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Original Article

An Anatomical Study of The Lumbar Epidural Space in Egyptians using Computerized Axial Scans

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ABSTRACT

Background: Racial differences have been proven to exist in different morphometric measurements. Therefore, each population should have its own measurements to provide a complete and accurate data base. The precise dimensions of the lumbar epidural space are critical for many spinal surgeries. However, the existed data-base is limited in accuracy as well as in the parameters recorded.

Aim of the Work: This study was performed to provide a large and accurate data base of lumbar epidural spinal morphometric measurements in a segmental manner in normal Egyptian population and to clarify the influence of age and sex on these measurements.

Subjects and Methods: Morphometric characteristics of the lumbar epidural space were studied in 160 Egyptians aged 27- 74 years using computerized axial scans.

Results: The study revealed sex- and age-dependent differences in some of the measurements of the lumbar epidural space. The ligamenta flava thickness increased significantly with advancing age, while the length decreased significantly. The presence of fat in the antero-lateral recesses was more by age increase. On the other hand, the distance from the skin to the posterior epidural space and the distance from the posterior wall of the spinal canal to the dural sac decreased significantly with age. Moreover, the transverse and the antero-posterior diameters of the spinal canal, the facet joint space and the depth of the lateral recess decreased significantly with advancing age. Regarding gender, the distance from the skin to the posterior epidural space was significantly longer in females than in males. While length and thickness of ligamenta flava, the facet joint space and the depth of the lateral recess were significantly more in males.

Conclusion: Computerized axial scan clearly may reveal the anatomy of the epidural space, and this work may be a useful guideline to the anatomy of the lumbar spine among Egyptians. Data obtained should be considered during evaluation of the state of the lumbar epidural space before and during spinal surgery and in the diagnosis of the pathological processes in the lumbar region.

Key Words: lumbar epidural space, anatomy, morphometry, CT scan, Egyptians.

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INTRODUCTION

Epidural anesthesia combined with general anesthesia has become a standard treatment for pain management in major abdominal and thoracic surgery *(Willschke et al., 2005)*. Furthermore, many physicians have selected epidural space for injecting medications *(Cassel, 2000)*. However, one of the most important problems encountered when administering epidural anesthesia or medication is failure to identify the epidural space *(Lirk et al., 2004)*. Moreover, the safe and successful performance of a lumbar puncture and spinal surgery demands a working and specific knowledge of epidural space anatomy *(Boon et al., 2004)* and because of the potential effect of the geometry of the epidural space on the technique and spread of drugs, interest has centered on the detailed anatomy of this region *(Westbrook et al., 1993)*. Misunderstanding of the anatomy of the epidural space may result in failure or complications of the procedure *(Boon et al., 2004)*.

The increased longevity of the world's population has resulted in a growing number of elderly people requiring medical care and consequently the number of elderly surgical patients will continue to grow *(Veering, 2006)*. Lumbar epidural anesthesia is often used in elderly patients for orthopedic, urological, gynecological and lower abdominal surgeries *(Lloyd-Sherlock, 2000)*. In addition, *Simon et al. (2004)* studied the absorption of anesthetic drugs after epidural administration in elderly and revealed that the changes in the absorption of the drugs are best explained by anatomical considerations rather than pharmacodynamic and pharmacokinetic changes.

The importance of the size and shape of structures and their complex relationships to neighboring anatomical structures has become apparent with the development of the widely used imaging techniques like computed tomography and magnetic resonance imaging. The usage of these techniques in determination of anatomical morphometric values of the epidural space is possible without the use of cadaver measurements *(Safak et al., 2010)*.

This study aimed at identifying the normal variation in the CT appearance of the lumbar epidural space among a sample of Egyptian population with emphasis on the influence of age and sex on the morphometric measurements to establish a normative range for the lumbar epidural space in the general population.

SUBJECTS AND METHODS

Lumbar epidural space was evaluated in one hundred and sixty Egyptian subjects who underwent lumbar spine CT scanning for diagnosis of back pain through a cross-sectional study that was carried out in Suez Canal University hospital. Each participant gave approval and a written consent after explanation of the aim and the procedures of the work. Subjects with history of scoliosis, spondylolisthesis, congenital anomalies, intermittent claudication, trauma, myelography and/or operations in the back were excluded from the study. The age of the participants ranged from 27-74 years and they were evenly divided into two groups according to age (middle age group from 25-50 years and old age group >50 years). The study subjects were carefully selected to represent equally both sexes and both age groups. Weight and height were recorded for each subject.

All scans were obtained on a General Electric (GE) 8800 CT/ T scanner using the retrospective target review (GE trademark) software package with the bone algorithm and target factor of two. Typical scan parameters used were as follows : KVP 120, variable m A. Scan time 9.6 seconds. The lumbar CT scan protocol originally requested on each subject was not altered. Thus, all subjects were scanned in the supine position and the lumbar spine either in a neutral or non-lordotic (flexed) position. Section thickness with 1.5 mm thick taken at 3-, 5-, or 10-mm intervals over the whole of the lumber spine. These sections were then subjected to the retrospective review software to optimize image quality. All films of CT were checked and the measurements were taken by the same radiologist to reduce the intra-observer error. Each parameter was measured three times and the means of measurements were recorded.

From these scans, the following features were assessed:

I. Shape of the vertebral canal: it was determined by measuring the midsagittal and interpedicular diameters of the vertebral canal and the trefoil shape was expressed as a ratio of a transverse measurement taken at one-third of the distance from the midpoint of the interpedicular diameter to the apex of the neural arch, and the full interpedicular diameter. A vertebral canal is trefoil in shape if the ratio is less than 0.6667 *(Papp et al., 1995)* (Fig. 1).

