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Topographic anatomy of the spinal cord and vertebromedullary relationships in *Mazama gouazoubira* Fisher, 1814 (Artiodactyla; Cervidae)

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ABTRACT. To gain an understanding of the detailed anatomical aspects of *Mazama gouazoubira* (brocket deer), this paper describes the relationships between its spinal cord and the vertebral canal, adding information with a clinical and surgical approach. Three specimens of *M. gouazoubira* were prepared following the methods normally used in anatomy. The epaxial muscles and vertebral arches were removed to expose the spinal cord and the spinal nerve roots. The dimensions of the medullary segments were measured using a pachymeter with 0.05 mm precision. The spinal cord is cylindroidal, dorsoventrally flattened, with an average craniosacral length of 656.27 mm, and has two dilatations corresponding to the cervical and lumbar intumescences. The cervical, thoracic, lumbar and sacrocaudal segments showed an average length of 175.07, 226.03, 123.47 and 43.63 mm, with indices of 28.02, 35.34, 19.68 and 6.93%, respectively. The medullary cone, whose average length is 46.27 mm, begins between L2 and L3 and ends between S1 and S2, with a mean index of 7.53%. The overall average distance between the nerve roots of the cervical, thoracic and lumbosacral segments was 2.23, 2.06 and 1.98 cm, respectively.

Key words: brocket deer, neural system, skeletopy, spinal cord.

RESUMO. Anatomia topográfica da medula espinal e relações vértebro-medulares em *Mazama gouazoubira* Fisher, 1814 (Artiodactyla; Cervidae). Propondo conhecer os aspectos anatômicos pormenorizados de *Mazama gouazoubira* (veado catingueiro), o presente trabalho descreve as relações entre sua medula espinal e o canal vertebral, adicionando informações com enfoque clínico-cirúrgico. Utilizaram-se três espécimes de *M. gouazoubira* que foram preparados seguindo métodos usuais em anatomia. Retirou-se a musculatura epiaxial e os arcos vertebrais para a exposição da medula espinal e raízes dos nervos espinais. As dimensões dos segmentos medulares foram obtidas utilizando um paquímetro de precisão 0,05 mm. A medula espinal possui a forma cilindróide, aplanada dorsoventralmente, com comprimento crânio-sacral médio de 656,27 mm, possui duas dilatações correspondentes às intumescências cervical e lombar. Os segmentos cervical, torácico, lombar e sacro-caudal apresentam 175,07; 226,03; 123,47 e 43,63 mm de comprimento médio, com índices de 28,02; 35,34; 19,68 e 6,93% respectivamente. O cone medular de comprimento médio 46,27 mm inicia-se entre L2 e L3 e termina em S1 e S2, com índice médio de 7,53%. A média geral obtida para a distância entre as raízes dos nervos dos segmentos cervical, torácico e lombossacral foi de 2,23; 2,06 e 1,98 cm, respectivamente.

Palavras-chave: medula espinal, veado catingueiro, esqueletopia, sistema neural.

Introduction

Brazil has the most varied mastofauna of the entire Neotropical region (ROCHA; DALPONTE, 2006). Cervids are a group of animals that belong to the order Artiodactyla and the family Cervidae is distributed worldwide in a variety of biomes, although they are becoming rare in several areas of natural occurrence (MARQUES et al., 2007). According to Melo et al. (2007), six different genera are endemic to South America: *Blastocerus*, *Hippocamelus*, *Ozotoceros*, *Pudu*, *Odocoileus* and *Mazama*. The cervid *Mazama gouazoubira*, known popularly as brocket deer, is grayish brown and the ventral side of its tail is white. Its antlers are short simple straight spikes, and it has characteristic odor glands behind its eyes and in its hocks (NASCIMENTO et al., 2000).

The degree of threat and ecological importance of this group have highlighted the need to include information about these animals in environmental inventories and diagnoses. Moreover, knowledge of the topography of the spinal cord is indispensable in clinical practice for the diagnosis, prognosis and treatment of vertebromedullary injuries, and it is sometimes necessary to locate injuries of the central nervous system at a vertebral level, a method that is possible by associating specific sensory and motor deficiencies in a given spinal segment (DYCE et al., 2004; MACHADO, 2003), especially in anesthesiology, in order to block specific spinal nerves (DYCE et al., 2004).

