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Morphometric Analysis of Lumbosacral Canal in Human Foetuses

Análisis Morfométrico del Canal Lumbosacro en Fetos Humanos

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SUMMARY: Lumbosacral part of the spinal canal requires special attention because this is the site commonly involved in spina bifida, tethered cord syndrome and some other pathologies like fatty tumours in the spine, cysts and syrinxes. The diagnosis as well as the treatment of neural tube defects mandates an accurate knowledge of morphometry of lumbosacral vertebral canal. There are various reports on radiological morphometric measurements in human foetuses by various authors but these possess inherent variability due to imaging techniques, patient positioning, observer's measuring techniques and normal and pathological variations. To overcome all these limitations, direct measurements by vernier calliper were preferred. 30 Formalin preserved human foetuses, of all age groups and both sexes, free of congenital craniovertebral anomalies, were obtained from the museum of Dept. of Anatomy, J.N. Medical College AMU Aligarh for the present study. Foetuses were divided into five groups (I-V) based on their gestational ages. Group I foetuses were of less than 17 weeks, II of 17-20 weeks, III of 21-25 weeks, IV of 26-30 weeks and V of more than 30 weeks. Each group contained 6 foetuses having both male and female, 3 each. Morphometric parameters taken into account were length of lumbar canal, maximum transverse diameters of lumbar vertebral canal at different vertebral levels, heights of the posterior surfaces of bodies of all lumbar vertebrae and length of sacral canal. Readings of adjacent groups were compared and results were analyzed by using Student's 't' test. Lumbar canal starts growing in length significantly in group III foetuses onward. There was consistency in the growth of lumbar canal diameters with gestational age at all levels. Heights of vertebral bodies of Ist two lumbar vertebrae showed variability in some adjacent groups. The same in the next three grew constantly with the growth of foetuses. Sacral canal showed variable growth in lengths in different groups. Steady growth in the length and diameter of the lumbar canal may be used for approximate age of foetuses for medicolegal reasons.

KEY WORDS: Lumbar canal; Sacral canal; Human foetuses; Foetal growth; Lumbar vertebrae; Foetal morphometry.

INTRODUCTION

With increasing interest in intrauterine foetal surgeries for corrective developmental defects, mandates thorough and precise knowledge of not only the events that are occurring but also the pace at which they are occurring. Lumbosacral canal contains the lower part of spinal cord, the conus medullaris and nerve roots, forming cauda equina. Any morphometric change in it may have impact on its content and consequent clinical presentation. That is why the morphometry of the spinal canal and its contents in general or lumbosacral canal specially had been the points of focus for many authors in the past. Birnholz (1983) obtained ultrasound images of lumbar spine in 128 clinically normal foetuses of gestational age between 11-41 weeks. He calculated average lumbar spacing from distance between centra of at least four lumbar bodies. van Sehaik *et al*. (1985) studied cross sectional morphology of the bodies and pedicles of L3, L4 and L5 in transaxial computed tomographic sections (CT) in a series of 213 vertebrae. Hawass *et al*. (1987) assessed the length of the spinal cord relative to the vertebral column during foetal development using translumbar myelograms. Wilson & Prince (1989) determined the location of conus medullaris in normal children by reviewing a series of magnetic resonance (MR) images of the lumbar spine. Wallny *et al*. (1999) performed foetal lumbar spine volumetry by three dimensional ultrasound to evaluate three dimensional sonographic volume measurements of the thracolumbar spine from 16-25 weeks of gestation in the normally developing foetuses. Wallny *et al*. (2002) performed another cross-sectional ultrasound study in which the size of the foetal lumbar spinal canal was

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evaluated between 16 and 41weeks of gestation. Zalel *et al*. (2006) in a study performed high resolution sonographic examinations of foetuses between 13 to 40 weeks to determine the normal anatomical relationship of the conus medullaris of the spinal cord with the vertebral column and length of lumbar spine during different stages of gestation. Widjaja *et al*. (2006) performed postmortem magnetic resonance imaging on 30 foetuses ranging from 14-41 gestational weeks to study normal lumbar spine. All the above studies were radiological i.e. without any direct measurement. These studies possess inherent variability due to imaging technique, patient positioning, observer measurement error, and normal and pathologic variations in anatomy. In the present study, the different morphometric indices were measured by vernier calliper to avoid all the above limitations.

