Iranian Journal of Veterinary Research, Shiraz University, Vol. 9, No. 4, Ser. No. 25, 2008

Histomorphometric study of the spinal cord segments in the chick and adult male ostrich (*Struthio camelus*)

Rahmanifar, F.[1*]**; Mansouri, S. H.**[2] **and Ghazi, S. R.**[2]

[1]Graduated from School of Veterinary Medicine, Shiraz University, Shiraz, Iran; [2]Department of Anatomical Sciences, School of Veterinary Medicine, Shiraz University, Shiraz, Iran

[*]**Correspondence:** F. Rahmanifar, Graduated from School of Veterinary Medicine, Shiraz University, Shiraz, Iran. E-mail: f.rahmanifar@yahoo.com

(Received 29 Apr 2008; revised version 8 Sept 2008; accepted 10 Sept 2008)

Summary

In this study, the vertical, transverse and oblique diameters of the spinal cord segments (C_1, C_6, C_{12}, C_{18}, T_1, T_4, L_1, L_4, L_6 and L_8) and the ratio of gray matter to white matter in chick (l month) and adult (18 months) male ostriches, each group consisted of 3 animals, were measured with standard micrometric method using 6 µm thick sections by light microscope. With advancement of age, the ratio of gray matter to white matter was reduced but the diameters of spinal cord segments were increased. Statistically, there were significant differences in parameters measured between the two age groups ($P<0.05$).

Key words: Spinal cord segments, Gray matter, White matter, Ostrich

Introduction

According to Streeter (1919), in the early stages of development in human, the spinal cord and the vertebral column grow side by side in a metameric manner but this growth at 30 millimeter embryonic stage interrupts and the vertebral column grows more rapidly than the spinal cord. The widest spinal cord segments of adult human were identified at 6th cervical segment and 12th thoracic segment, 38 and 36 millimeters, respectively (Williams *et al*., 1989). In addition, Sharma and Rao (1971) and Malinska *et al*. (1976) measured the spinal cord of buffalo and mole, respectively and reported different diameters of the spinal cord segments.

The allometric growth rate of the spinal cord in relation to the vertebral column was also studied in one humped male camel (Ghazi *et al*., 1998), rabbit (Ghazi *et al*., 2000a) male and female adult fowl and turkey (Ghazi *et al*., 2000b), male and female domestic goose (Ghazi *et al*., 2000c) and newborn male and female laboratory animals (Ghazi *et al*., 2001).

The spinal cord segments were also studied microscopically, in prenatal and postnatal ages of male cat and male dog (Mansouri *et al*., 2001, 2002) and adult male and female pigeon (Khaksar *et al*., 2002).

No information appears to be available on histomorphometric study of the various regions of the spinal cord in chick and adult male ostrich; hence the present study was undertaken.

Materials and Methods

Six male ostriches of 2 different ages (1 and 18 months, 3 animals in each group) were selected. All animals were killed humanly and then they were eviscerated. The skull and vertebral column along with intact brain and spinal cord were dissected.

A piece of cranium was removed, and 10% buffered formalin solution was injected into the lateral ventricles of brain. In this way, the fixative was spread easily in all ventricles, central canal of spinal cord and subarachnoid space. The specimens were then transferred into big containers of fresh buffered formalin solution, and 48 h later, the spinal cord segments were further dissected free without damaging the meningeal layers.

After identifying the spinal cord segments, the 1st, 6th, 12th and 18th cervical, 1st and 4th thoracic and 1st, 4th, 6th and 8th lumbar spinal cord segments were removed. Subsequently, 6 µm thick serial paraffin sections were prepared from each spinal segment and stained with haematoxylin and eosin. The vertical, transverse and oblique diameters of the spinal cord segments were measured using ocular micrometer. The ocular graticule lattice line was used to determine the ratio of gray matter to white matter (Cope, 1982), and then data were analyzed by independent sample t-test, paired sample t-test and Tamhane using SPSS software.

Results

The results of the present study indicated an increase in transverse, vertical and oblique diameters of the spinal cord segments from chick to adult male ostrich (Table 1).

The longest to shortest vertical diameters of spinal cord segments in chick ostriches were identified as follows: 6th, 4th, 8th and, 1st lumbar, 18th cervical, 1st and 4th thoracic and 12th, 6th and 1st cervical segments.

The 4th lumbar spinal cord segment had the longest vertical diameter in adult male ostrich followed by 6th lumbar, 18th cervical, 1st and 8th lumbar, 1st thoracic, 12th cervical, 4th thoracic and 6th and 1st cervical segments.