The anatomy of the medullary segments has been studied and described in humans (WILLIAMS et al., 1995), felines, monkeys (CARVALHO-BARROS et al., 2003), sheep (RAO, 1990), coatis (GREGORES et al., 2010), freshwater dolphins (MACHADO et al., 2003) and sea lions (FETTUCCIA; SIMÕES-LOPES, 2004), but the pattern of the medullary topography of *M. gouazoubira* has not yet been reported. Several aspects such as the macroscopy of the brachial plexus (MELO et al., 2007), the biology (RICHARD; JULIÁ, 2001) and the incidence of parasites (DEEM et al., 2004; MARQUES et al., 2007) of this deer have been reported, but there is a paucity of information about its anatomy, particularly about its nervous system.

Considering the importance of detailed knowledge about the comparative anatomy of the nervous system of vertebrates and its use in veterinary medicine, the purpose of this investigation was to describe the segments of the spinal cord and the vertebromedullary relationships in *M. gouazoubira.*

Material and methods

This study was based on three specimens of *M. gouazoubira* which were sent by the Environmental Police to the Federal University of Uberlândia Faculty of Veterinary Medicine in Uberlândia, State of Minas Gerais, Brazil. The cervids were dubbed E1 – adult female, E2 – adult male, and E3 – young female.

The skin, epaxial muscles, vertebral arches and epidural fatty tissue were removed from the back, exposing the spinal cord and the spinal nerve roots. The craniosacral (CS) length of the animals was measured with a pachymeter with 0.05 mm precision, starting from the external occipital protuberance to the sacrocaudal interarch space. The medullary segments evaluated were the cervical (CS), thoracic (TS), lumbar (LS), and sacrocaudal (SCS) segments and the medullary cone (CM). The indices of each segment of the spinal cord were then calculated, in percentage, by dividing the length of the medullary segment by the sacrocaudal length. The mean lengths of the medullary segments were determined by applying a simple descriptive statistic, and the distances between the nerve roots were determined based on an analysis of variance and on Tukey's test with 5% significance.

Results and discussion

Table 1 lists the mean values of the length of the segments of the spinal cord of *M. gouazoubira*, while Table 2 shows the percent index of each segment in relation to the craniocaudal length, and Table 3 indicates the topography of the medullary segments.

Table 1. Length, in millimeters, of the cervical (CS), thoracic (TS), lumbar (LS), sacrocaudal (SCS), medullary cone (CM), and craniosacral (CS) segments and the spinal cord (SpC) of *M. gouazoubira*.

	E1	E2	E3
SC	184.4	173.9	166.9
TS	255.4	228.4	194.3
LS	139.1	123.3	108.0
SCS	39.0	37.7	54.2
CM	35.1	44.3	59.4
CS	658.8	652.4	567.6
SpC	617.9	563.3	523.4

Table 2. Index, in percentage, of the cervical (CS), thoracic (TS), lumbar (LS), and sacrocaudal (SCS) segments and the medullary cone (CM) in relation to the craniosacral (CS) length of *M. gouazoubira*.

	E1	E2	E3
CS	28.00	26.65	29.40
TS	38.77	35.01	32.23
LS	21.11	18.90	19.03
SCS	5.46	5.78	9.55
CM	5.33	9.55	10.46

Table 3. Topography of the beginning (B) and end (E) of the cervical (CS), thoracic (TS), lumbar (LS) and sacrocaudal (SCS) segments of the spinal cord and the medullary cone (CM) in M. gouazoubira. FM- foramen magnum, C7- seventh cervical vertebra, T1- first thoracic vertebra, T13- thirteenth thoracic vertebra, L1- first lumbar vertebra, L2- second lumbar vertebra, L3- third lumbar vertebra, L5- fifth lumbar vertebra, L6- sixth lumbar vertebra, S1- first sacral vertebra, S2- second sacral vertebra, S3- third sacral vertebra, S4- fourth sacral vertebra.