II. Position and shape of the dural sac within the canal.

III. Position and amount of fat within the epidural space.

IV. Organization, length and thickness of ligamentum flavum (Fig. 2).

V. Distances: (a) from the skin to the posterior border of the epidural space in the midline, (b) from the posterior wall of the spinal canal to the dural sac, and (c) from the posterior longitudinal ligament to the inferior vena cava.

VI. Transverse and antero-posterior diameters of the spinal canal: the transverse diameter of the lumbar spinal canal was measured as the minimum distance between the medial surfaces of the pedicles of the given vertebra (interpedicular distance) *(Jones & Thomson, 1986)* while, the antero-posterior diameter was taken as the shortest midline perpendicular distance from the posterior margin of the vertebral body to the inner margin of the neural arch *(Jahangir et al., 2003)* (Fig. 1).

VII. Facet joint space (Fig. 2).

VIII. Depth of the lateral recess: The lateral recess is the region of the lumbar canal that is bordered laterally by the pedicle, posteriorly by the superior articular facet and ligamentum flavum, and anteriorly by the vertebral body, endplate margin and disc margin *(Çolak et al., 2008)*. The depth of the lateral recess was measured between the superior articular facet and the top part of the pedicle *(Dincer et al., 1991)* (Fig. 1).

Statistical analysis: Each parameter was measured three times and the mean value was used to reduce the intra-observer error (the margin of error was within 0.1 millimeter). Data were analyzed using Statistical Package for Social Science (SPSS) version 14.0. The mean, standard deviation, Student t test and linear and non-linear regression methods were used to analyze the data. The level of significance was $p < 0.05$. Pearson's correlation test was used to determine correlation coefficients.

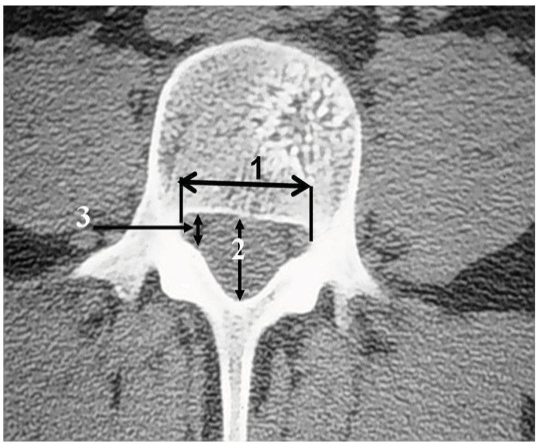

Fig. 1: A photograph showing the measurements of the spinal canal; transverse diameter (1), anteroposterior diameter (2) and depth of the lateral recess (3).

Fig. 2: A photograph showing the metric measurements of the ligamentum flavum. Note the length of the ligament (L), thickness of the ligament (T) and the arrow points to the site of facet joint (FJ).

RESULTS

(I) Middle-age group: As regards the spinal canal, it was found to be oval in the upper lumbar region and became triangular in the lower one. Nearly, almost middle age subjects showed trefoil configuration only at the fifth lumbar vertebra except for eight subjects in which the thecal sac changed from oval at the L2/3 interspace to triangular at L3/4 (with the apex of the triangle presenting to the posterior epidural space). Five out of these eight subjects were males while the other three were females. The difference between the two sexes was insignificant. Figures (3, 7) show the difference in the spinal canal shape between the first lumbar level to the fifth level.

Posteriorly, and in both sexes, the vertebral canal was formed mainly by the vertebral arch and the ligamentum flava. Between the vertebral arches, there was a posterior recess enclosed between the ligamentum flava filled with fat, which gave a curved profile to the vertebral canal (Fig. 4). The ligamentum flavum was found to be formed of two parts with a midline gap between them (Fig. 4) in 51 subjects (63.75% of middle-age subjects) and in the rest of the subjects (36.25%) there was a continuity between the two parts of the ligamentum flavum (Fig. 5).This midline gap was found to be present significantly more in the upper lumbar region than in the lower one in both sexes and was found in 27 males (52.9% of subjects with midline gaps) and 24 females (47.1% of subjects with midline gaps). This difference between the two sexes was found to be insignificant. The incidence of this midline gaps of ligamentum flavum in both sexes is presented in Table (1).

In both sexes, the ligamentum flavum thickness was noted to increase significantly with the level of the spine and the increments at L4-5 and L3-4 were larger than that at L2-3 and L5-S1 (Table 2).

The dural sac was found to be apposed anteriorly to the vertebral bodies, the intervertebral discs, and the overlying posterior longitudinal ligament and to the epidural fat where it was present in the posterior and antero-lateral recesses (Fig. 4). The dural sac usually showed an oval or hexagonal shape in the transverse views at the first and second lumbar vertebral levels, and the shape of an inverted triangle below the level of the third lumbar vertebra. A dorsal midline fold of dura was observed in thirteen cases of the scans (16.25%). Seven out of these thirteen cases were females while the other six were males. The difference between the two sexes was found to be insignificant.

In both sexes, fat was found in the intervertebral foramina mostly around nerve roots, in the midline recess between the ligamenta flava and the vertebral canal and in the antero-lateral recesses where the vertebral canal became trefoil. The amount of fat in the antero-lateral recesses was noticed to be more in females than in males.