The 8th lumbar spinal cord segment had the longest transverse diameter in chick male ostrich followed by 6th, 4th and 1st lumbar, 1st cervical, 1st thoracic, 18th and 12th cervical, 4th thoracic and 6th cervical segments. The 6th lumbar spinal cord segment had the longest transverse diameter in adult male ostriches followed by 8th and 4th lumbar, 1st cervical, 1st lumbar, 1st thoracic, 18th cervical, 4th thoracic and 12th and 6th cervical segments.

The longest oblique diameter in chick male ostriches was observed in the 8th lumbar spinal cord segment followed by 6th, 4th and 1st lumbar, 1st thoracic, 18th, 1st and 12th cervical, 4th thoracic and 6th cervical segments.

The 6th lumbar spinal cord segment had the longest oblique diameter in adult male

Table 1: Transverse, vertical, and oblique diameters (Mean ± SD, in µm) of the spinal cord in different segments in two age groups of the male ostrich

Segments	Chick			Adult		
	transverse	vertical	oblique	transverse	vertical	oblique
C1	3637.1 ±131.5^{a}	2503.2 ±32.9^{a}	3310.7 ±197.2^{ab}	6508.6 ±404.4^{a}	3885.3 ±409.2^{a}	6293.3 ±380.9^{ab}
C6	2929.0 ±134.5^{b}	2597.9 ±201.7^{abc}	2795.0 ±134.5^{c}	5042.6 ±109.7^{h}	4343.4 ±244.4^{bj}	4995.2 ±148.7^{cd}
C12	3124.0 ±67.2^{c}	2657.0 ±134.5^{b}	2994.0 ±67.2^{d}	5274.4 ±283.0^{bc}	4572.4 ±235.9^{bcde}	5047.6 ±220.7^{e}
C18	3414.7 ±266.4^{d}	3043.4 ±427.2^{cde}	3365.6 ±327.0^{ab}	5680.7 ±315.6^{bde}	5050.6 ±374.5^{cfgh}	5575.5 ±210.1^{cf}
T1	3440.7 ±197.2^{d}	2923.6 ±65.7^{d}	3440.7 ±197.2^{b}	6121.3 ±237.5^{adf}	4749.3 ±365.0^{fi}	6044.5 ±325.2^{a}
T4	2966.9 ±139.4^{b}	2712.7 ±125.8^{c}	2903.3 ±164.0^{e}	5460.1 ±523.0^{ce}	4351.5 ±275.6^{j}	5256.0 ±598.3^{def}
L1	3861.0 ±403.7^{e}	3180.7 ±239.4^{e}	3680.4 ±331.2^{f}	6177.3 ±362.9^{f}	4967.9 ±385.8^{dg}	6105.57 ±426.0^{b}
L4	6286.2 ±558.6^{f}	4175.6 ±95.9^{f}	5230.7 ±828.9^{g}	9629.6 ±799.8^{g}	6769.8 ±328.9^{e}	9526.3 ±768.5^{g}
L6	7058.7 ±267.7^{g}	4269.8 ±135.7^{g}	6698.79 ±350.8^{h}	10937.5 ±966.0^{i}	6112.6 ±444.3^{k}	10860.6 ±947.0^{h}
L8	7424.4 ±543.3^{h}	3952.0 ±213.6^{h}	7228.0 ±882.3^{i}	10138.8 ±564.6^{g}	4946.7 ±317.7^{hi}	10072.6 ±680.1^{gh}

Similar alphabets in columns shows non-significant differences (P>0.05). C: Cervical, T: Thoracic and L: Lumbar ostriches followed by 8th and 4th lumbar, 1st cervical, 1st lumbar, 1st thoracic, 18th cervical, 4th thoracic and 12th and 6th cervical segments.

Statistical analysis showed significant differences in vertical, transverse and oblique diameters of spinal cord segments between chick and adult male ostriches ($P<0.05$).

Comparing the vertical, transverse and oblique diameters of spinal cord segments in the two age groups revealed that the transverse and oblique diameters are consistently longer than the vertical diameters. The transverse diameter of spinal cord in chicks was significantly different in various segments except for 6th cervical with 4th thoracic and 18th cervical with 1st thoracic segments. The oblique diameter of spinal cord in chicks was also significantly different in various segments except for 1st cervical with 18th cervical and 1st thoracic, and 1st thoracic with 18th cervical segments.

The vertical diameter of spinal cord in chicks was also significantly different in various segments except for 1st cervical with 6th cervical, 6th cervical with 12th cervical and 4th thoracic, 4th thoracic with 12th cervical, 1st thoracic with 18th cervical and 18th cervical with 1st lumbar segments ($P<0.05$).

The transverse diameter of spinal cord in adult ostriches was significantly different in various segments except for 1st cervical with 1st thoracic, 12th cervical with 18th cervical and 4th thoracic, 18th cervical with 1st lumbar, 1st and 4th thoracic, 1st lumber with 1st thoracic and 4th lumbar with 8th lumbar segments.

