Original Article

LUMBOSACRAL PLEXUS OF THE MONGOLIAN GERBIL (*Meriones unguiculatus* Milne-Edwards, 1867)

*PLEXO LOMBOSSACRAL DO GERBIL (*Meriones unguiculatus *Milne-Edwards, 1867)*

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ABSTRACT: The Mongolian gerbil, belonging to the Muridae family, is characterized as an economic asset in the pet market due to its easy management. Current research analyzes and describes the origin of the nerves that make up the lumbosacral plexus in the species, foregrounding comparative anatomy, especially among wild rodents. The experiment, approved by the Committee of Institutional Bioethics, involved 15 animals which had been used in other studies and were donated to the Laboratory of Applied Animal Morphophysiology of the Federal Rural University of the Semi-Arid, Mossoró, Rio Grande do Norte, Brazil. The animals were fixed in a water solution of formaldehyde 10%. After 72 hours, they were dissected, the abdominal cavity was opened and eviscerated, and the psoas minor, psoas major and the quadratus lumborum muscles were removed to inspect the nerves that form the lumbosacral plexus. Results were given in percentages and grouped in tables. The lumbosacral plexus of the Mongolian gerbil frequently derived from the ventral roots of the last thorax nerves, from the seven lumbar nerves and from the four sacral nerves (Type II – T_{12}-S_4). The nerves of the gerbil´s lumbosacral plexus are the iliohypogastricus, ilioinguinalis, cutaneus femoris lateralis, genitofemoralis, femoralis, obturatorius, ischiadicus, gluteus cranialis, pudendus, gluteus caudalis and rectales caudales nerves. Information on the origin of the nerves of the gerbil´s lumbosacral plexus and their description is relevant for clinical and surgical studies, and for the application of techniques or anesthetic drugs.

KEYWORDS: Nervous system. Lumbosacral plexus. Rodent. Muridae. *Meriones unguiculatus*.

INTRODUCTION

The Mongolian gerbil or squirrel is a rodent native to the desert regions of Northeastern China and Mongolia. The docile, fecund and easily managed animal has singular characteristics which are highly important for the pet market and for experimental models in studies on the application of drugs, such as local, peridural and spinal anesthesia (LICHTENBERGER; JEFF, 2007; GAERTNER et al., 2008). The gerbil may present morphofunctional characteristics which are highly relevant for comparative studies with other mammals, including human beings (SANTOS et al., 2003).

Specialized literature provides scanty reports on the anatomy of the nervous system of the species (FREWEIN, 1978; KÜNZEL, 1985; CASTRO-PACHECO et al., 2001; KUCHINKA et al., 2008), particularly on the lumbosacral innervation. The literature (LOPES et al., 2012; OLIVEIRA et al., 2014; TONINI et al., 2014) describes the lumbosacral plexus as a structure formed by the interaction between the lumbar and the sacral plexuses, generally made up of nerve roots derived from the last lumbar vertebra and from the first sacral vertebra, innerving the pelvis and the region´s viscera.

Lesions in the lumbosacral plexus or in associated nerves may cause loss of spinal reflexes and conscious proprioception in the pelvis, atrophy, paralysis and loss of flection or voluntary extension of the muscles and even the inability to bear body weight (LORENZ; KORNEGAY, 2006). Information on the formation of the plexus is not merely a contribution for the study of comparative anatomy but also provides adequate descriptions on the clinical, surgical and anesthetic behavior to veterinarians. Due to scarcity of data on the anatomy of the species, particularly on the nervous system, current paper will contribute towards the use of the animals as experimental models. Therefore, this study was undertaken to analyze and to describe the origin of the nerves that make up the lumbosacral plexus in the Mongolian gerbil, foregrounding comparative anatomy, especially among wild rodents.

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MATERIAL AND METHODS

Fifteen adult animals (10 males and 5 females) were used. They originated from previous studies performed in the Laboratory of Animal Parasitology of the Federal Rural University of the Semi-Arid (Protocol CEUA n. 04/2014, Process n. 23091.005376/2013-67) and donated to the Laboratory of Applied Animal Morphophysiology.

The animals were fixed in formaldehyde solution 10% and dissected after 72 h. A median longitudinal incision from the xiphoid cartilage to the anus was performed so that the abdominal cavity could be accessed and the animals eviscerated. The m. psoas major, m. psoas minor and the m. lumbar quadratus were exposed and removed. The pubis bone was removed by a scissor and the muscles close to the intervertebrate foramens were dissected. Cotton pads moistened in a solution of hydrogen peroxide 2% were placed under the nerves for 12 h.