The distance from the skin to the posterior epidural space ranged from 53 to 82 mm in females, while in males it ranged from 49 to 73 mm. In both sexes, the distance was greater in the lower than in the upper lumbar segments, being greatest at the third and forth interspaces and least at the first interspace. The difference in the mean values between males and females was proved to be significant (Table 3). The distance from the posterior wall of the spinal canal to the dural sac varied along the length of the spinal canal. This distance ranged in males from 5.2-7.2 mm, while in females it ranged from 4.6-6.5 mm. The difference between both sexes was proved to be significant (Table 3).

A significant sex difference regarding the distance from the posterior longitudinal ligament to the inferior vena cava was also found as males had a significant greater distance from the posterior longitudinal ligament to the inferior vena cava than females (Table 3).

The transverse diameter of the spinal canal gradually increased from L1 to L5. It was minimum at L1 and maximum at L5. The differences between the mean transverse diameters in males and females at all of the five lumbar levels were found to be significant. On the contrary, measurements of the antero-posterior diameters of the spinal canal showed a gradual decrease from L1 to L5 and a significant sex difference was also found (Table 3). The depth of the lateral recsess was found to diminish from the upper to the lower lumbar regions in both sexes. The difference between depths in both sexes was proved to be statistically significant (Table 2). The facet joint space was proved to be significantly different between both sexes (Table 2). A significant difference between right and left sides in the means of depth of the lateral recess and facet joint spaces at the same level was also noted (Table 2).

(II) Old-age group: Regarding shape of the spinal canal, it was noted to be oval in the upper lumbar region and became triangular in the lower one. Only twelve old-age subjects (15% of old-age group) showed change in the shape of the thecal sac from oval at the L2/3 interspace to triangular at L3/4 (with the apex of the triangle presenting to the posterior epidural space) while the majority of old-age subjects (85% of old-age subjects) showed this change in the shape of the thecal sac only at the fifth lumbar vertebra. Seven out of these twelve subjects were males while the other five subjects were females. The difference between both sexes was found to be insignificant (Figs. 3, 7).

The vertebral canal was found to be formed posteriorly by the vertebral arches and the ligamenta flava. Between the ligamenta flava, a posterior recess filled with fat was noted that preserved the curved profile of the vertebral canal. The ligamentum flavum was found to be formed of two parts with a midline gap between them in 53 subjects (66.25% of old-age group) and in the rest of the subjects (33.75% of old-age group) a continuity between the two parts of the ligamentum flavum was observed. Incidence of this midline gap was present significantly more in upper lumbar region than in the lower one and was found in 27 males (50.9% of subjects with midline gap) and 26 females (49.1% of subjects with midline gap). This difference between the two sexes was found to be insignificant. The incidence of the midline gaps versus the number of subjects in the old-age group is presented in Table (4).

In addition, the ligamenta flava thickness was noticed to increase with the level of the vertebral region in both sexes and the increments at L4-5 and L3-4 were larger than those at L2-3 and L5-S1 (Table 5).

The dural sac was apposed anteriorly to the vertebral bodies, the intervertebral discs, and the overlying posterior longitudinal ligament and to the epidural fat where it was present in the posterior and antero-lateral recesses. The dural sac showed an oval or hexagonal shape on the transverse views at the first and second lumbar vertebral levels, and an inverted triangle below the level of the third lumbar vertebra. A dorsal midline fold of dura was observed in nine cases of the scans (11.25% of old-age group). Four out of these nine cases were males while the other five were females. The difference between the two sexes was insignificant. In both sexes, fat was found in the intervertebral foramina mostly around nerve roots, in the midline recess between the ligamenta flava and the vertebral canal and in the antero-lateral recesses where the vertebral canal became trefoil. The presence of fat in the antero-lateral recesses was noticed to be more in males than in females.

The distance from the skin to the posterior epidural space ranged from 40 to 51 mm in males, while in females, it ranged from 43 to 52 mm. In both sexes, the distance was greater in the lower lumbar segments than in the upper segments, being greatest at the third and forth interspaces and least at the first interspace. The difference in the mean values between both sexes was proved to be significant (Table 6). The distance from the posterior wall of the spinal canal to the dural sac ranged from 4.3- 6.3 mm in males, while in females it ranged from 3.8-5.6 mm. The difference between both sexes was proved to be significant (Table 6). Moreover, a significant difference between males and females concerning the distance from the posterior longitudinal ligament to the inferior vena cava was also found as males presented with statistically significant higher measurements than females (Table 6).

Regarding the diameters of the spinal canal, a gradual increase in the transverse diameter of the spinal canal from L1 to L 5 was found while the anteroposterior diameter of the spinal canal showed a gradual decrease from L 1 to L 5. Furthermore the difference between males and females mean values concerning the diameters of the spinal canal was proved to be significant (Table 6). The depth of the lateral recess was found to diminish from the upper to the lower lumbar regions in both sexes (Table 5).

The differences between mean values of males and females concerning facet joint space and depth of the lateral recess were proved to be significantly different between both sexes (Table 5). A statistically significant difference between right and left sides at the same spinal level regarding facet joint space and depth of the lateral recess was noted (Table 5).

In both middle and old age groups, there was a relationship between subject weight and the distance from the skin to the posterior epidural distance. Heavier subjects had a significantly greater distance from the skin to the posterior epidural space.

Moreover, subject body weight correlated significantly with the thickness of ligamenta flava at the L2/3 interspace only. Furthermore, the ligamenta flava thickness correlated significantly with age as they seemed to be thinner in younger than in older subjects.

