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Origin and branching of the phrenic nerve (*Sus scrofa domesticus* Linnaeus, 1758) of the Pen Ar Lan Line

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***Abstract*— *Swine farming has increasingly developing worldwide due to advances in genetic improvement, thus, researchers are investigating possible anatomical variations in new lineages. The objective of this study was to assess the origin and branching of the phrenic nerve in 27 swine (Sus scrofa domesticus – Linnaeus, 1758) fetuses of the Pen Ar Lan line—19 males and 8 females. They were dissected after fixing in a 10% formaldehyde solution. The phrenic nerve originated from 51 (94.4%) antimeres of the fifth cervical spinal nerve (C5), 54 (100%) antimeres of the sixth cervical spinal nerve (C6), and six (11.11%) antimeres of the seventh cervical spinal nerve (C7). Considering this distribution, the phrenic nerve emitted fibers to the pericardium and branched into the diaphragm muscle in all specimens evaluated. Six different branching were found, most frequently in the dorsal, lateral, and ventral branches in 22 (40.74%) antimeres, followed by branching to dorsal branches and ventrolateral trunk in 18 antimeres (33.33%). In addition, two of the branching found are not cited in scientific literature, denoting their variability. The dorsal branches were distributed to the pillar muscles in the lumbar part, the ventral branches to the sternal part, and the lateral branches to the dorsal part.*

Keywords*— *Peripheral nervous system, Cervical plexus, Diaphragm muscle.

I. INTRODUCTION

Swine farming has increasingly developing worldwide due to advances in genetic improvement focused on producing precocious animals, and improving their growth speed, production, and reproduction. Thus, researchers are investigating anatomical variations in current swine lines **[1]**.

The Pen Ar Lan line is from Denmark; it is obtained by crossing animals from the Landrace and Large White lines, which is frequently used by Brazilian pig farmers for breeding, and is developed by Brazilian companies in partnership with foreign laboratories **[2]**.

The phrenic nerve in pigs is formed by ventral branches of the fifth (C5), sixth (C6), and seventh (C7) cervical spinal nerves; the roots of the C5 and C7 are thin. These roots converge in a single trunk at the level of the seventh cervical vertebra and, then, are distributed into the diaphragm muscle **[3]**.

Studies on the origin, branching, and distribution of the phrenic nerve have been conducted on *Callithrix jacchus* **[4]**, *Dasysprocta agouti* **[5]**, *Capra hircus* **[6]**, and domestic cats **[7]**. Several studies on pigs describe the origin and distribution of various nerves, such as the femoral, sciatic, and rectal caudal nerves **[1, 8-9]**. however, none of them give information on the origin and distribution of the phrenic nerve in swine fetuses of the Pen Ar Lan line.

In this context, the objective of this study was to analyze the origin and branching of the phrenic nerve in swine (*Sus scrofa domesticus* – Linnaeus, 1758) fetuses of the Pen Ar Lan line.

II. MATERIALS AND METHODS

Twenty-seven swine (*Sus scrofa domesticus* – Linnaeus, 1758) fetuses of the Pen Ar Lan line—eight females and 19 males—were used in the present study. The animals belonged to the Animal Anatomy Laboratory of the Faculty of Veterinary Medicine of the Federal University of Uberlândia, Minas Gerais, Brazil.

The specimens were fixed through an incision in the dorsal-ventral direction at the level of the ninth

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intercostal space; the thoracic aorta was then individualized and two cannulas were introduced—one in the cranial and other in the caudal direction—to inject a 10% formaldehyde solution; then, the animals were submerged in opaque vats containing a solution at the same concentration.

The dissections began with the removal of the cutaneous and adipose tissues from the cervical and thoracic regions. Then, a median incision was made in the cranioventral direction ventrally to the jaw bone, passing medially through the sternum bone to its xyloid process, to access the mediastinum region.

The trachea, esophagus, and muscles of the cervical region were folded to visualize the cervical and thoracic vertebrae, mainly the costal process of the sixth cervical vertebra, and the first rib, which are important reference points; thus, it was possible to identify the actual origin of the phrenic nerve.

Dissections were performed in the mediastinum regions to verify the distribution of the phrenic nerve; this distribution was observed in the diaphragm muscle.

When necessary, an 8x-magnifying glass was used to visualize the structures. The documentation was made from schematic drawings and photographs of the origins and distributions of the phrenic nerves, and the nomenclature used was based on the Nomina Anatomica Veterinaria **[10]**.

The statistical analysis for the origins and branching of the phrenic nerve was based on descriptive analysis with simple percentage.