Photographs of the different nerve arrangements that compose the lumbosacral plexus were taken to illustrate the results. Data were grouped in tables as percentages and analyzed immediately. The nomenclature was based on the International Committee on Veterinary Gross Anatomical Nomenclature (2012).

Fisher´s exact test was employed to calculate probability when left and right antimeres of males and females were paired.

RESULTS

Dissection revealed that the gerbil´s lumbosacral plexus has two formations: Type 1 with T_{12}-S_3 nerve roots (Figure 1A) and Type II with T_{12}-S_4 roots (Figure 1B).

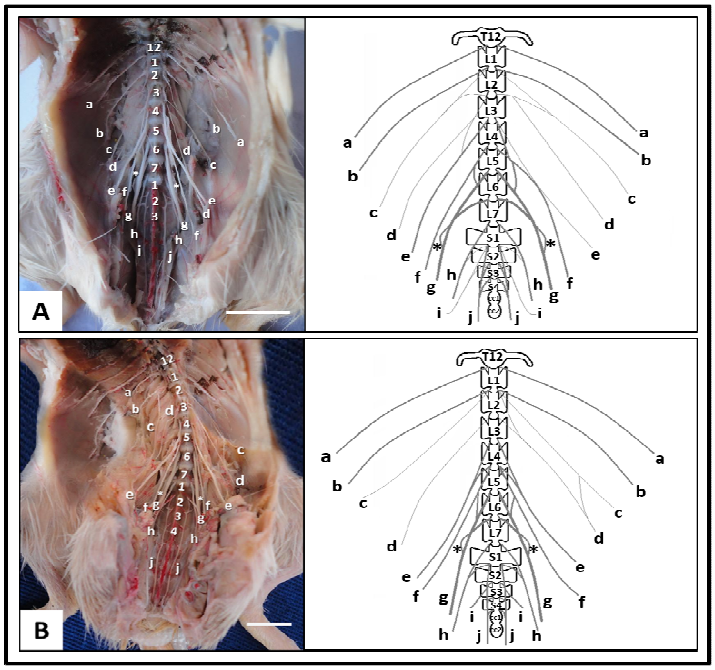

Figure 1. Origin of the gerbil´s lumbosacral plexus. A: Type I (T_{12}-S_3). B: Type II (T_{12}-S_4). The iliohypogastricus (a), ilioinguinalis (b), cutaneus femoris lateralis (c), genitofemoralis (d), femoralis (e), obturatorius (f), ischiadicus (g), pudendus (h), rectales caudales (i) and gluteus caudalis (*) nerves may be seen. bar = 1cm.

Type II was more frequent (Table 1).The values P= 81.39% and P= 42.3% characterized respectively the right and left antimeres (between male and female). Since P rate for both was higher than 5%, the hypothesis for independent characteristics is proved, or rather, there is no gender dependence for Types I and II in the two cases.

The iliohypogastricus, ilioinguinalis, cutaneus femoris lateralis, genitofemoralis, femoralis, obturatorius, ischiadicus, gluteus cranialis, pudendus, gluteus caudalis and rectales caudales nerves constituted the gerbil´s lumbosacral plexus.

The iliohypogastricus nerve is a fine unisegment branch derived from the nerve root of the last thorax vertebra (T_{12}) in eleven specimens or from the first lumbar branch in four specimens. The nerve follows obliquely in a caudal direction and parallel to the ilioinguinalis nerve.

Table 1. Origin of the gerbil´s lumbosacral plexus. Data are given for the right (RA) and left (LA) antimeres.

Type	Origin	Frequency (%)			
		Male		Female	
		RA	LA	RA	LA
I	$T_{12} – S_3$	20.00	26.66	13.33	6.66
II	$T_{12} – S_4$	46.66	40.00	20.00	26.66
Total		66.66	66.66	33.33	33.33

Fisher´s exact test ($p \leq 0.05$)

The ilioinguinalis nerve is frequently formed by L_1 branches only, or by L_2 branches and in certain cases may receive a small contribution of L_1. On the right antimere, the nerve passes obliquely in a caudal direction close to the medial section of the right kidney, close to the renal hilum. The nerve passes in a caudal direction on the left antimere and runs ventrally to the left supra-renal gland.

