ORIGINAL ARTICLE

EVALUATION OF TERMINAL VERTEBRAL PLATE ON CERVICAL SPINE AT DIFFERENT AGE GROUPS AND ITS CORRELATION WITH INTERVERTEBRAL DISC THICKNESS

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ABSTRACT

Objective: To evaluate, by means of histomorphometry, terminal vertebral plate thickness, intervertebral disc thickness and its correlation on different age groups, seeking to identify its correlation. Methods: C4-C5 and C5-C6 cervical segments removed from human cadavers of both genders were assessed and divided into five groups of 10-year age intervals, from 21 years old. TVP and intervertebral disc thickness evaluation was made by means of histomorphometry of histological slides stained with hematoxylin and eosyn. Lower C4 TVP, upper C5 TVP, and upper C6 TVP de were compared between each other and to the interposed intervertebral disc thickness between relevant TVP. Results: The thickness of terminal vertebral plates adjacent to the same ID did not show statistic differences. However, the comparison of upper and lower vertebral plates thickness on the same cervical vertebra (C5), showed statistical difference on all age groups studied. We found a statistical correlation coefficient above 80% between terminal vertebral plate and adjacent intervertebral disc, with a proportional thickness reduction of both structures on the different cervical levels studied, and also on the different age groups assessed. Conclusion: Terminal vertebral plate shows a morphologic correlation with the intervertebral disc next to it, and does not show correlation with the terminal vertebral plate on the same vertebra.

Keywords – Spine; Intervertebral disc; Cadaver

INTRODUCTION

The intervertebral disc (ID) is an avascular structure composed of collagen fibers, proteoglycans, and water[(1)]. The nutrition of the intervertebral disc occurs through diffusion of nutrients through the vertebral end plate[(2)].

The vertebral end plate (VEP) is an anatomical

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structure that is present in the vertebrae and is in close proximity to the intervertebral disc (ID). The VEP is formed by a thin layer of cartilage located cranial and caudally between the ID and the cancellous bone of the vertebral body. Its thickness ranges from 0.6 mm to 3 mm in adults. The VEP consists of a hydrated gel of proteoglycan molecules that are interlaced by collagen fibers[3]. The VEP has a structure similar to the ID, showing no direct connections with the vertebral body and connecting directly to the ID through the middle lamella of the annulus fibrosus[4]. The biochemical composition of the VEP is critical to maintaining the nutrition and integrity of the ID. Proteoglycans are the main regulators of the transport of essential solutes in and out of the ID[5]. As the ID is an avascular structure, its maintenance depends on the diffusion of nutrients through the VEP. Besides constituting a barrier to control the selective passage of nutrients into the vertebral disc, the VEP prevents the decrease in proteoglycan concentration of the intervertebral disc material, a factor crucial in the pathophysiology of degenerative disc disease[6]. The VEP also has an important mechanical function. The hydrostatic pressure absorbed by the intervertebral discs during the transmission of axial loads is also partially distributed in the VEP, thus preventing an excessive load on the adjacent vertebral body[7]. In addition, the VEP also acts as an intermediate physical barrier, preventing the collapse of the intervertebral disc against the vertebral body during the homogeneous distribution of hydrostatic loads.

Considering the functional relationship of the VEP and the intervertebral disc, this study was designed with the objective of observing the thickness of the VEP and the thickness of the intervertebral disc in different age groups, trying to identify their correlation.

METHODS

The study was approved by the Ethics Committee of the Hospital das Clínicas, Ribeirão Preto School of Medicine, USP, and by the party responsible for the Death Verification Service of Ribeirão Preto (SVOI, Serviço de Verificação de Óbitos), and for the Center for Forensic Medicine (Cemel, Centro de Medicina Legal).

The material studied was removed during the autopsy of 50 human cadavers (30 males and 20 females), aged 21 to 69 years (45.04 +15.63). The 50 bodies were divided into five age groups, each group consisting of 10 cadavers. Group 1 consisted of cadavers aged between 21 and 30 years, group 2, aged between 31 and 40 years, group 3, aged between 41 and 50 years, group 4, aged between 51 and 60, and group 5, aged between 61 and 70 years.

The vertebral segments chosen for the study were: C4-C5 and C5-C6, considering their degree of mobility and the incidence of degenerative disc disease in these segments (PTGDI).