There was also a significant relationship between the trefoil configuration shape of the spinal canal and the small midsagittal diameter of the canal where more trefoil configuration were found with smaller midsagittal diameter. There was no relation between subject height and any of the morphometric parameters.

Table 1: Incidence of midline gap of ligamentum flavum in the middle-age group.

level	Middle-age group (51 cases)			
	Males		Females	
	No.	%	No.	%
L 1/ 2	27	52.94	24	47.05
L 2/ 3	19	36.53	19	37.25
L 3/ 4	18	35.29	16	31.37
L 4/5	21	41.18	18	35.29
L5/S1	9	17.65	7	13.72

Table 2: Means of measurements (mm) in both sides of males and females in the middle-age group.

parameter	Males Means ±SD		Females Means ±SD	
Length of Ligamentum flavum				
	Rt	Lt	Rt	Lt
L1	18.0±0.04	17.0±0.66	14.0±0.54*	15.0±0.55*
L2	19.0±0.65	18.0±0.23	15.0±0.07*	14.0±0.65*
L3	20.0±0.54	19.0±0.37	16.0±0.51*	15.0±0.90*
L4	16.0±0.09	18.0±0.778	14.0±0.24*	14.0±0.73*
L5	17.0±0.10	17.0±0.05	15.0±0.63*	15.0±0.56*
Thickness of Ligamentum flavum				
	Rt	Lt	Rt	Lt
L1	34.0±0.08	35.0±0.54	32.0±0.80*	33.0±0.76*
L2	36.0±0.77	35.0±0.85	34.0±0.54*	33.0±0.66*
L3	38.0±0.19	39.0±0.77	36.0±0.45*	37.0±0.87*
L4	40.0±0.54	41.0±0.32	38.0±0.58*	37.0±0.51*
L5	35.0±0.88	34.0±0.08	33.0±0.53*	32.0±0.40*
Facet joint space				
	Rt	Lt	Rt	Lt
L1	12.0±3.09	11.0±2.86	10.0±4.02*	9.0±2.09*
L2	13.0±4.53	10.0±3.87	11.0±3.06*	10.0±3.60*
L3	15.0±2.87	13.0±2.01	13.0±3.73*	11.0±2.67*
L4	13.0±2.90	11.0±3.09	11.0±3.21*	10.0±2.00*
L5	10.0±1.90	9.0±2.03	9.0±2.45*	8.0±2.09*
Depth of Lateral Recess				
	Rt	Lt	Rt	Lt
L1	17.0±0.40	16.0±0.77	15.0±0.58*	14.0±0.50*
L2	16.0±0.43	15.0±0.94	14.0±0.92*	13.0±0.66*
L3	15.0±0.67	14.0±0.55	13.0±0.50*	12.0±0.73*
L4	13.0±0.77	12.0±0.29	12.0±0.65*	11.0±0.49*
L5	11.0±0.08	10.0±0.56	10.0±0.63*	9.0±0.84*

* denotes significant difference in the corresponding measurements between males and females at $P<0.05$

Table 3: Means of measurements (mm) in the middle-age group.

parameter	Males Means ±SD		Females Means ±SD	
Distance from skin to posterior epidural space				
L1	49.0±1.05		53.0±1.74*	
L2	50.0±0.98		56.0±1.05*	
L3	67.0±1.48		73.0±0.89*	
L4	73.0±1.66		82.0±0.71*	
L5	64.0±0.94		71.0±0.93*	
Distance from posterior wall of the spinal canal to dural sac				
L1	5.2±0.04		4.6±0.06*	
L2	5.4±0.60		4.9±0.86*	
L3	6.7±0.37		6.1±0.93*	
L4	7.2±0.75		6.5±0.83*	
L5	6.5±0.93		5.8±0.91*	
Distance from posterior longitudinal ligament to inferior vena cava				
L1	37.0±1.00		35.0±1.05*	
L2	37.0±1.65		35.0±1.68*	
L3	39.0±1.91		37.0±1.04*	
L4	38.0±1.52		36.0±1.62*	
L5	38.0±1.44		36.0±1.36*	
Diameters of spinal canal				
	Antero-posterior	Transverse	Antero-posterior	Transverse
L1	23.3±0.05	22.9±0.09	22.3±0.31*	21.4±1.00*
L2	23.0±0.43	23.5.±0.10	22.0±0.54*	24.7±0.39*
L3	22.0±0.09	24.0±0.43	21.0±0.63*	26.8±0.85*
L4	21.3±0.03	25.0±0.55	20.1±0.97*	27.6±0.05*
L5	16.4±0.76	27.1±0.43	15.2±0.59*	28.9±0.80*

*P<0.05

Table 4: Incidence of the midline gap in the old-age group.

level	Old-age group (53 cases)			
	Males		**Females**	
	No.	%	No.	%
L 1/ 2	27	50.94	26	49.05
L 2/ 3	20	37.73	18	33.96
L 3/ 4	19	35.84	17	32.07
L 4/5	18	33.96	17	32.07
L5/S1	8	15.09	9	16.98

Table 5: Means of measurements (mm) in both sides of males and females in the old-age group.