III. RESULTS

The evaluation of the 27 swine fetuses of the Pen Ar Lan line showed that the phrenic nerve originated from the union of the ventral branches of the cervical nerves, and the contribution to its formation is variable. The nerve originated from 51 antimeres (94.4%) of the ventral branches of the fifth cervical spinal nerve (C5), 54 antimeres (100%) of the ventral branches of the sixth cervical spinal nerve (C6), and six antimeres (11.11%) of the ventral branches of the seventh cervical spinal nerve (C7) (Table 1).

Table 1. Individual contribution of the ventral branches of the cervical spinal nerves to the formation of the phrenic nerve in swine (Sus scrofa domestucus Linnaeus, 1758) fetuses of the Pen Ar Lan line, in the right and left antimeres. Uberlândia, MG, Brazil, 2018.

Individual contribution			
Cervical spinal nerve	Right antimere	Left antimere	Overall
C5	26 (96.29%)	25 (92.59%)	51 (94,4%)
C6	27 (100%)	27 (100%)	54 (100%)
C7	2 (7.4%)	4 (14.81%)	6 (11,1%)

The phrenic nerve originated from 48 antimeres (88.88%) of the ventral branches of the C5 and C6; three antimeres (5.55%) of the C5, C6, and C7; and three antimeres (5.55%) of the C6 and C7. The phrenic nerve presented symmetry in relation to its origin in 23 animals (85.18%), i.e., the nerve roots that originated it in both antimeres coincided in number; in the case of asymmetry, this coincidence was not observed. This symmetry occurred by the union of the ventral branches of C5 and C6 in 22 specimens (81.48%) and by the union of the ventral branches of C6 and C7 in one animal (3.7%).

Table 2. Combined contribution of the ventral branches of the cervical spinal nerves to the formation of the phrenic nerve in swine (Sus scrofa domesticus Linnaeus, 1758) fetuses of the Pen Ar Lan line, in the right and left antimeres. Uberlândia, MG, Brazil, 2018.

Joint contribution			
Cervical spinal nerves	Right antimere	Left antimere	Overall
C5 and C6	25 (92.59%)	23 (85.18%)	48 (88.88%)
C5, C6, and C7	1 (3.70%)	2 (7.40%)	3 (5.55%)
C6 and C7	1 (3.70%)	2 (7.40%)	3 (5.55%)

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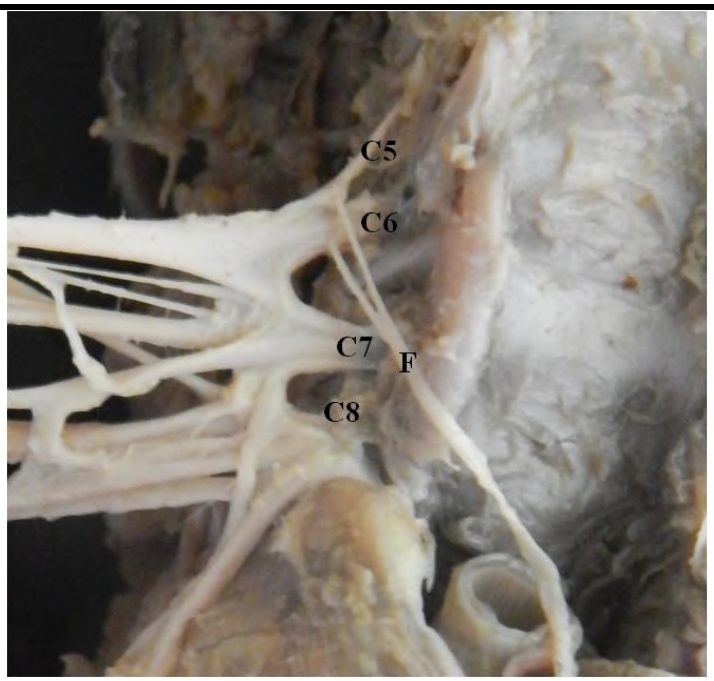

Fig. 1 Ventral branches of the cervical spinal nerves (C5 to C8) of swine (Sus scrofa domesticus) fetuses showing the most common origin of the phrenic nerve (F) in C5 and C6.

The phrenic nerves of all fetuses evaluated (100%) crossed the lateral regions of the mediastinum region and emitted fibers to the pericardium and to the diaphragm muscle. Six types of branching were observed, most frequently the dorsal, lateral, and ventral branches in 22 antimeres (40.74%), followed by branching to dorsal branches and ventrolateral trunk in 18 antimeres (33.33%).

Terminal branching in ventral branches and dorsolateral trunk were also observed in three antimeres (5.55%); lateral branches, dorsal branches, and ventrolateral trunk in four antimeres (7.40%); dorsal and ventral branches in six antimeres (11.11%); and dorsolateral and ventrolateral trunks in one antimere (1.85%).