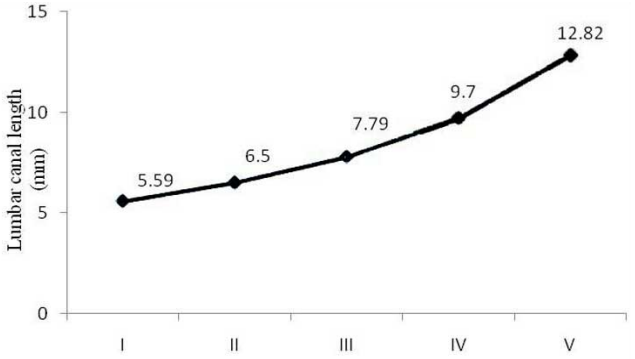

Fig. 1. Graphic presentation of gestational age vs. lumbar canal length (mm).

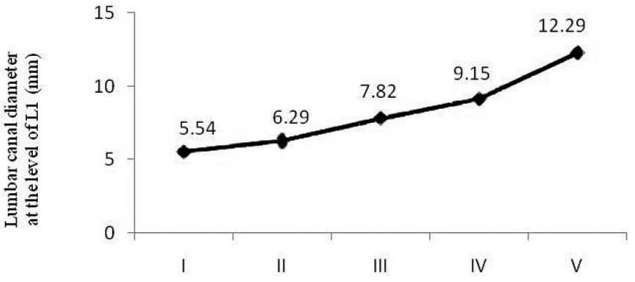

Fig. 2. Graphic presentation of gestational age vs. lumbar canal diameter at the L1 (mm).

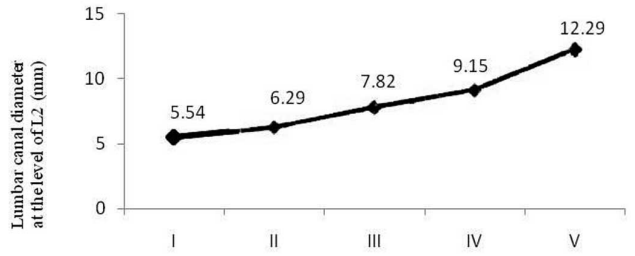

Fig. 3. Graphic presentation of gestational age vs. lumbar canal diameter at the L2 (mm).

MATERIAL AND METHOD

This study was carried out on 30 formalin preserved human foetuses, of all age groups and both sexes, free of congenital craniovertebral anomalies. Foetuses were obtained from the museum of the department of anatomy J. N. Medical College, A.M.U., Aligarh and divided into five groups (I-V) based or their gestational ages. Each group consisting of 6 foetuses (3 male and 3 female). Group I contained foetuses of less than 17 weeks, group II between 17-20 weeks, group III between 21-25 weeks, group IV between 26-30 weeks and group V included foetuses of more than 30 weeks. The parameters used for gestational age was foetal foot length. Fair correlation between foot length and gestational age was documented by using Streeter's data (Streeter, 1920) (Table I). External genitalia were taken into consideration to determine the sex. All the measurements before and after the dissection, were done directly with the help of vernier calliper. Morphometric indices taken into account were:

Length of lumbar canal, from upper border of 1st lumbar vertebra to lower border of 5th lumbar vertebra.

Maximum diameters of lumbar vertebral canal, at each lumbar vertebral level.
Height of the posterior surfaces of body of individual lumbar vertebra i.e. L1, L2, L3, L4 and L5.
Length of sacral canal, from upper border of Ist sacral vertebra to lower border of 5th sacral.

Results were put in tabulated form showing readings in each group (Table III-XIV). Findings of adjacent groups in each table were analyzed by using Student's 't' test. Results were additionally presented in graphs form (Figs. 1 to 12) to see the pattern of growth.

RESULTS AND DISCUSSION

Lumbar canal length (Table III increased during majority of the foetal groups in the study. The growth was statistically insignificant between group I and II foetuses. Thereafter the growth was highly significant ($p < 0.001$) with percent increase ranging from 20 to 30. Wallny *et al*. (1999) found a statistically significant increased in lumbar canal length with advancing gestational age. Wallny *et al*. (2002) performed another cross-sectional ultrasound study in which the size of the foetal lumbar spinal canal was evaluated between 16 and 41 weeks of gestation. They found that with advancing gestational age there was a statically

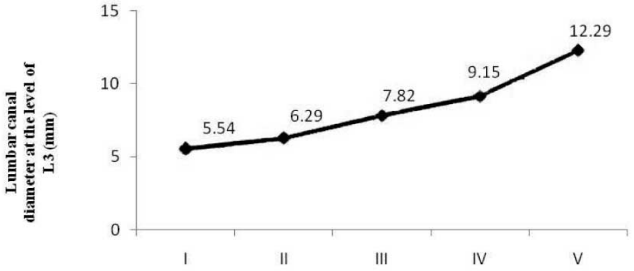

Fig. 4. Graphic presentation of gestational age vs. lumbar canal diameter at the Level of L3 (mm).