parameter	Males Means ±SD		Females Means ±SD	
Length of Ligamentum flavum				
	Rt	Lt	Rt	Lt
L1	15.0±1.10	13.0±0.78	13.0±0.11*	11.0±0.40*
L2	15.0±1.63	15.0±1.04	13.0±0.97*	13.0±0.56*
L3	16.0±1.23	15.0±1.05	14.0±1.00*	14.0±0.48*
L4	14.0±0.99	14.0±0.89	12.0±1.00*	12.0±1.01*
L5	15.0±0.67	15.0±0.56	13.0±0.90*	11.0±0.76*
Thickness of Ligamentum flavum				
	Rt	Lt	Rt	Lt
L1	37.0±0.90	39.0±0.67	35.0±0.33*	35.0±0.78*
L2	40.0±1.05	39.0±0.50	38.0±1.67*	37.0±0.09*
L3	42.0±1.66	40.0±1.00	40.0±0.31*	38.0±0.62*
L4	43.0±0.98	42.0±0.78	41.0±0.99*	40.0±0.59*
L5	39.0±0.56	40.0±0.50	37.0±0.60*	36.0±0.71*
Facet joint space				
	Rt	Lt	Rt	Lt
L1	9.0±1.08	8.0±1.80	7.0±0.76*	6.0±1.39*
L2	10.0±1.50	10.0±1.09	8.0±0.59*	8.0±1.30*
L3	12.0±0.90	11.0±1.12	10.0±1.44*	9.0±0.79*
L4	11.0±0.48	10.0±0.78	9.0±1.60*	8.0±1.04*
L5	9.0±1.04	8.0±0.69	8.0±1.34*	7.0±1.22*
Depth of Lateral Recess				
	Rt	Lt	Rt	Lt
L1	15.0±1.10	14.0±2.65	14.0±2.53*	13.0±2.43*
L2	14.0±2.03	13.0±2.09	13.0±1.99*	12.0±2.00*
L3	13.0±1.76	12.0±0.99	12.0±2.02*	11.0±2.09*
L4	11.0±1.77	10.0±0.95	10.0±1.60*	9.0±0.98*
L5	10.0±2.00	9.0±1.06	9.0±1.42*	8.0±1.50*

* denotes significant difference in the corresponding measurements between males and females at $P<0.05$

Table 6: Means of measurements (mm) in the old-age group.

parameter	Males Means ±SD		Females Means ±SD	
Distance from skin to posterior epidural space				
L1	40.0±1.54		43.0±1.98*	
L2	43.0±2.65		47.0±2.08*	
L3	48.0±1.23		50.0±2.97*	
L4	51.0±1.06		54.0±1.99*	
L5	47.0±2.09		52.0±1.32*	
Distance from posterior wall of the spinal canal to dural sac				
L1	4.3±0.03		3.8±0.98*	
L2	4.5±0.32		4.0±0.77*	
L3	5.1±0.76		4.4±0.51*	
L4	6.3±0.54		5.6±0.05*	
L5	5.8±0.66		4.7±0.66*	
Distance from posterior longitudinal ligament to inferior vena cava				
L1	34.0±0.60		32.0±0.54*	
L2	34.0±0.43		32.0±0.91*	
L3	36.0±0.76		34.0±0.29*	
L4	37.0±0.44		35.0±0.54*	
L5	36.0±0.70		33.0±0.82	
Diameters of spinal canal				
	Antero-posterior	Transverse	Antero-posterior	Transverse
L1	21.3±0.23	20.7±0.66	20.2±0.88*	21.8±0.59*
L2	21.9±0.99	22.5±0.54	20.4±0.65*	23.9±0.44*
L3	21.4±0.76	22.9±0.21	20.2±0.08*	23.9±0.30*
L4	21.2±0.57	24.3±0.80	19.0±0.48*	25.9±0.76*
L5	17.4±0.50	27.3±0.63	16.2±0.32*	28.8±0.80*

*P<0.05

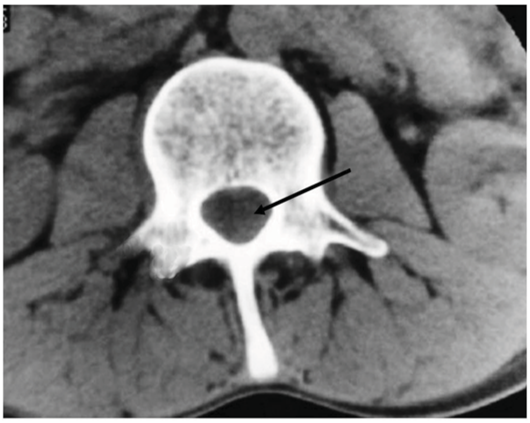

Fig. 3: A photograph of a scan of the first lumbar vertebra demonstrating the ovoid shape of the vertebral canal (arrow).

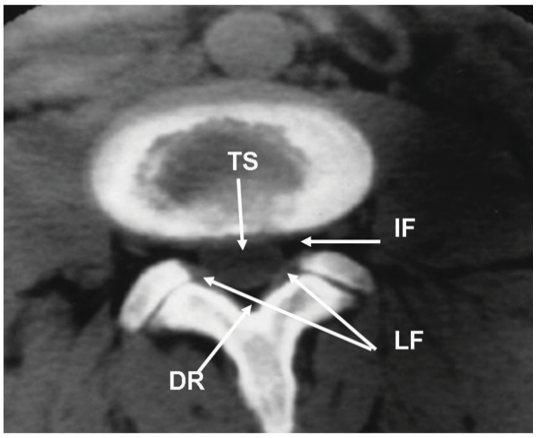

Fig. 4: A photograph of a scan through the L2-3 disc showing the thecal sac (TH) bounded posteriorly by fat in the dorsal recess (DR) and in the intervertebral foramina (IF). The thecal sac (TS) is in apposition to the ligamentum flava (LF) posterolaterally which are shown to be formed of two separate parts.