Terminal branches of the phrenic nerve presented symmetry in 11 specimens, which were identified in the branching of the dorsal branche and ventrolateral trunk of five specimens (45.45%); in the dorsal, lateral, and ventral branches of five specimens (45.45%); and in the lateral and dorsal branches, and ventrolateral trunk of one specimen (9.09%).

The branches were directed to specific regions of the diaphragm muscle, in which the dorsal branches were distributed to the pillar muscles in the lumbar part, the ventral branches to the sternal part, and the lateral branches to the costal part. After the divisions in branches and trunks, the branching to the peripheral portion of the diaphragm muscle differed according to the animal, possibly to all this diaphragm muscle had the necessary innervation for its functioning (Figure 2).

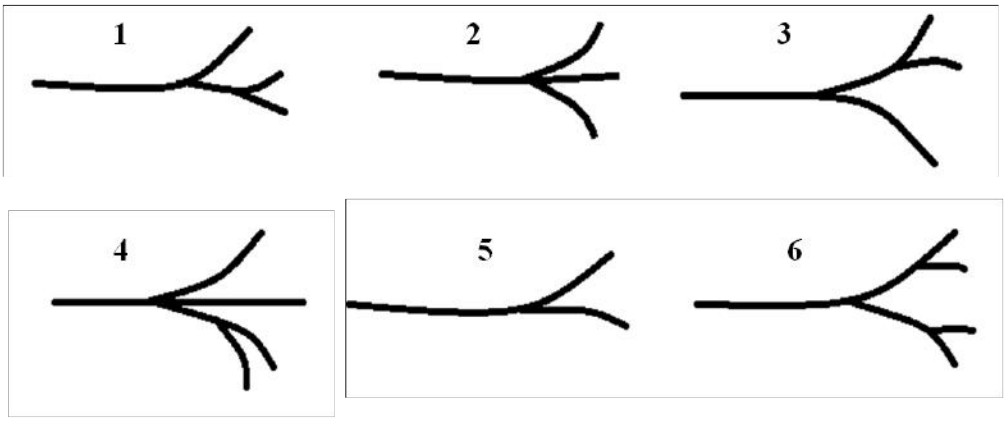

Fig. 2 Schematic drawing of the branching of the phrenic nerves in the diaphragm muscle in swine (Sus scrofa domesticus Linnaeus, 1758) fetuses of the Pen Ar Lan line. Dorsal and ventrolateral (1); dorsal, lateral, and ventral (2); ventral and dorsolateral (3); lateral, dorsal, and ventrolateral (4); dorsal and ventral (5); and dorsolateral and ventrolateral (6).

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Table 3. Branching types of the phrenic nerve to the diaphragm muscle in the right and left antimeres of swine (Sus scrofa domesticus Linnaeus ,1758) fetuses of the Pen Ar Lan line. Uberlândia-MG, Brazil, 2018.

	Antimere		
Branching	Right	Left	Overall
Dorsal and ventrolateral	7 (25.92%)	11 (40.74%)	18 (33.33%)
Dorsal, lateral, and ventral	14 (51.85%)	8 (29.62%)	22 (40.74%)
Ventral and dorsolateral	2 (7.40%)	1 (3.70%)	3 (5.55%)
Lateral, dorsal, and ventrolateral	3 (11.11%)	1 (3.70%)	4 (7.40%)
Dorsal e ventral	0	6 (22.22%)	6 (11.11%)
Dorsolateral e ventrolateral	1 (3.70%)	0	1 (1.85%)

Fig. 3 Ventral perspective of the thoracic cavity of swine (Sus scrofa domesticus Linnaeus, 1758) fetuses of the Pen Ar Lan line. Phrenic nerve in the mediastinum region and its distribution in the dorsal branch and ventrolateral trunk . Phrenic nerve (1); ventrolateral trunk (2); dorsal branch (3); pericardium (4); and diaphragm muscle (5).

IV. DISCUSSION

The origin and branching of the phrenic nerve in swine fetuses of the Pen Ar Lan line occur mainly through the contribution of ventral branches of the fifth cervical spinal nerve (C5) and sixth cervical spinal nerve (C6); ventral branches of C6 were found in all animals analyzed, confirming the results found by Almeida et al. (2008) **[11]** for Santa Inês sheep.

Combined contribution of the ventral branches of C5 and C6 was found in 48 specimens (88.88%), differing from the results found by Getty (1981) **[3]** for swine and ruminants, and by Dyce, Sack, and Wensing (2010) **[11]** for domestic ruminants, who reported that this nerve originates from the ventral branches of C5, C6, and C7; this configuration was found in three (5.55%) animals in the present study.

