	5.6 ± 0.3	5	4 ± 0.4	3.14	<0.001
C-7	Second trimester	10	3.3 ± 0.9	5	3.5 ± 0.6	0.7	Insignificant
	Third trimester	10	5.7 ± 0.4	5	3.9 ± 0.5	4.7	<0.001

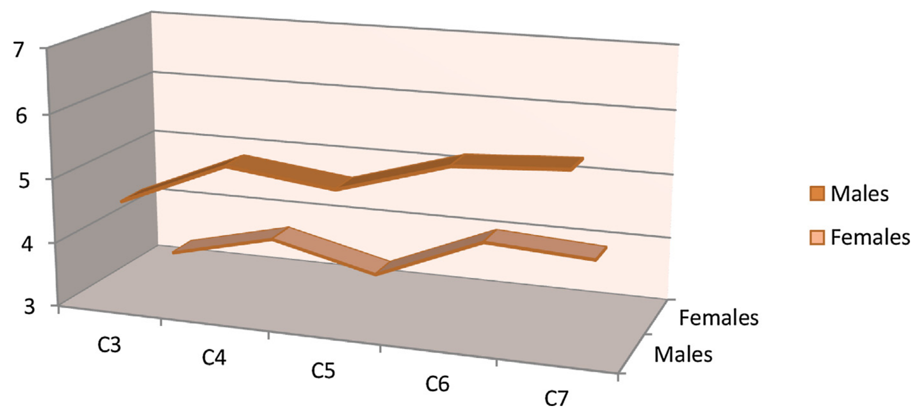

Fig. 5. Comparison of height at different cervical vertebrae level in both groups in third trimester.

3.1. Calculation of Kappa coefficient of transverse diameter for sexual dimorphism:

The gender of the foetus was decided on the basis of external genitalia. With the help of above mentioned values of transverse diameter in both the genders the sex of the patient was decided. 17 males and 10 females were correctly diagnosed whereas interpretation of 3 foetuses of both the genders was inappropriate.

$\kappa = \Pr(a) - \Pr(e)/1 - \Pr(e)$

$\Pr(a) = 17 + 10/33 = 0.81$

$\Pr(e) = (60.6 \times 60.6) + (39.4 \times 39.4)/10000 = 0.52$

$\kappa = 0.81 - 0.52/1 - 0.52 = 0.6$ (Good agreement)

3.2. Calculation of Kappa coefficient of height for sexual dimorphism:

With the help of above mentioned values of heights in both the genders the sex of the patient was decided. 14 males and 10 females were correctly diagnosed whereas interpretation of 6 foetuses of both the genders was inappropriate.

$\kappa = \Pr(a) - \Pr(e)/1 - \Pr(e)$

$\Pr(a) = 14 + 10/36 = 0.6$

$\Pr(e) = (55.5 \times 55.5) + (44.4 \times 44.4)/10000 = 0.5$

$\kappa = 0.6–0.5/1–0.5 = 0.2$ (Moderate agreement).

Transverse diameter of cervical vertebral bodies with Cohen's Kappa coefficient of 0.6 as compared to height with Cohen's Kappa coefficient of 0.2 proves to be a better indicator of sexual dimorphism in foetuses in third trimester of pregnancy.

4. Discussion

Literature on foetal anatomy and morphology of cervical spine and spinal cord was scanty which required exploration to unwrap various facts and correct massive existing fallacies.

Transverse diameters of spinal canal at all five cervical vertebral levels showed one interesting common feature and that was a steady but variable rate of growth with advancing gestational age. Similar study was done by Castellana and Kosa [12] who did comprehensive morphological study on cervical vertebrae in the foetal- neonatal human skeleton. But their emphasis was ossification centres for use in forensic and anthropological osteology. They did not provide any information about the diameters of vertebral foramina. Sharma et al. [13] in 2013 studied the dimension of cervical vertebral canal in five different groups I–V with gestational ages of less than[17–26] and more than 30 weeks respectively to determine the reference values for the cervical part of vertebral canal. Length of cervical part of vertebral canal and transverse diameters at different vertebral levels were documented by the help of vernier caliper. The widest part of cervical vertebral canal was observed in the upper segment in first three groups, middle in group IV and in the lower part in foetuses of group V.

Ordinarily the cervical spinal canal spans were clinically important to establish diagnosis of developmental canal stenosis. Such conditions used to become symptomatic in adults when a myelopathy might result from compression of the cervical cord by small osteophytes or by hyperextension injury without fracture or dislocation.[14] Numerous studies[15–17] have been done to postulate the reference values of dimensions of these vertebrae in adults to make the diagnosis. But the literature regarding the dimensions of vertebral bodies in foetuses is lacking.

In present study average prenatal standards were established for the early development of cervical part of vertebral column which can be used in future for evaluation of pathologic deviations in human vertebral column in as early as 2nd trimester. Dorrit et al. [18] studied vertebrae from 13 normal human foetuses (10-24 weeks of gestation) by using radiography in lateral, frontal and axial views with the same above intension. They provided only qualitative informations of observation. Several scientists made an attempt to explore foetal skeletal anatomy but in animals. Sittertet al. [19] defined and described the lengths, widths and heights of the vertebrae of giraffe from foetal through neonatal life to maturity. Scientists[19,20] have also standardized the morphometry of cervical vertebral bodies in humans during postnatal period and found it to be reliable information to study the growth.

Sexual dimorphism was seen in both the parameters only in third trimester and was entirely lacking in second trimester. Specific reference related to sexual dimorphism for cervical spine of human foetuses did not exist in literature. But the same for adult humans did exist in scientific records. On[21] noted cervical spinal canal in females narrower than those in males. O'Higgins et al. [22] observed both cervical canal width and cervical vertebral body size more in male subjects. In contrast to adults, the vertebral canal is wider in females as compared to male foetuses. Our findings are supported by Sharma et al. [23] in 2013who institute that male Indian foetuses have narrower and longer spinal canal as compared to females. In an another study[24] done in 2013 on Indian foetuses it was found that Antero-posterior diameter of cervical part of spinal cord was significantly more in males and transverse diameter was more in females in third trimester. This also proves that a wider vertebral canal will be needed to accommodate a broad cervical part of spinal cord in females as compared to male foetuses.

Another important medico-legal reason for studying cervical spinal canal was because of the fact that although foetal vertebral column bones were small, they were more massive than other parts of skeleton and therefore was highly resistant to decay.[12] Enormous literature supported our finding regarding correlation between foetal cervical vertebral morphology and gestational age. Marginean et al. [25] found direct correlation between cervical vertebral morphology of foetuses and newborns and gestational age. Filly et al. [26] evaluated foetal spine sonographically to determine gestational age during the second trimester.

5. Conclusion

1) The transverse diameter and height of cervical vertebrae at different vertebral levels (C3–C7) are more in third trimester as compared to second trimester exhibiting a steady but variable rate of growth with advancing gestational age.
2) Sexual difference at different vertebral levels was observed in only third trimester.
3) The values of transverse diameter were more in females and height in males at all levels of cervical vertebrae.
4) Transverse diameter of cervical vertebral canal with Cohen's Kappa coefficient of 0.6 as compared to height with Cohen's Kappa coefficient of 0.2 proves to be a better indicator of sexual dimorphism in foetuses in third trimester of pregnancy.

Conflict of interest

None.

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