The vertebral segments chosen for the study were collected during autopsy by cutting across the lower and upper third of the vertebral bodies adjacent to the intervertebral disc selected for the study. The next cut was made in the sagittal plane dividing the anatomical specimen in half. The two halves were sectioned by 3-mm thick parasagittal cuts, with the medial sides of each half being used for the study (Figure 1).

Before the preparation of anatomical specimens, anteroposterior (AP) and lateral radiographs were taken according to the standard technique for observing the presence of disc degeneration. The study excluded those segments that had radiographic signs of disc degeneration. Segments that presented radiographic signs of disc degeneration were excluded from the study. The evaluation of the radiographs

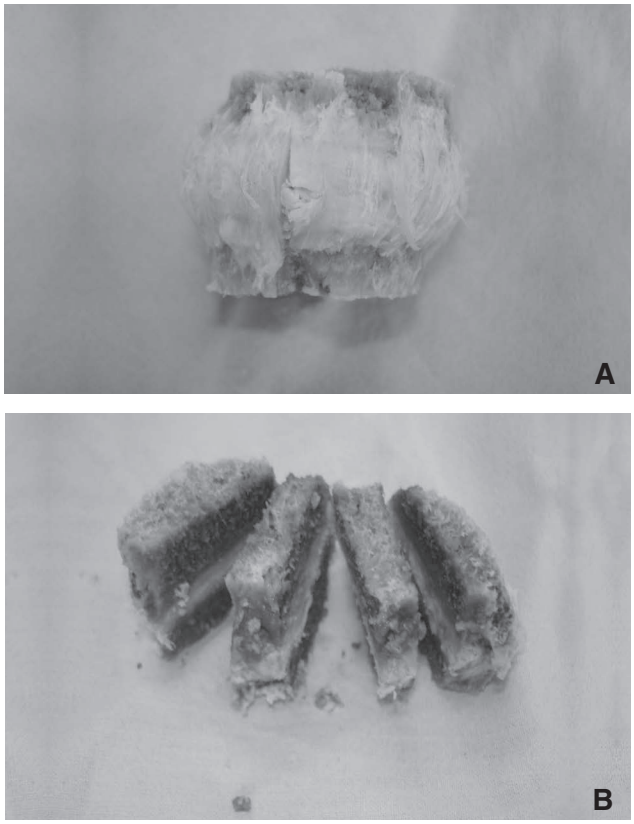

Figure 1 – Front view of the anatomical specimen containing the C5-C6 intervertebral disc and part of the adjacent vertebral bodies before (A) and after (B) making cuts in the sagittal plane.

was performed independently by a radiologist. The parameters used to assess the presence of disc degeneration were: reduction of disc space, subchondral bone sclerosis, presence of vertebral osteophytosis, subchondral resorption of bone cysts, and presence of perilesional osteopenia.

The two 3-mm thick cuts resulting from the sagittal and parasagittal cuts of the anatomical specimen were prepared for histological study by being fixed in 10% neutral formalin, decalcified with trichloroacetic acid, and embedded in paraffin. Cuts of 5µ-thick were made in the sagittal axis of the anatomical specimens, covering the adjacent vertebral bodies and the intermediate intervertebral disc. The sections were stained with hematoxylin and eosin and examined under light microscopy (Figure 2).

The thickness of the ID and the adjacent VEP – the distal upper vertebra VEP and the proximal inferior vertebra VEP – were evaluated by histomorphometry using a Zeiss® ocular integrator with 10x magnification and a 40x lens. The central third of the VEP and the ID was selected to measure the thickness. We studied the relationship between the height of the ID and the height of the adjacent vertebral end plates in the region defined for the study. This correlation was evaluated in the total group of subjects studied and the different age groups. The thickness of the analyzed structures in relation with increasing age was also studied.

Statistical study of the related parameters was performed using analysis of variance (ANOVA), using the PROC GLM procedure of SAS version 9.

The correlation between the thickness of the vertebral end plate and intervertebral disc at different ages was performed by ANOVA, using the PROC GLM procedure of SAS version 9.

RESULTS

The values of the thickness of the VEP and the ID in the cervical segments selected for the study are shown in Table 1.

The height of the C4-C5 and C5-C6 intervertebral disc decreased with increasing age, with statistically significant differences observed between the age groups studied ($p < 0.05$) (Chart 1).