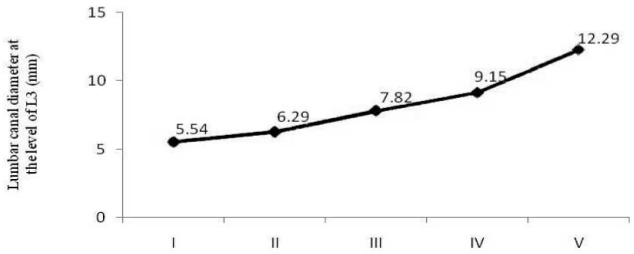

Fig. 5. Graphic presentation of gestational age vs. lumbar canal diameter at the Level of L4 (mm).

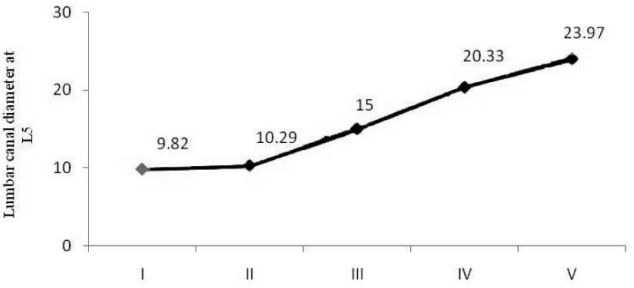

Fig. 6. Graphic presentation of gestational age vs. lumbar canal diameter at L5 (mm).

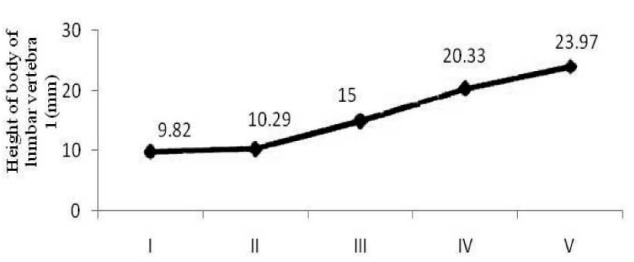

Fig. 7. Graphic presentation of gestational age vs. height of lumbar vertebra L1 (mm).

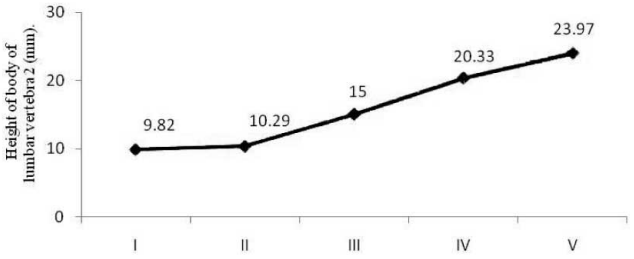

Fig. 8. Graphic presentation of gestational age vs. height of body of lumbar vertebra L2 (mm).

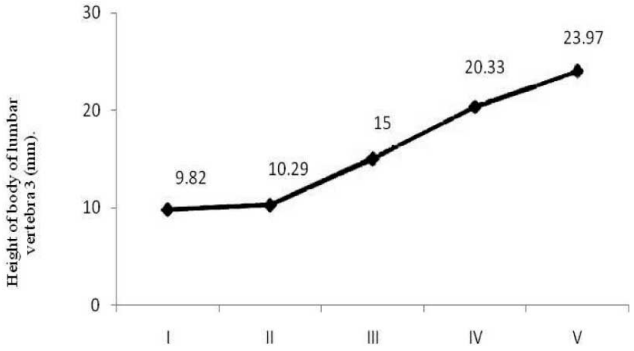

Fig. 9. Graphic presentation of gestational age vs. height of body of Lumbar vertebra L3 (mm).