	E1		E2		E3	
	B	E	B	E	B	E
CS	FM	T1	FM	T1	FM	C7
TS	T1	T13	T1	L1	C7	L1
LS	T13	L5	L1	L5	L1	L5
SCS	L5	S3	L5	S4	L5	S3
CM	L6/S1	S2/S3	L6	S2/S3	L2	S2

The spinal column of *M. gouazoubira* has seven cervical, thirteen thoracic, six lumbar, and five sacral vertebrae. Thirty-two pairs of spinal nerves were measured, eight cervical, thirteen thoracic, six lumbar and five sacral pairs.

In domestic animals, the spinal cord is divided into cervical, thoracic, lumbar, sacral, and caudal or coccygeal segments. Wild animals such as *Chrysocium brachiurus* (MACHADO et al., 2002), *Arctocephalus australis* (MACHADO et al., 2003), *Tamandua tetradactila* and *M. gouazoubira* show the same segmentation, but the two last segments are considered a single fraction (Figures 1 and 2).

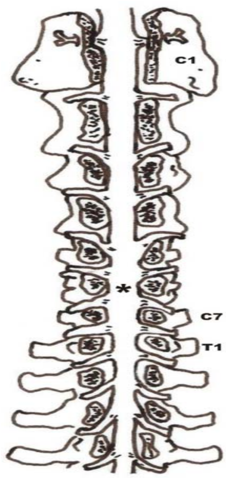

Figure 1. Schematic diagram of the spinal cord of *M. gouazoubira*. First cervical vertebra (C1), seventh cervical vertebra (C7), first thoracic vertebra (T1), and cervical intumescence (*).

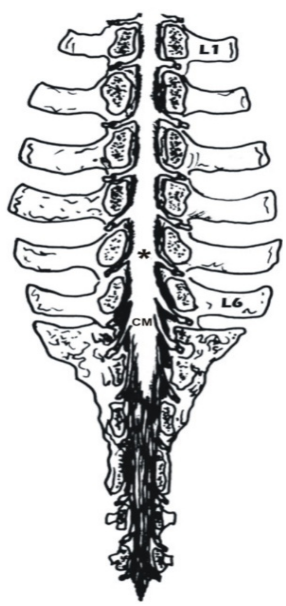

Figure 2. Schematic diagram of the lumbar segment and sacrocaudal segments of the spinal cord of *M. gouazoubira*. First lumbar vertebra (L1), sixth lumbar vertebra (L6), lumbar intumescence (*), and medullary cone (CM).

The spinal cord of *M. gouazoubira* is an elongated and cylindroidal mass, dorsoventrally flattened, with two dilatations called the cervical and lumbar intumescences, like those of other animals (Figures 1 and 2). The cord ends between S3 and S4 in *M. gouazoubira* (Table 3), at the level of the second sacral vertebra in horses, cattle (DEEM et al., 2004) and sheep (RAO, 1990), in the cranial portion of the seventh lumbar vertebra in dogs (GETTY et al., 1986), at S3 in buffalos (RAO, 1976) and impalas (RAO et al., 1993), and between L1 and L2 in humans (WILLIAMS et al., 1995).

In the relationship between the medullary segments and the length of the vertebral column, the indices of the cervical, thoracic, lumbar and sacrocaudal segments are, respectively, 18.47, 35.26, 34.17 and 12.02% in *Oryctolagus cuniculus* (SANTOS et al., 1999), 22.40, 49.32; 24.07 and 3.68% in *Felis concolor*, 21.97, 50.83, 11.20 and 15.97% in *Tamandua tetradactyla*, and 28.02, 35.34, 19.68 and 6.93% in *M. gouazoubira* (Table 2).

The average lengths of the medullary segments are 175.07 mm for the cervical, 226.03 mm for the thoracic, 123.47 mm for the lumbar and 43.63 mm for the sacrocaudal segment. Notable differences have been found between the indices of the segments of the spinal cord of *M. gouazoubira* and those of other species.