According to Miller (1979) **[13]** and Getty (1981) **[3]**, phrenic nerve in dogs originates from ventral branches of C5, C6, and C7, with possible contribution of ventral branches of C4. No contribution of branches of C4 was found in the present study. The phrenic nerve of humans originates from ventral branches of C3 to C5 **[14]**. In the swine animals evaluated in the present study, this nerve originates from ventral branches of C5 in 94.4% of the antimeres, however, no contribution of the ventral branches of C3 and C4 was found.

The phrenic nerve was symmetric in relation to its origin in 23 animals (85.18%), i.e., the nerve roots that originated it coincided in number in both antimeres. Similar result was found by Almeida et al. (2008) for sheep; they found phrenic nerve symmetry in 63.33% of the animals.

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According to Almeida et al. (2008) **[11]**, the left phrenic nerve of Santa Inês sheep originates exclusively from ventral branches of C6 in 6.67% of the animals. However, the phrenic nerve of all animals analyzed in the present study was constituted by two or more ventral branches of spinal nerves, confirming its plurisegmental characteristic **[15]**.

The primary source of the sensory fibers of the pericardium in humans is derived from the phrenic nerve **[14]**. Small filaments of fibers from the phrenic nerve to the pericardium were found in all swine fetuses, denoting the importance of this nerve in the nervous supply of the pericardium.

Six types of phrenic nerve branching were observed in the animals evaluated; the most frequent was the trifurcation in dorsal, lateral, and ventral branches, which was present in 22 antimeres (40.74%). Trifurcation in dorsal, lateral, and ventral branches was observed in 25% of domestic cats **[7]**; 11.8% (right antimere) and 23.5% (left antimere) of *Dasyprocta agouti*; 32.5% (right antimere) and 12.5% (left antimere) of goats **[6]**; with no predominance of trifurcation.

Moreover, the trifurcation in dorsal, lateral, and ventral branches presented symmetry in both antimeres in five specimens (45.45%). Similarly, Carvalho et al. (1996) **[5]** and Miglino et al. (1985) **[6]** found symmetry in one (*Dasysprocta agouti*) and three (goats) animals, respectively.

Branching to dorsal branch and ventrolateral trunk was the second more frequent, found in 18 antimeres (33.33%) of the swine fetuses evaluated. This type of branching was found in 6.66% of cats **[7]**; 17.6% (right antimere) and 41.2% (left antimere) of *Dasysprocta agouti* **[5]**; and in 40% (right antimere) and 75% (left antimere) of goats **[6]**. Symmetry in this branching was found in five antimeres (45.45%), similar results to those found by Moreira et al. (2007) in two domestic cats; and by Miglino et al. (1985) **[6]** in 13 goats.

Branching to dorsolateral trunk and ventral branch was the most common for domestic cats (63.33%) **[7]**, and was found in 64.77% (right antimere) and 23.5% (left antimere) in *Dasysprocta agouti* **[5]**. Contrastingly, this branching was found only in 5.55% of the antimeres of the animals analyzed in the present study.

Two branching of the phrenic nerve found in the Pen Ar Lan swine fetuses were not found in the scientific literature, denoting the variability of the branching of this nerve. This branching in lateral and dorsal branches and ventrolateral trunk was verified in four antimeres (7.40%), and the division in dorsal and ventral branches was found in six antimeres (11.11%).

Most studies found on the phrenic nerve refer to adult animals. The use of fetuses in the present study, and by Rosa (2012) **[8]**, Lizardo et al. (2013) **[16]** and Santos et al. (2013) **[1]** is to make easier the obtaining and handling of the material when compared to the use of adult animals.

Ferraz et al. (2006) **[17]** studied the intra-pelvic part of the ischiatic nerve of fetuses of Zebu cattle and reported that it is probable that the sciatic nerve of adult animals presents similar origin and position to that found in the fetuses, considering the proportions between nervous system structures and adjacent tissues. Thus, it is assumed that it is also true for the origin and distribution of the phrenic nerve in the swine fetuses of the Pen Ar Lan line.

All the anatomical variations of the phrenic nerve origin and branching found and reported in the present study are important in cases of affections, and for clinical or surgical approaches that involve or compromise these structures.

V. CONCLUSIONS

The phrenic nerve of swine (*Sus scrofa domesticus* – Linnaeus, 1758*)* fetuses of the Pen Ar Lan line originates from the fifth cervical spinal nerve (C5) to the seventh cervical spinal nerve (C7), with higher contribution of C5 and C6. It emitted fibers to the pericardium and to the diaphragm muscle.

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