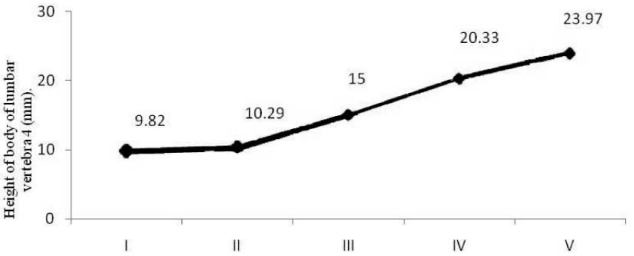

Fig. 10. Graphic presentation of gestational age vs. height of body of lumbar vertebra L4 (mm).

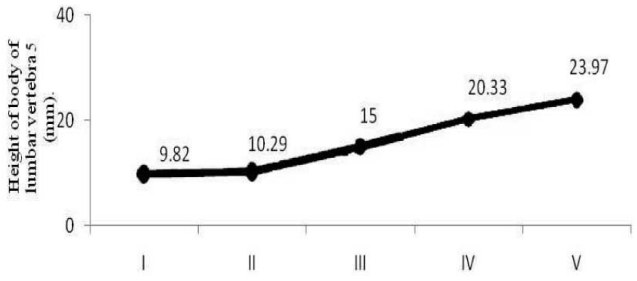

Fig. 11. Graphic presentation of gestational age vs. height of body of lumbar vertebra L5 (mm).

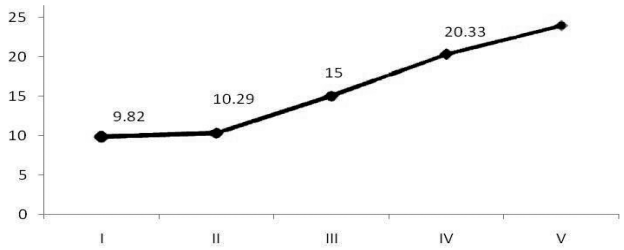

Fig. 12. Graphic presentation of gestational age vs. sacral canal length (mm).

Table I. Streeter's Data.

Gestational Age (weeks)	Foot length (mm)
11	7
12	9
13	11
14	14
15	17
16	20
17	23
18	27
19	31
20	33
21	35
22	40
23	42
24	45
25	48
26	50
27	53
28	55
29	57
30	59
31	61
32	63
33	65
34	68
35	71
36	74
37	77
38	79
39	81
40	83

Table II. Determination of gestational of foetuses under observation.

Serial Number	Foot length	Gestational age
1	17	15
2	17	15
3	18	15-16
4	20	16
5	20	16
6	20	16
7	23	17
8	23	17
9	25	17-18
10	27	18
11	27	18
12	31	19
13	35	21
14	35	21
15	40	22
16	40	22
17	41	22-23
18	46	24-25
19	50	26
20	50	26
21	50	26
22	55	28
23	57	29
24	59	30
25	61	31
26	62	31-32
27	63	32
28	63	32
29	65	33
30	74	36

significant increase in lumbar canal length. A close correlation was also found between lumbar spine length, head circumference, abdominal circumference and femur length. Czyz & Kedzia (2003) noted that the development of the lumbar vertebral column during the foetal period was ongoing, although not in a proportional way. The percentage participation of the lumbar segment in the length of the whole vertebral column increased from 17.5 to 22%. Jeffery *et al.* (2003) found that the most rapid period of growth for the lumbar vertebral canal is between 12 and 32 weeks in utero. Lumbar canal diameter at the level of L1 (Table IV) increased throughout the study range. Growth was extremely significant throughout i.e. from 15 weeks to 36 weeks ($p < 0.001$). Lumbar canal diameter at L2, L3, L4 and L5 (Table V, VI and VIII) also showed the growth pattern similar to L1. Height of lumbar vertebra 1 (Table IX) showed variable growth. Growth was insignificant between group I and II. Significant growth occurred during 21-25 weeks ($p<0.01$). After 25 weeks growth was highly significant ($p<0.001$).

Height of lumbar vertebra 2 (Table X) changed insignificantly between groups I and II. There was highly significant growth between groups II and III ($p<0.001$). Growth continued thereafter also at a significant rate ($p<0.01$).