The funneling of the lumbar segment of the spinal cord originates in the medullary cone (ERHART, 1992; GETTY et al., 1986; GODINHO et al., 1987), which begins between L5 and L6 in *Equus caballus* and *Chrysocium brachiurus* (MACHADO et al., 2002), between L6 and L7 in *Oryctolagus cuniculus* (SANTOS et al., 1999), in L5 of *Arctocephalus australis* (MACHADO et al., 2003), L6 of *Herpailurus yagouaroundi* (CARVALHO et al., 2003) and *Felis catus* (CÂMARA-FILHO et al., 1998), varies between L5 and L7 in pacas (SCAVONE et al., 2007) and between L2 and L6 in *M. gouazoubira* (Table 3, Figures 2 and 3).

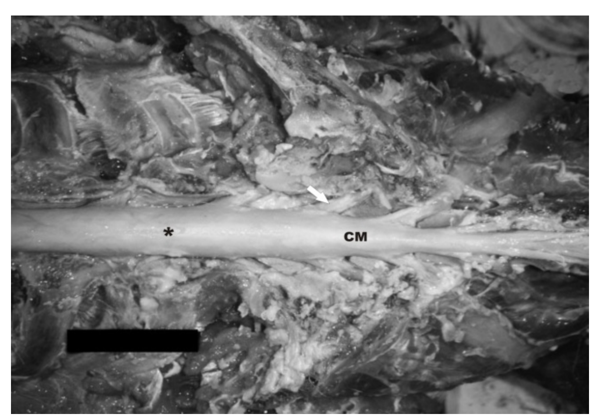

Figure 3. Caudal portion of the spinal cord of *M. gouazoubira*. Lumbar intumescence (*), medullary cone (CM), and root of the second sacral nerve (arrow). Bar: 3 cm.

The apex of the medullary cone occurs between the fifth or sixth lumbar vertebra in pigs, between the sixth or seventh lumbar vertebra in dogs, the second sacral vertebra in horses, and more variably between the sixth lumbar and third sacral vertebrae in cats (DYCE et al., 2004). However, Câmara-Filho et al. (1998) describe the end of the medullary cone in *Felis catus* as occurring in the first sacral vertebra. In *A. australis*, the medullary cone ends in the body of the sixth lumbar vertebra (MACHADO et al., 2002), in *H. yagouaroundi* in the second lumbar vertebra (CARVALHO et al., 2003), in pacas it varies between L7 and S1 (SCAVONE et al., 2007), and in rabbits (SANTOS et al., 1999) between S1 and S4, as it does in *M. gouazoubira*, where it extends to the sacral portion of the vertebral column, more specifically between S2 and S3 (Figures 2 and 3). This arrangement differs from other ruminants, since Dyce et al. (2004) reported that in the latter, the medullary cone ends at the level of the sixth lumbar vertebra.

The reported lengths of the medullary cone are 100 mm in horses, 45.1 mm in rabbits (SANTOS et al., 1999), 88.5 mm in sheep (SANTOS et al., 1999); and 33.9 mm in *Agouti paca* (SCAVONE et al., 2007). The medullary cone lengths measured in *M. gouazoubira* were 35.1 mm, 44.3 mm and 59.4 mm in specimens E1, E2 and E3, respectively, with a mean length index of 7.53%.

In *M. gouazoubira*, thickening of the spinal cord corresponding to the cervical intumescence was found between segments C4-T1 and of lumbar intumescence between L3-L6 (Figures 1 and 2). In buffalos, this thickening includes segments C6-T1 for the cervical and L3-S1 for the lumbar intumescence (RAO, 1976). In sheep, these dilatations correspond to C5-T2 and L4-S1, respectively (RAO, 1990), while in cats the cervical segment in C3 showed the largest volume (THOMAS; COMBS, 1962), and in impala these values were reported in C3-L13 and L2, respectively (RAO et al., 1993). In *M. gouazoubira*, the two intumescences represent only a small portion of each segment of the spinal cord and are shorter than in the other aforementioned animals.

The distances between the spinal nerve roots (Figure 4) vary conspicuously along the length of the spinal cord (Table 4).