The vertical diameter of spinal cord in adult ostriches was also significantly different in various segments except for 6th cervical with 12th cervical and 4th thoracic, 12th cervical with 18th cervical, 1st and 4th thoracic, 18th cervical with 1st thoracic, 1st and 8th lumbar, 1st thoracic with 1st lumbar and 8th lumbar with 1st thoracic and 1st lumbar segments.

The oblique diameter of spinal cord in adult ostriches was also significantly different in various segments except for 1st cervical with 1st thoracic, 1st cervical with 1st lumbar, 6th cervical with 18th cervical, 6th cervical with 4th thoracic, 12th cervical with 4th thoracic, 18th cervical with 4th thoracic and 8th lumbar with 4th and 6th lumbar segments ($P<0.05$).

The ratio of gray matter to white matter was decreased from chick to adult age groups (Table 2). The largest to smallest ratio of gray matter to white matter of spinal cord segments in chick ostriches are as follows: 8th, 6th and 4th lumbar, 1st cervical, 1st lumbar, 4th thoracic with 1st thoracic together and 18th, 12th and 6th cervical segments.

Table 2: The proportion of gray matter to white matter of the spinal cord (Mean ± SD) in different segments in two age groups of the male ostrich

Segments	Chick	Adult
C1	0.62 ± 0.12^a	0.15 ± 0.01^a
C6	0.19 ± 0.01^b	0.10 ± 0.02^b
C12	0.21 ± 0.02^c	0.11 ± 0.04^c
C18	0.22 ± 0.02^d	0.12 ± 0.02^d
T1	0.26 ± 0.01^e	0.13 ± 0.03^c
T4	0.26 ± 0.01^e	0.14 ± 0.01^e
L1	0.33 ± 0.01^f	0.16 ± 0.01^f
L4	0.68 ± 0.01^g	0.38 ± 0.01^g
L6	0.73 ± 0.02^h	0.40 ± 0.02^g
L8	0.89 ± 0.01^i	0.41 ± 0.03^h

Similar alphabets in columns shows non-significant differences ($P>0.05$)

The ratio of gray matter to white matter of spinal cord segments in adult male ostriches decreased as follows: 8th, 6th, 4th and 1st lumbar, 1st cervical, 4th and 1st thoracic and 18th, 12th and 6th cervical.

Statistical analysis showed significant differences in the ratio of gray matter to white matter of spinal cord segments between chick and adult male ostriches ($P<0.05$).

The ratio of gray matter to white matter of spinal cord segments in each age group was also significantly different. However, some exceptions including 1st thoracic with 4th thoracic in chicks group and 12th cervical with 18th cervical in adults group were noticed.

Discussion

The maximum transverse and oblique diameters of spinal cord segments in male adult ostriches were observed in the 6th lumbar segment and the maximum vertical diameter was in the 4th lumbar segment. In chick male ostriches, the maximum transverse and oblique diameters belonged to 8th lumbar, and the maximum vertical diameter was observed in the 6th lumbar segment. The minimum transverse and oblique diameters belonged to the 6th cervical segment in both age groups, while the minimum vertical diameter was observed in the 1st cervical segment in both chick and adult ostriches.

The results in both age groups indicated that the diameters of spinal cord are increased with age, therefore the spinal cord becomes thicker in advanced ages which can be due to the innervation of large body mass.

The long transverse, vertical and oblique diameters in lumbar region, in both age groups, may be due to involvement of this region in the formation of the lumbosacral plexus and therefore, its innervations to the hind limb.

The appearance of oval shape of 1st cervical segment noticed in the present study can be due to the minimum vertical diameter of this segment in both age groups. The minimum transverse and oblique diameters of the 6th cervical segment, in both age groups, can be due to the limited innervations of this segment. The results of the present study are in agreement with the previous study on the measurement of the oblique diameter of lumbar area in male and female fowl (Ghazi *et al*., 2000b). They also reported that the largest transverse diameter in male and female fowl belonged to the lumbosacral area, whereas the shortest vertical and transverse diameters were indicated in coccygeal area. In addition, they found that the maximum vertical and transverse diameters in male and female turkey were obtained from lumbosacral area and the minimum vertical and transverse diameters belonged to the coccygeal area, again indicating the involvement of the lumbosacral region supplying the hind limb (Ghazi *et al*., 2000b).

The results are not in agreement with previous study on spinal cord segments in male and female goose, which indicated that the largest transverse and vertical diameters belonged to the last cervical segment, whereas the shortest transverse and vertical diameters were identified in the first coccygeal segment (Ghazi *et al*., 2000c) indicating the potential activity of the cervical region in innervation of the thoracic limb.