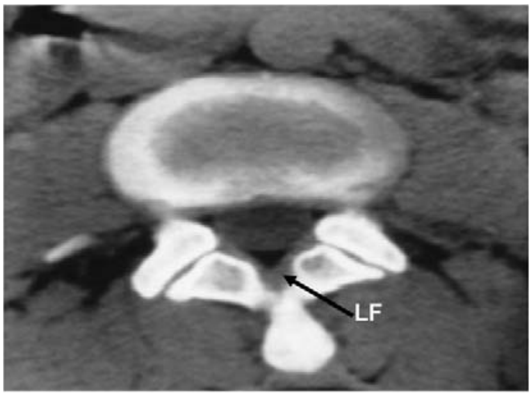

Fig. 5: A photograph of a scan through the third lumbar vertebra showing the continuity of the ligamentum flavum (LF).

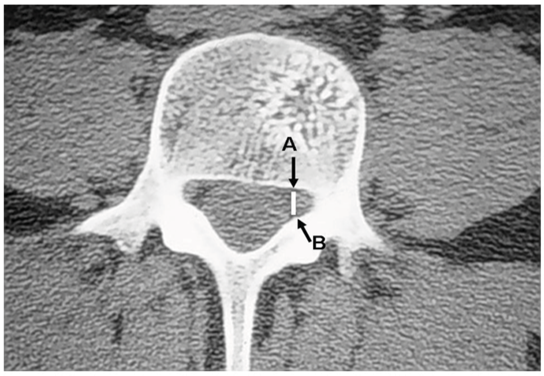

Fig. 6: A photograph of a scan at the fourth lumbar vertebral showing a normal lateral recess (white line) between the posterior surface of the vertebral body (arrow A) and the anteromedial portion of the superior articular facet (arrow B) at the level of the superior border of the corresponding pedicle.

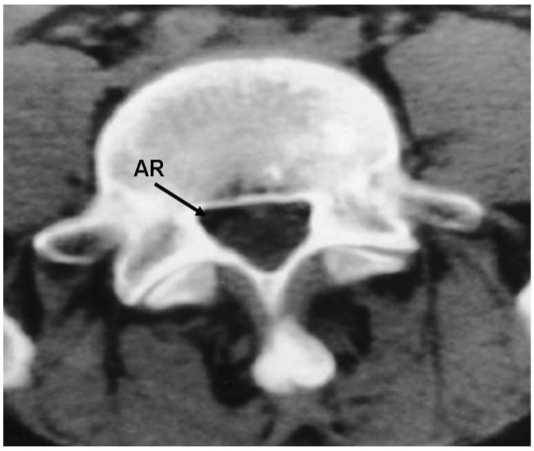

Fig. 7: A photograph of a scan through the fifth lumbar vertebra showing the triangular shape of the vertebral canal with presence of anterolateral recess (AR).

DISCUSSION

The current study revealed change in the shape of the vertebral canal from oval in the upper lumbar region to triangular in the lower one. Moreover, this trefoil configuration in the fifth lumbar vertebra was noted to increase significantly with age. These findings were in accordance with those detected by *Harrison (1999)* who mentioned that as the trefoil shape of the lumbar canal is commonly seen on CT or MRI in patients with low back pain with radicular symptoms, this trefoil shape of the vertebral canal can have troublesome clinical consequences because as the cross-sectional area is reduced by osseous narrowing there is relatively less room for soft-tissue structures and the neural contents may be compromised in a small canal. Furthermore *Armstrong (1952)* and *Papp et al.*

(1995) reported that both a small midsagittal diameter and a trefoil shape can have clinical significance, particularly in combination. The present study has shown that a small lateral recess depth is an essential constituent in the formation of the trefoil configuration and a significant relationship between the trefoil shape and the small midsagittal diameter was noted. Although the etiology of the trefoil shape and developmental stenosis is not well-known, *Clark et al. (1985)* and *Porter and Pavitt (1987)* have suggested that infant malnutrition may be responsible for sagittal narrowness of the lumbar canal. However, in the current study a significant increase in the occurrence of the trefoil shape of the vertebral canal with age was found, suggesting that trefoil shape could result from degenerative changes rather than from any developmental contribution. This finding is contrary to that reported by *Papp et al. (1995)* who reported a significant increase in the occurrence of trefoil shape until adulthood but no significant difference was detected above and below 40 years of age, suggesting that trefoil shape is largely developmental and that any contribution from degenerative change is relatively small. In fact, independent factors could be involved which could only be resolved by longitudinal and genetic studies.

In this study, we detected the presence of a midline fold of dura mater that was significantly more frequent in the middle-aged subjects than in the elderly ones. The existence of a dorsomedian fold of dura mater has been a matter of contention ever since *Luyendijk and van Voorthuisen (1966)* first described it. It has not been found in textbooks of anatomy, and was initially an explanation of an artifact found in epidurograms. *Luyendijk (1976)* then produced photographic evidence of such a fold found at laminectomy, although *Westbrook et al. (1993)* claimed that the existence of the midline fold is still controversial. A study done by *Hogan (1996)* revealed that there was no evidence of the plica or any septation. He explained the appearance of connective tissue band to be due to the presence of epidural fat pad that has fallen away and remained connected by its pedicle to the apex of the epidural space. However, the presence of a midline fold of dura mater was also noted by *Husemeyer and White (1980)*. Anyhow, it is believed that the dorsomedial fold of dura mater exists only in a small percentage of the indigenous population.