Table III. Lumbar canal length (mm)

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	18.31 ± 0.84	-	-
II	6	20.20 ± 0.72	+10.32	Insignificant
III	6	26.39 ± 0.43	+30.64	< 0.001
IV	6	31.67 ± 0.40	+20.00	<0.001
V	6	39.80 ±1.36	+25.67	<0.001

Table IV. Lumbar canal diameter at the level of L1 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	5.59 ± 0.03	-	-
II	6	6.50 ± 0.02	+16.27	<0.001
III	6	7.79 ± 0.02	+19.84	< 0.001
IV	6	9.70 ± 0.06	+24.51	<0.001
V	6	12.82 ± 0.02	+32.16	<0.001

Table V. Lumbar canal diameter at the level of L2 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	5.98 ± 0.06	-	-
II	6	6.90 ± 0.06	+15.38	<0.001
III	6	8.40 ± 0.05	+21.73	< 0.001
IV	6	10.57 ± 0.04	+25.83	<0.001
V	6	13.20 ± 0.10	+24.88	<0.001

Table VI. Lumbar canal diameter at the level of L3 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	5.79 ± 0.02	-	-
II	6	6.57 ± 0.04	+13.5	<0.001
III	6	7.82 ± 0.05	+19.02	< 0.001
IV	6	9.81 ± 0.04	+25.44	<0.001
V	6	12.87 ± 0.02	+31.19	<0.001

Table VII. Lumbar canal diameter at the level of L4 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	5.54 ± 0.04	-	-
II	6	6.29 ± 0.03	+13.53	<0.001
III	6	7.82 ± 0.05	+19.56	< 0.001
IV	6	9.15 ± 0.13	+17.00	<0.001
V	6	12.29 ± 0.03	+34.31	<0.001

Table VIII. Lumbar canal diameter at L5 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	5.31 ± 0.04	-	-
II	6	6.17 ± 0.02	+16.19	<0.001
III	6	7.30 ± 0.04	+18.31	< 0.001
IV	6	9.01 ± 0.09	+23.42	<0.001
V	6	11.20 ± 0.03	+24.30	<0.001

Table IX. Height of body of lumbar vertebra L1 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	3.09 ± 0.07	-	-
II	6	3.24 ± 0.05	+4.85	insignificant
III	6	3.99 ± 0.06	+23.14	< 0.01
IV	6	5.04 ± 0.07	+26.31	<0.001
V	6	6.50 ± 0.03	+28.96	<0.001

Table X. Height of body of lumbar vertebra L 2 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	3.22 ± 0.04	-	-
II	6	3.33 ± 0.02	+3.41	insignificant
III	6	4.05 ± 0.08	+21.62	< 0.001
IV	6	5.19 ± 0.05	+28.14	<0.01
V	6	6.57 ± 0.05	+21.58	<0.01

Table XI. Height of body of lumbar vertebra L3 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	3.27 ± 0.04	-	-
II	6	3.36 ± 0.04	+2.75	insignificant
III	6	4.33 ± 0.04	+28.86	< 0.001
IV	6	5.32 ± 0.02	+22.86	<0.001
V	6	6.58 ± 0.02	+23.68	<0.001

Table XII. Height of body of lumbar vertebra L 4 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	3.16 ± 0.02	-	-
II	6	3.19 ± 0.02	+0.94	insignificant
III	6	4.13 ± 0.05	+29.46	< 0.001
IV	6	5.14 ± 0.10	+24.45	<0.001
V	6	6.23 ± 0.05	+21.20	<0.001

Table XIII. Height of body of lumbar vertebra L 5 (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	2.86 ± 0.02	-	-
II	6	2.09 ± 0.03	-26.92	insignificant
III	6	3.94 ± 0.03	+88.51	< 0.001
IV	6	4.89 ± 0.03	+24.11	<0.001
V	6	6.10 ± 0.08	+24.74	<0.001

Table XIV. Sacral canal length (mm).

Group	Number of case (n)	Mean ± SD (mm)	Percent change	P value
I	6	9.82 ± 0.26	-	-
II	6	10.29 ± 0.33	+4.78	insignificant
III	6	15.00± 0.41	+45.77	< 0.001
IV	6	20.33 ± 0.56	+35.53	<0.01
V	6	23.97 ± 0.25	+17.90	<0.001