The VEP thickness also showed decreasing values with increasing age, with a statistically significant difference ($p < 0.05$) observed between the age groups evaluated (Chart 2).

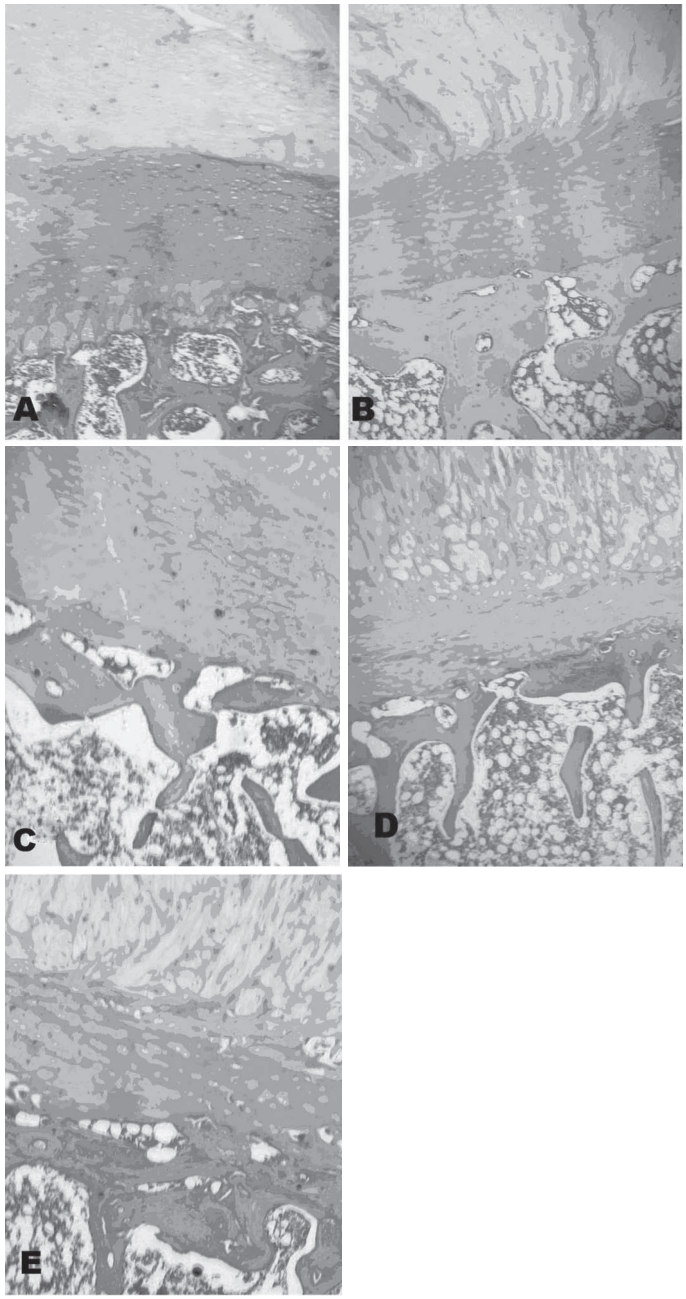

Figure 2 – Photomicrograph illustrating the VEP, the intervertebral disc, and the cancellous bone of the vertebral body at the C4-C5 vertebral level, from an individual in group 1 (A), group 2 (B), group 3 (C), group 4 (D), and group 5 (E), under HE staining and under 400x magnification.

The thickness of the vertebral end plates adjacent to the C4-C5 and C5-C6 ID did not reveal a statistical difference ($p > 0.05$) in all the groups studied. However, a statistical difference was observed between the height of the distal and proximal VEP C5. Thus, the adjacent vertebral end plates at the same ID showed no difference in thickness, though they belonged to different vertebrae. Whereas the VEPs belonging to the same vertebra were in contact with distinct IDs, there were differences in their thicknesses.

Table 1 – Mean values of the thickness of the VEP and the intervertebral disc (C4-C5 and C5-C6) in the vertebral segments studied.