In the current study, fat was noted to be present mainly in the antero-lateral recess of the vertebral canal. *Reina et al. (2006)* agreed about the presence of fat in the epidural space, but they mentioned that the fat is mainly located on the dorsal side of the epidural space. *Sherif and Mahfouz, (2004)* added that determination and specification of the epidural fat are important as epidural fat interposition between the dura mater and spinous process may be a helpful sign for the diagnosis of spondylolysis on mid-sagittal MRI imaging of the lumbar spine. Significantly more presence of fat in the anterolateral recesses in the old-age group than that in the middle-age group may explain the more incidence of the trefoil configuration of the vertebral canal in the old-age subjects than in the middle-age ones which has been noted in the current study.

The loss of resistance technique, used to identify the epidural space, is thought to rely on the penetration of the ligamenta flava. However, the exact morphology of the ligamentum flavum at different vertebral levels remains controversial *(Lirk et al., 2004)*. *Sakamaki et al. (2009)* added that as the ligamentum flavum covers most of the posterolateral part of the lumbar spinal canal, its thickening can be attributed to the development of lumbar canal encroachment. In this study, it was found that the thickness of the ligamenta flava was increased significantly in old-age group as compared with the middle-age group. On the other hand, the length of the ligamenta flava was found to decrease significantly in old-age group than in the middle-age one. Additionally the current study also revealed that the thickness of ligamenta flava increased significantly in males than in females in both the middle- and the old- age groups. The above mentioned results were in accordance with those obtained by *Fukuyama et al. (1995)*, *Sairyo et al. (2005)* and *Sakamaki et al. (2009)*. Moreover, the present study also showed that the increase in the thickness of the ligamenta flava was significantly more in the lower lumbar segments than in the upper segments. *Safak et al. (2010)* and *Sakamaki et al. (2009)* mentioned that the ligamenta flava thickness increased with age and the largest increments were found at L4-5 and this thickening had already started in patients with ages of 30-39 years. *Safak et al. (2010)* explained that, the increased thickness at the lower levels was attributed to the greater mechanical stress at these levels. These results strongly support and enhance measuring thickness of the ligamenta flava at different segments of the epidural region and not to focus only at L4-5 segment as the thickness of ligamentum flavum at L2-3 may serve as an indicator of lumbar spinal canal stenosis. This is in agreement with *Sakamaki et al. (2009)* who recommended that thickness of the ligamentum flavum should be evaluated according to its location, to make a diagnosis of hypertrophy as preoperative evaluation of these measures may enable the diagnosis of disease, and determine the type of and side for surgery, and the results of treatment.

In the present study we noted the presence of a midline gap between the ligamenta flava. *Lirk et et al. (2004)* and *Chhabra et al. (2008)* also reported a presence of a midline gap between the ligamenta flava which was more apparent in the cervical and thoracic regions than in the lumbar region and in the upper lumbar segments than in the lower one. On the other side *Zarzur (1984)* and *Olszewski et al. (1996)* found no evidence of the presence of the midline gap between the ligamenta flava. A cryomicrotome investigation done by *Hogan, (1991)* on 38 cadavers revealed that ligamentum flavum midline fusion could be absent "to a variable degree.. Results from our investigation support the latter findings. This is important because the ligamentum flavum is a crucial structure in epidural anesthesia, which has been described as vital in the elicitation of a "loss-of resistance" which refers to the distinct elastic resistance offered by the ligamentum flavum before entering the epidural space *(Zarzur, 1984; Chhabra et al., 2008)*.

The distance from the skin to the posterior border of the epidural sac in our study was found to decrease significantly in the old-age as compared to the middle-age group. Moreover, in the middle-age group, females had a significant more distance than males while in the old-age group, the opposite was found . We also proved that heavier patients had a greater distance between the skin and the dura. The fact that the distance from the skin to the posterior border of the epidural sac reflects the state of the thickness of the subcutaneous tissue in addition to the thickness of the bodies of the vertebrae could explain the previous results. Females presented with more distance in the middle-age group than males could be due to the presence of more subcutaneous fat than that in males while in the old-age group and possibly under the effect of hormonal withdrawal effect in females causing degenerative and osteoporotic changes resulting in decrease in this distance than that in males. In the present study, the distance from the skin to the posterior border of the epidural sac in middle-aged group ranged from 4.9 to 6.9cm. While in the old age group, the distance ranged from 4.3 to 5cm. *Malak et al. (2007)* measured the distance from the skin to posterior epidural space among Pakistani people; they found that the mean of the distance was 4.15cm±0.5. They also mentioned that the posterior epidural distance has direct relation with weight than height. Another study done by *Shiroyama et al. (2003)* measured the distance from the skin to the posterior epidural space among Japanese people, they found that the mean of the distance was 5cm±0.5. *Shim et al. (1996)* measured the posterior epidural distance among Korean people and revealed that the mean of the posterior epidural distance was 4.4 cm, they also proved a significant correlation between the posterior epidural distance and the weight. We suggest that the above mentioned variations are due to the fact that the measurements are likely to be affected by racial variations.