Table 4. Mean distances between the right (R) and left (L) spinal nerve roots in *M. gouazoubira*. E1 (specimen 1), E2 (specimen 2), E3 (specimen 3). Cervical (CS), thoracic (TS) and lumbosacral segments (LSS) of the spinal cord.

		E1	E2	E3
CS	R	2.25	2.22	2.06
	L	2.49	2.13	2.21
TS	R	2.18	2.18	1.76
	L	2.39	2.11	1.76
LSS	R	2.26	1.62	1.88
	L	2.73	1.48	1.91

The measurements of segment C2-C6 show the longest distances between nerve roots. There is a stable decrease between the values measured in the region of the thoracic segment and an increase in the region comprised between segments L2-L5. However, the space between C2-C3 shows the longest distances between nerve roots. The longest distances between nerve roots have been reported in segments C2-C6 in buffalos (RAO, 1976), C2-C3 in dogs (FLETCHER; KITCHELL, 1966), C2-C4 in sheep (RAO, 1990) and C2-C3 impalas (RAO et al., 1993).

The distances between nerve roots are similar in buffalos (RAO, 1976), sheep (RAO, 1990), impalas (RAO et al., 1993) and dogs (FLETCHER; KITCHELL, 1966). In buffalos, impalas and dogs, the highest values are found in the cervical region, precisely between C2-C3, as in *M. gouazoubira.* In sheep, the longest distances between nerve roots are also found between C3-C4, i.e., a distance of 2.97 cm (RAO, 1990). Generally speaking, the measurements described for buffalos, sheep, impalas and dogs are similar to those of *M. gouazoubira*.

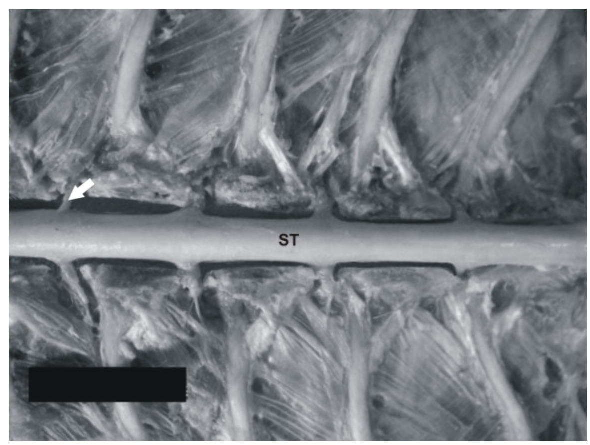

Figure 4. Thoracic segment (ST) of the spinal cord of *M. gouazoubira*. Root of the tenth thoracic nerve (arrow). Bar: 3 cm.

In cats, Thomas and Combs (1962) stated these distances decreased between segments T10-T12. In impalas, Rao et al. (1993) confirmed a decrease of these values in the craniocaudal direction, and reported that the smallest distances were found between T1-T2. This statement cannot be made for *M. gouazoubira*, since the distance between nerve roots varies constantly along the length of the spinal cord (Figure 4). One can therefore only infer that these values are stable or tend to vary toward lower values in the craniocaudal direction, except for segments L3-L6, which present the lumbar intumescence.

No significant variations were found in the distances of the nerve roots of the cervical segment in the two antimeres, where the overall average distance was 2.23 cm. The analysis of the thoracic segment showed a significant variation in the right and left antimeres of specimen E3, in which the measured values were smaller than in E1 and E2. The mean index of the distances was 2.06 cm. The lumbosacral segment of specimen E1 varied significantly in relation to that of E2 and E3. The overall average in this segment was 1.98 cm.

Conclusion

The indices of the length of the cervical, thoracic, lumbar and sacrocaudal segments of the spinal cord of *M. gouazoubira* are similar to those reported for other animals, especially ruminants, albeit with some peculiarities.

The distances measured between the spinal nerve roots show a tendency to decrease in the craniocaudal direction, except for the portions comprised between the cervical and lumbar intumescences.

In rare cases, no significant variations were found in the distances between the nerve roots in the various segments (cervical, thoracic and lumbosacral) in the different specimens (E1, E2 and E3).

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