	C4-C5 Level				C5-C6 Level		
	(mm)				(mm)		
Age group	VEP C4	ID	VEP C5		VEP C5	ID	VEP C6
	(inferior)		(superior)		(inferior)		(superior)
1	0.76 + 0.03	4.33 + 0.20	0.78 + 0.02		0.89 + 0.02	4.65 + 0.09	0.93 + 0.02
2	0.75 + 0.02	4.30 + 0.18	0.76 + 0.02		0.86 + 0.03	4.62 + 0.09	0.89 + 0.03
3	0.73 + 0.02	4.27 + 0.18	0.75 + 0.02		0.83 + 0.03	4.59 + 0.09	0.86 + 0.03
4	0.69 + 0.03	4.23 + 0.15	0.71 + 0.03		0.77 + 0.03	4.53 + 0.07	0.81 + 0.03
5	0.64 + 0.02	4.08 + 0.10	0.65 + 0.02		0.68 + 0.02	4.41 + 0.05	0.70 + 0.07
Total	0.71 + 0.04	4.24 + 0.08	0.73 + 0.08		0.80 + 0.07	4.56 + 0.08	0.83 + 0.07

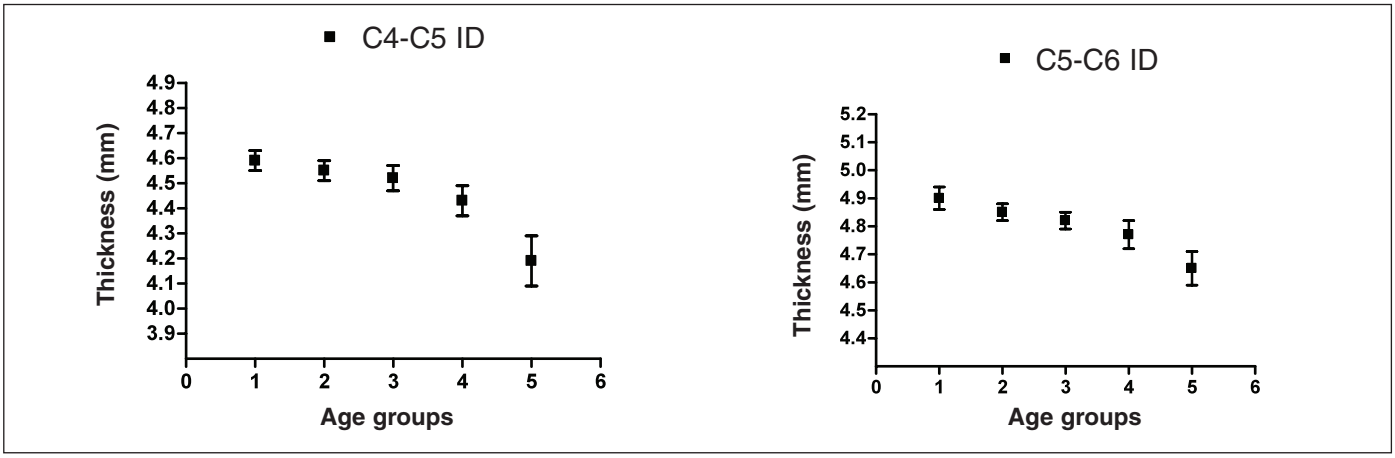

Chart 1 – The mean values and standard deviation of the thickness of intervertebral discs C4-C5 and C5-C6 are illustrated.

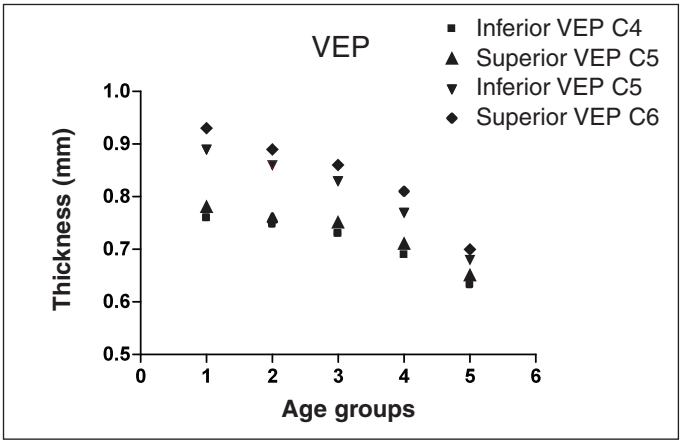

Chart 2 – Values of the average thickness of the VEP studied at different levels and in different age groups. Note the correlation between the thickness of the adjacent VEP at the same ID.