The cutaneus femoris lateralis nerve is formed by the bifurcation of the ventral branches L_1 and L_2 or only from L_2 branch. The iliohypogastricus, ilioinguinalis and cutaneus femoris lateralis nerves run ventrally and on the surface to the psoas minor muscle.

The genitofemoralis nerve derives from L_2 or from L_2-L_3. After its formation, the nerve emerges between the psoas minor and psoas major muscles.

The femoralis nerve has a variable origin and is derived frequently from L_3-L_4 branches or L_2-L_4. The obturatorius nerve is frequently made up of L_3-L_4 roots. The ischiadicus nerve originated from the joint branches of L_4-L_6.

The gluteus cranialis nerve is a relatively slim nerve, scarcely visible, and lies dorsally and intertwined to the ischiadicus nerve frequently formed by L_5-L_6. The gluteus caudalis nerve emerges frequently from the sacral ventral branches of S_1-S_2 or only from S_2.

The pudendus nerve is formed by a nexus between the nerve roots of L_7-S_1, or it may originate only from L_7.

The rectales caudales nerve runs caudally and ventrally along the sacral vertebrae. It is covered by sacrocaudal ventral muscles with the innervation of the sphincter ani externus and the levator ani muscles. The nerve originated frequently from S_1-S_4 in the specimens analyzed (Table 2).

Table 2. Origin of nerves of the lumbosacral plexus of the gerbil distributed on the right (RA) and left (LA) antimeres.

Nerves	Origin	Absolute frequency		Frequency (%)	
		RA	LA	RA	LA
Iliohypogastricus	T_{12}	11	11	73.33	73.33
	L_1	4	4	26.67	26.67
Ilioinguinalis	L_1	12	13	80.00	86.67
	L_1, L_2	1	0	6.67	0.00
	L_2	2	2	13.33	13.33
Cutaneus femoris lateralis	L_1, L_2	8	8	53.33	53.33
	L_2	7	7	46.67	46.67
Genitofemoralis	L_2	9	7	60.00	46.67
	L_2, L_3	6	6	40.00	40.00
	L_3	0	2	0.00	13.33
Femoralis	L_2, L_3, L_4	7	7	46.67	46.67
	L_3, L_4	8	7	53.33	46.67
	L_3, L_4, L_5	0	1	0.00	6.66

Obturatorius	L_3, L_4	13	13	86.67	86.67
	L_4	1	2	6.66	13.33
	L_4, L_5	1	0	6.66	0.00
Ischiadicus	L_3, L_4, L_5, L_6	1	0	6.67	0.00
	L_4, L_5, L_6	12	13	80.00	86.67
	L_4, L_5, L_6, L_7	2	2	13.33	13.33
Gluteus cranialis	L_5	1	1	6.67	6.67
	L_5, L_6	12	12	80.00	80.00
	L_6	2	1	13.33	6.67
	L_7	0	1	0.00	6.66
Pudendus	L_6, L_7	0	1	0.00	6.67
	L_7	6	6	40.00	40.00
	L_7, S_1	9	8	60.00	53.33
Gluteus caudalis	S_1	1	1	6.67	6.67
	S_1, S_2	9	9	60.00	60.00
	S_2	5	5	33.33	33.33
Rectales caudales	S_1, S_2, S_3	2	2	13.33	13.33
	S_1, S_2, S_3, S_4	13	13	86.67	86.67

DISCUSSION

The gerbil´s lumbar and sacral skeletontopy has seven lumbar vertebrae and four sacral vertebrae. Several variations in the number of lumbar and sacral vertebrae usually occur in rodents. In their studies on rock cavies, Lacerda et al. (2006) reported that the number varies between 6 and 7 lumbar vertebrae, while AYDIN et al. (2009) registered only four lumbar vertebrae for the porcupine. On the other hand, Oliveira et al. (2014) studying Spix's toothed-cavy observed variations in the number of sacral vertebrae, namely, between three and four, corroborating information that the amount of vertebrae of the spinal column may vary in rodents.

The factors that make up the lumbosacral plexus vary according to the number of vertebrae that constitute the lumbar and sacral regions. The gerbil´s plexus is mainly represented by branches from T_{12}-S_4. On the other hand, Greene (1963) shows that the lumbosacral plexus in rats derives from the last thorax nerve (T_{13}), from all lumbar nerves (L_1-L_6) and also from the sacral nerves (S_1, S_2).