It has also been reported in prenatal and postnatal male cat and male dog (Mansouri *et al*., 2001, 2002) that the diameter of spinal cord was increased with age and became thicker in advanced ages. These authors reported that the maximum diameters of spinal cord segments belonged to 8th cervical and 7th lumbar segments in both animals indicating the involvement of these segments in the formation of the brachial and lumbosacral plexuses, respectively.

Khaksar *et al*. (2002) studied the spinal cord segments in male and female adult pigeon and found that the longest transverse diameter of spinal cord segments in male and female adult pigeon belonged to the lumbosacral and 12th cervical segments, respectively. They also reported that the shortest transverse diameter was related to the 1st coccygeal segment in male and female pigeon, and the maximum and minimum vertical diameters in male and female pigeon were identified in 12th cervical and 1st coccygeal segments, respectively.

The comparison of the ratio of gray matter to white matter between the two age groups revealed that the maximum and minimum ratio were related to 8th lumbar and 6th cervical segments, respectively and the ratio of gray matter to white matter decreased with increasing age. In addition, the ratio of gray matter to white matter in lumbar region was more than cervical and thoracic regions. This could be more likely due to the outstanding role of this region in innervation of pelvic limb.

The maximum and minimum ratio of gray matter to white matter, in male and female fowl and turkey, were reported to be in lumbosacral area and 1st cervical segment, respectively (Ghazi *et al*., 2000b). The maximum and minimum ratio of gray matter to white matter in adult domestic goose were indicated in mid-lumbosacral area and 8th cervical segment, respectively (Ghazi *et al*., 2000c). This feature showing again the potential activity of the lumbosacral area.

It can be concluded that the transverse and oblique diameters of each spinal cord segment are larger than the vertical diameter. The largest measured diameters and ratio of gray matter to white matter were identified in lumbar areas, and this ratio was also greater in chick than in adult ostriches.

Acknowledgement

We are grateful to the Shiraz University for providing financial assistance.

References

Cope, GH (1982). *Stereological techniques and their application to the gastrointestinal tract and its glands*. 5th Edn., Ireland, Elsevier Scientific Pub., P: 2.

Ghazi, SR; Gholami, S and Khaksar, Z (1998). Allometric growth of the spinal cord in relation to the vertebral column during postnatal life in one humped male camel (*Camelus dromedarius*). J. Camel. Prac. Res., 5:75-79.

Ghazi, SR; Khaksar, Z; Gholami, S and Barazandeh, M (2000a). Study on the allometric growth rate of the spinal cord in relation to the vertebral column in rabbit. University of Tehran, J. Fac. Vet. Med., 55: 25-28.

Ghazi, SR; Khaksar, Z; Gholami, S; Najarzadeh, MR and Ghaisari, HR (2000b). Allometric growth rate of the spinal cord in relation to the vertebral column in the male and female fowl (*Gallus domesticus*) and turkey (*Meleagris gallopavo*). Iranian J. Vet. Res., 1(1): 39-52.

Ghazi, SR; Khaksar, Z; Gholami, S and Mohammadian, N (2000c). Allometric growth of the spinal cord in relation to the vertebral column in the male and female domestic goose (*Anser domesticus*). University of Tehran, J. Fac. Vet. Med., 55: 45-48.

Ghazi, SR; Khaksar, Z and Gholami, S (2001). Comparative study of the allometric growth rate of the spinal cord in relation to the vertebral column in newborn male and female laboratory animals: rabbit, guinea pig and rat. Iranian J. Vet. Res., 2(1): 18-24.

Khaksar, Z; Ghazi, SR and Gholami, S (2002). Quantitative study of the vertebral column and spinal cord in adult male and femal pigeons. University of Tehran, J. Fac. Vet. Med., 57: 39-42.

Malinska, J; Hubackova, E and Malinsky, J (1976). A topographical and quantitative anatomical study of the spinal cord in the mole. Acta University Palacky Olomus Faculty Med., 76: 169-178.

Mansouri, SH; Ghazi, SR and Monsefi, M (2001). Histomorphometric study of the various segments of the spinal cord in prenatal and postnatal ages of the male cat. Iranian J. Vet. Res., 3(2): 105-117.

Mansouri, SH; Ghazi, SR and Ay, J (2002). Histomorphometric study of the various segments of the spinal cord in prenatal and postnatal ages of the male dog. Iranian J. Vet. Res., 3(2): 141-149.

Sharma, DN and Rao, GS (1971). Anatomy of the spinal cord segments of buffalo (*Bubalus bubalis*). Acta Anat., 79: 51-59.

Streeter, GL (1919). Factors involved in the formation of the filum terminale. Am. J. Anat., 25: 1-11.

Williams, P; Warwick, R; Dyson, M and Bannister, L (1989). *Gray's anatomy*. 32th Edn., Churchill Livingston. P: 922.