The correlation coefficient between the height of the ID and the height of the adjacent VEP remained constant in the different age groups, as seen in Table 2. The reduction of ID height with increasing age was accompanied by the reduction of the height of the VEP, thereby maintaining the correlation.

DISCUSSION

The ID is an avascular structure and its nutrition occurs by diffusion of nutrients through the VEP[8]. Diffusion is not uniform through the VEP and the central region has been considered the site of the VEP in which the nutrition of the ID would be more critical and with a higher metabolic rate. This was the reason central part of the VEP and the ID was chosen for the study.

Studies of the nutrition and metabolism of the ID have shown that the central region of the VEP has a higher permeability to the diffusion of small solute molecules, while the lateral portion is relatively impermeable[9]. This permeability is attributed to the presence of a greater number of vascular endings in the central region of the cancellous bone of the vertebral body adjacent to the VEP. Crock et al. demonstrated that the main form of transport of small solute molecules occurs through the diffusion process through the central portion of the VEP[10]. However,

Table 2 – Values of the correlation coefficient between the VEP and ID adjacent in segments of the cervical spine related to the study. Note that the correlation coefficient was greater than 80% in all age groups.

			Age groups				
			1	2	3	4	5
Correlation coefficient	C4	mean	0.88	0.86	0.84	0.84	0.86
		SD	0.02	0.03	0.04	0.02	0.05
VEP X ID							
	C5 susp	mean	0.87	0.87	0.83	0.85	0.84
		SD	0.03	0.05	0.02	0.02	0.04
	C5 inf	mean	0.89	0.88	0.86	0.86	0.83
		SD	0.06	0.04	0.01	0.03	0.05
	C6	mean	0.88	0.85	0.84	0.85	0.88
		SD	0.05	0.06	0.02	0.02	0.02

other factors interfere with the passage of solutes from the VEP to the ID.

The biochemical composition of the VEP plays an important functional role in maintaining the integrity of the ID, and the proteoglycans are considered major regulators of the passive transport of essential solutes into and out of the ID, because of their negative charges[11]. Similarly to the nucleus pulposus, the proteoglycan constituents of the VEP, besides participating in the retention of water, confer a predominantly negative charge to the VEP and the nucleus pulposus, facilitating the diffusion of small negatively charged solutes such as oxygen and glucose, as well as the diffusion of positively charged solutes such as sodium and calcium. However, large negatively charged molecules such as immunoglobulins and enzyme macromolecules are relatively difficult to diffuse into the nucleus pulposus. Thus, the number of vascular endings in the central third of the VEP would be the two main factors influencing the passage of solutes by the VEP to the nucleus pulposus[6].

Considering the current conception of ID nutrition and the role of the VEP in this process, we established the hypothesis that there could be morphological correlation between the thickness of the VEP and ID, due to the intimate functional relationship between these structures. The established hypothesis was confirmed in the initial evaluation, and a correlation was observed between the thickness of the VEP and the height of the intermediate ID on all levels and in all age groups studied. We observed that the thickness of the VEP was not correlated in the same vertebra, but with the ID with which the VEP was in contact. This observation further supports the functional relationship between the VEP and the ID.

With increasing age, there is progressive reduction in the thickness of the ID, the VEP, and VEP permeability, resulting in the gradual reduction of disc nutrition. Progressive changes in the composition of the ID and the VEP of monkeys of increasing age were observed in association with a decreased amount of glycosaminoglycan sulfate and chondroitin sulfate, resulting in a reduction in the thickness of the VEP and ID, as well as the permeability of small solutes that nurtured the nucleus pulposus[12]. Similar changes in ID and VEP were observed in humans[13]. Our results confirmed this observation and the possible relationship between the ID and VEP. The proportional reduction of these structures with age was observed in our study.

The hypothesis that the thickness of the VEP is correlated with the thickness of the ID was confirmed in this study. This correlation has been established from a functional perspective, and a new approach to the understanding of phenomena related to nutrition and degeneration of ID can be established with the observed morphological results.

CONCLUSION

At the cervical levels assessed, progressive and proportional reduction of the thickness of the adjacent VEP and ID were observed in the different age groups studied. The vertebral end plate is morphologically correlated with the intervertebral disc with which it comes into contact, and shows no correlation with the vertebral end plate of the same vertebra.

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