Contrastingly to what has been reported on the paca (TONINI et. al., 2014), there were no significant variations between the origin of the plexus and gender.

Results for the gerbil under analysis differed from those described for the guinea-pig (COOPER; SCHILLER, 1975) since nerves derived from L_3-L_6 and S_1-S_3, featuring separately the lumbar and sacral trunk. They also differed from those on the paca (TONINI et al., 2014), formed from L_4-S_3; from those of the rock cavy (LACERDA et al., 2006) and Spix's yellow toothed-cavy (OLIVEIRA et al., 2014) derived from L_5-S_3. Difference may be related to the acquisition of morphological characteristics throughout the evolution process which may have differentiated the cavid from the murid rodent groups or they may be related to such behavior as great agility, greater capacity for cramming, climbing trees or jumping.

The gerbil revealed iliohypogastricus, ilioinguinalis and genitofemoralis nerves as branches of the lumbar plexus, described as normal by Warwick & Williams (1995) for human beings. Bolk (1898), quoted by El-Assy (1966), showed that the first root in the human lumbosacral plexus is either T_{12} or L_1, similar to results on the Mongolian squirrel.

The gerbil´s iliohypogastricus nerve originates from the ventral branch of the last thorax nerve (T_{12}), differing from that in the rat (GREENE, 1963) and in the porcupine (AYDIN et al., 2009) formed by T_{13} and T_{15}, respectively.

Gerbil´s ilioinguinalis nerve is frequently derived from L_1. The nerve in the red squirrel (AYDIN, 2010) and in the chinchilla (MARTINEZ-PEREIRA; RICKES, 2011) is formed by roots

derived from L_3 and demonstrated a nerve arrangement different from that of the gerbil.

The cutaneus femoris lateralis nerve has a similar formation as that of the anteater (CRUZ et al., 2014), differing from reports on the chinchilla (MARTINEZ-PEREIRA; RICKES, 2011) formed exclusively from L_4, and on the paca (TONINI et al., 2014) derived from L_5.

The genitofemoralis nerve confirmed results by Erden (1993) for asses, or L_2-L_3. However, results differed from those in the chinchilla (MARTINEZ-PEREIRA; RICKES, 2011) derived exclusively from L_3, and in the paca (TONINI et al., 2014) derived exclusively by L_4.

The gerbil´s femoralis nerve derives from L_3-L_4 branches or L_2-L_4 and contrasts description by Lacerda et al. (2006) and Oliveira et al. (2011), Oliveira et al. (2014) and Tonini et al. (2014) with regard to the cavy, Spix's yellow toothed-cavy and paca, respectively, whose origins derive from L_5-L_6.

The gerbil´s obturatorius nerve is formed by L_3 and L_4, as in the seal (CASTRO et al., 2009). The obturatorius nerve in the ocelot (LOPES et al., 2012) and in the paca (TONINI et al., 2014) derives from L_5 and L_6, or rather, different from that of the gerbil.

The gerbil´s ischiadicus nerve is frequently formed from the L_4-L_6 and differs from the same nerve in the rock cavy (LACERDA et al., 2006; SANTOS et al., 2006), in Spix's yellow toothed-cavy (OLIVEIRA et. al., 2010; 2014) and in the paca (TONINI et al., 2014) originating from L_6, L_7, S_1 and S_2.

The gluteus cranialis nerve originates from L_5-L_6, different from that of the rock cavy (LACERDA et al., 2006) and Spix's yellow toothed-cavy (OLIVEIRA et al., 2014), with its origin in L_7. It also differs from the porcupine´s nerve (AYDIN et al., 2009) which derives from L_3-L_4 in males and from L_3 in females.

The pudendus nerve frequently derives from L_7-S_1 or only from L_7, different from reports on the rock cavy (LACERDA et al., 2006), seal (CASTRO et al., 2009), Spix's yellow toothed-cavy (OLIVEIRA et al., 2014), paca (TONINI et al., 2014), pig and other domestic carnivorous animals (GETTY, 1986; SCHALLER, 1999), where it originates from S_2-S_3.

The gerbil´s gluteus caudalis nerve frequently originates from the roots of S_1 and S_2. This is different from reports on the rock cavy (LACERDA et al., 2006) derived from L_7 and S_1, and on the paca (TONINI et al., 2014).