Low back pain is a common clinical problem and the etiology in many of these patients is narrowing of the spinal canal that implies narrowing of the canal with possible subsequent neural compression. In the current study, it has been found that, the maximum mean anteroposterior diameter was in L1 while the minimum was in L5 in both age groups. This is matching with the results reported by *Hinck et al. (1965)* in their study in western population and to *Lee et al. (1996)* in their study in Korean population. However, there was difference between the mean values reported in their work compared to ours. Racial differences may be the underlying cause. On the other hand, the values reported in the current study are nearly similar to those reported by *Amonoo-Kuofi et al. (1991)* in their study on Saudi population. Anatomically, lumbar spinal stenosis sub-classifications include central canal and lateral recess stenosis as the lateral recess is one of the main compression sites in lumbar spinal canal stenosis *(Çolak et al., 2008)*. The classification of lumbar stenosis is important because of the implications of the underlying etiology and because it affects the therapeutic strategy, specifically the surgical approach. Lateral recess stenosis is defined as narrowing (less than 3-4 mm) between the facet of the superior articulating process and posterior vertebral margin. Such narrowing may impinge the nerve root and subsequently elicit radicular pain. In this study, we tried to document the depth of lateral recess in the different levels of the lumbar region in addition to prove that there is a significant age changes which should be considered by clinicians when diagnosing and managing lumbar spinal stenosis. Moreover, a significant age and sex accompanied changes of the facet joint space have been found in the current study. These variations should be considered by clinicians when evaluating and managing low back pain as facet joint injections when used can be helpful in managing low back pain as mentioned by *Orpen and Birch (2003)*.

In this study, we found significant differences in some of the measured parameters between contra-lateral sides at the same level. Depending on this result it can be suggested that there is an asymmetry related with some parameters. It is stated in the literature that asymmetry reflects the magnitude of developmental instability/ stability in an organism, which is the appearance of, or predisposition to, deviations from normal ontogeny *(Tovée et al., 2000; Tomkinson et al., 2003)*. Besides the developmental perturbations, this asymmetry may reflect the asymmetrical mechanical stress which is beard during life time. This asymmetrical mechanical stress is suggested to be the result of side preference of the individuals as well. However we did not evaluate side preferences of the individuals in our study. We have no further explanation for the reason of this finding or its importance.

According to the results obtained from the current study, we can conclude that, computerized axial scans may clearly reveal the anatomy of the epidural space. Our results may be a useful guideline of the anatomy of the lumbar spine among Egyptians, helping in performing safe and efficient spinal surgeries.

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دراسة تشريحية للحيز القطنى خارج الام الجافية بين المصريين باستخدام الاشعة المقطعية

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ملخص البحث

اثبتت الدراسات العديدة و جود فروق عرقية فى مختلف القياسات المورفومترية و من ثم يتعين على كل امة ان يوجد لها قاعدة بيانات خاصة بها. وعلى الرغم من أن الأبعاد الدقيقة للحيزالقطنى خارج الام الجافية بالغة الأهمية بالنسبة للعمليات الجراحية في العمود الفقري، فإن قاعدة البيانات المورفومترية المتوفرة محدودة في دقتها وفى نوعيتها.

الهدف من الدراسة: و قد أجريت هذه الدراسة لتقدم قاعدة بيانات مورفومترية دقيقة و مجزاة للقياسات المترية فى منطقة الحيز القطنى خارج الام الجافية في العمود الفقري بين المصريين مع إيلاء اهتمام خاص لتأثير العمر والجنس على تلك القياسات.

طرق البحث: الخصائص المورفومترية للحيز القطنى خارج الام الجافية درست في ١٦٠ شخصا مصريا تتراوح اعمارهم من ٢٧ -- ٧٤ سنة باستخدام الاشعة المقطعية.

النتائج: كشفت الدراسة عن اختلافات تعتمد على الجنس والعمر في بعض أبعاد الحيز القطنى خارج الام الجافية. فقد وجد انه مع التقدم في السن ازداد سمك الرباط الاصفربشكل ملحوظ في حين ان طوله قد انخفض إلى حد كبير. كما ان كمية وجود الدهون في الفجوة الامامية الجانبية كانت اكثرمع التقدم فى السن ،وعلى الجانب الاخرفقد وجد ان البعد ما بين الجلد إلى الحيزالخلفى خارج الام الجافية والبعد مابين الحد الخلفي للقناة الشوكية الى كيس الجافية قد انخفضوا مع التقدم فى العمر. هذا بالاضافة الى الانخفاض فى الأبعاد العرضية ، والأمامية خلفية للقناة الشوكية، و فضاء المفصل المسطح (facet joint space) وعمق الفجوة الجانبية مع التقدم في السن. فيما يتعلق بنوع الجنس ،فقد وجد ان البعد ما بين الجلد إلى الحيزالخلفى خارج الام الجافية كان اكبر بشكل ملحوظ في الإناث عنه فى الذكور، في حين ان طول وسمك الرباط الاصفر، تجويف المفصل المسطح(facet joint space) وعمق الفجوة الجانبية كانوا اكبر بشكل ملموس في الذكور عنه من الإناث.

الخلاصة: استنتجت هذه الدراسة ان استخدام الاشعة المقطعية قد يكشف بوضوح تشريح الحيز القطنى خارج الام الجافية، وهذا العمل قد يكون دليلا مفيدا لتشريح الفقرات القطنية بين المصريين. وتشير البيانات التي تم الحصول عليها انه ينبغي أن يؤخذ في الاعتبار تقييم حالة الحيزالقطنى خارج الام الجافية قبل وأثناء العمليات الجراحية في العمود الفقري وكذلك فى تشخيص الحالات المرضية في المنطقة القطنية في العمود الفقري.