Height of lumbar vertebra 3, 4 and 5 (Table XI, XII and XIII) also changed insignificantly up to 20 weeks. After 20 weeks their heights continued to grow at a highly significant rate ($p<0.001$). Ursu *et al*. (1996) studied the development of lumbosacral vertebral canal and dural sac in human foetuses. They found that the most rapid growth period of the spinal canal parameters is between 18-36 weeks of gestation. After 30 weeks of intrauterine life, the upper lumbar canal grew faster than the lower lumbar region. In our study rapid growth of lumbosacral canal also occurred during 20-36 weeks. Widjaja *et al*. performed postmortem magnetic resonance imaging on 30 foetuses ranging from 14-41 gestational weeks to study normal lumbar spine. They found that the height and area of the vertebral body increased linearly with gestational age ($p<=0.01$). Sacral canal length (Table XIV) increased in major portion of gestational period. Between groups I and II weeks change in sacral canal length was insignificant. Highly significant growth occurred thereafter i.e. during 21-25 weeks ($p<0.001$). Growth was also significant between 26-30 weeks ($p<0.01$). Again after 30 weeks highly significant growth of sacral canal occurred ($p<0.001$). We observed that most rapid growth occurred during 21-25 weeks and after 30 weeks (Fig. 1). It was concluded that the length of lumbar canal showed significant growth in the last three group of foetuses i.e. between 21-25, 26-30 and >30 weeks of gestation. There was steady growth in the transverse diameters of lumbar canal at all lumbar vertebral levels (Figs. 2 to 6). Heights of the all lumbar vertebral bodies showed variable and significant growth pattern and sacral canal length showed significant growth in groups III, IV and V. Variations noticed in our findings compared to reports of previous authors might be due to racial factors as our study was performed in Indian foetuses. Parameters showing steady growth seemed to be important in determination of gestational age and therefore of great medicolegal importance.

SUMAYYA; FARUQI, N. A.; ANSARI, M. S. & GHAUS, F. Análisis morfométrico del canal lumbosacro en fetos humanos. ***Int. J. Morphol., 29(3)***:868-875, 2011.

RESUMEN: La porción lumbosacra del canal espinal requiere una atención especial; es un sitio frecuentemente implicado en la espina bífida, el síndrome de médula anclada y algunas otras patologías como tumores de grasa en la columna vertebral, quistes y siringomelia. El diagnóstico y el tratamiento de los defectos del tubo neural requieren de un conocimiento preciso de la morfometría del canal vertebral lumbosacro. Existen diversos informes radiológicos sobre mediciones morfométricas en fetos humanos por parte de diversos investigadores, pero estos poseen una variabilidad inherente debido a las técnicas de imagen, posicionamiento del paciente, técnicas de medición del observador y, las variaciones normales y patológicas. Para superar todas estas limitaciones, para las mediciones directas se utilizó un caliper vernier. 30 fetos humanos conservados en formalina, de todas las edades y de ambos sexos, sin anomalías congénitas craneovertebrales, fueron obtenidos del museo del Departamento de Anatomía, J. N. Facultad de Medicina de la UMA, Aligarh. Los fetos fueron divididos en cinco grupos (I-V) sobre la base de su edad gestacional. El grupo I de fetos fueron los menores de 17 semanas, el II de 17-20 semanas, el III de 21-25 semanas, IV de 26 a 30 semanas, V de más de 30 semanas. Cada grupo contenía 6 fetos de ambos sexos (1:1/H:M)). Los parámetros morfométricos tomados en cuenta fueron la longitud del canal lumbar, el diámetro transversal máximo del canal vertebral lumbar en diferentes niveles, la altura de las superficies posteriores de los cuerpos de todas las vértebras lumbares y la longitud del canal sacro. Las mediciones de los grupos fueron comparadas y analizadas mediante el uso de la prueba de "t". El canal lumbar comenzó a aumentar en longitud

significativamente desde el grupo de fetos III en adelante. No hubo consistencia en el crecimiento de los diámetros del canal lumbar con la edad gestacional en todos los niveles. Las alturas de los primeros dos cuerpos vertebrales lumbares mostraron variabilidad en los grupos adyacentes. Lo mismo se observó en los tres siguientes, que crecieron constantemente con el crecimiento de los fetos. El canal sacro mostró un crecimiento variable en longitud en los diferentes grupos. El crecimiento constante en la longitud y el diámetro del canal lumbar pueden ser utilizados para determinar la edad aproximada de los fetos por razones médico-legales.

PALABRAS CLAVE: Canal lumbar; Canal sacro; Fetos humanos; Crecimiento fetal; Vértebras lumbares; Morfometría fetal.

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