The rectales caudales nerve has a plurisegment origin, frequently from S_1-S_4. In the porcupine (AYDIN et al., 2009) it originates from the branches of S_2, the nerve derives from S_2 and S_3 in the dog (GETTY, 1986) and in the chinchilla (MARTINEZ-PEREIRA; RICKES, 2011).

Table 3. Origin of the brachial plexus nerves in different mammalian species.

Nerves	Species					
	Oryctolagus cuniculus	*Kerodon rupestres*	*Sciurus vulgaris*	*Chinchilla lanígera*	*Galea spixii*	*Cuniculus paca*
Iliohypogastricus	–	–	$L_1 – L_2$	$L_1 – L_2$	–	–
Ilioinguinalis	–	–	L_3	L_3	–	–
Cutaneus femoris lateralis	–	–	L_4	L_4	–	L_5
Genitofemoralis	–	–	L_4	L_3	–	L_4
Femoralis	$L_4 – L_6$	$L_5 – L_6$	$L_4 – L_5$	$L_4 – L_5$	$L_5 – L_6$	$L_5 – L_6$
Obturatorius	$L_6 – L7$	$L_5 L_7$ / $L_6 L_7$	$L_4 – L_5$	$L_4 – L_5$	$L_5 – L_6$	L_6
Ischiadicus	$L_6 – S_3$	$L_6 – S_2$	$L_6 – S_2$	L_5, L_6, S_1	$L_6 – S_1$	$L_6 S_2$ / $L_7 S_2$
Gluteus cranialis	–	L_7	–	L_5, L_6, S_1	L_7	$L_6 – L_7$
Pudendus	$S_2 – S_3$	$S_2 – S_3$	$S_1 – S_2$	$S_1 – S_2$	$S_2 – S_3$	$S_2 – S_3$
Gluteus caudalis	–	$L_7 – S_1$	–	L_5, L_6, S_1	$L_7 – S_1$	S_1
Rectales caudales	–	–	$S_1 – S_2$	$S_2 – S_3$	–	$S_2 – S_3$
Reference	Greenaway et al., 2001	Lacerda et al., 2006	Aydin, 2010	Martinez-Pereira; Rickes, 2011	Oliveira et al., 2014	Tonini et al., 2014

CONCLUSIONS

The gerbil´s lumbosacral plexus is derived from nexuses between the ventral branches of the spinal nerves that emerge from the last thorax vertebra up to the fourth sacral vertebra (T_{12}-S_4). The iliohypogastricus, ilioinguinalis, cutaneus femoris lateralis, genitofemoralis, femoralis, obturatorius, ischiadicus, gluteus cranialis, pudendus, gluteus caudalis and rectales caudales nerves participate in the species´s plexus.

RESUMO: O esquilo da Mongólia é um roedor pertencente à família Muridae, caracterizado por seu interesse econômico no mercado pet e por ser de fácil manejo. Esta pesquisa analisa e descreve a origem dos nervos que formam o plexo lombossacral da espécie. No experimento foram utilizados 15 animais, provenientes de outros estudos aprovados pelo Comitê de Bioética Institucional, que foram doados ao Laboratório de Morfofisiologia Animal Aplicada da Universidade Federal Rural do Semi-Árido, Mossoró, Rio Grande do Norte. Os animais foram fixados em solução aquosa de formaldeído a 10%. Após 72 horas, os animais foram dissecados, realizando-se a abertura da cavidade abdominal, depois, eviscerados e em seguida, os músculos psoas maior, psoas menor e quadrado lombar foram removidos para visualização dos nervos que formam o plexo lombossacral. Os resultados foram expressos em percentagens e agrupados em tabelas. O plexo lombossacral do gerbil originou-se mais frequentemente das raízes ventrais do último nervo torácico, dos sete nervos lombares e dos quatro nervos sacrais (Tipo II – T_{12}-S_4). Os nervos que formaram o plexo lombossacral do gerbil foram: ílio-hipogástrico, ílioinguinal, cutâneo femoral lateral, genitofemoral, femoral, obturatório, isquiático, glúteo cranial, pudendo, glúteo caudal, e nervo retal caudal. O conhecimento sobre a origem e os nervos do plexo lombossacral no gerbil mostra-se útil para estudos clínico-cirúrgicos e aplicação de técnicas ou fármacos anestésicos.

PALAVRAS-CHAVE: Sistema nervoso. Plexo lombossacral. Roedor. Muridae. *Meriones unguiculatus*.

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