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Irrigation of the mammary glands of sows (*Sus scrofa domesticus* Linnaeus, 1758)

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***Abstract*—** *The irrigation of the mammary glands of crossbred sows was studied by contrast radiographic examination in order to provide subsidies to related areas. Dissection had been performed on seven female pigs, with different body weights, and prior to puberty, with a mean age of three months, originated from pig farms in Brazil. Barium Sulfate had been injected in four specimens. Radiographic examination was performed for visualization of the arterial distribution to the glands. It has been concluded that the mammary arteries responsible for the irrigation of the mammary glands in sows originate from the superficial cranial and the caudal epigastric arteries. Among the arteries identified by dissection and contrast radiography, it has been verified that the cranial arteries present larger calibers when compared to caudal arteries. The use of contrast radiography has revealed to be efficient for the topographic identification of the vessels, the caliber, and the distribution to the mammary glands.*

Keywords*— *Anatomy, Arteries, Radiography, Swine, Teats.

I. INTRODUCTION

For centuries now, human beings have been resorting to swine as a source of protein and as biological models, whereas these animals contribute for the development of biotechnology as bio-reactors (being modified to produce therapeutic proteins in the study of diseases) and they moreover provide man with organs where their genetic traits are reformulated (xenotransplantation) [1].

Pig farming is a branch of production in constant growth over the latest decades, and a major part of that phenomenon is owed, among other factors, to the genetic enhancement added to a formulation of a high-quality diet that is being deployed on the species [2]. Pork meat is the most widely consumed variety in the whole world, as it accounts for providing nearly 38.0% of the entire daily protein intake worldwide [3].

In Brazil, over the 2nd quarter of 2016, 10.46 million swine were slaughtered, generating an 8.0% increase by comparison with the same period of the previous year - that being an all-time record, since the these polls commenced in 1997 [4]. Since the production of swine takes on an international high level, there must be concern in regard of a product's having quality and quantity, whilst strict measures of sanitary and nutritional control are attained. Nevertheless, the phase which requires a higher degree of caution is that of the piglet. When these animals are not well nursed, huge negative impacts on the production and on the payoff are generated - especially when there is a reduction or a disruption in the lactogenesis of the swine matrices [2].

The intake of colostrum within the first 24 to 36 hours after birth is very important for the viability of the piglets, which are born without any immune protection against pathogenic microorganisms that exist in their new environment and, when the piglets ingest the colostrum, they acquire antibodies from the mother, gaining passive immunity [5-7]. This secretion is also capable of providing the energy and the nutrients that account for the maturing and the development of the intestinal epithelium, whilst propitiating anatomical, immunological, and physiological alterations that are crucial to the efficiency of the digestive system [8].

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The mammary gland is one of the forming organs of the female reproductive system, being responsible for the lactation, the final phase of reproduction [9]. Although that structure is similar throughout all the species that comprise the mammals, there are variations in regard of its morphological aspect and the concentration of the components found in the secreted milk [10]. The differences in size of the caudal mammary glands - in relation to the cranial ones - is an aggravating factor in the growth of piglets, as is seen that the cranial ones are bigger and, as a consequence, provide the ejection of colostrum with a higher number of immunoglobulins [11].

In light of the importance played by nursing in the development of piglets, it is plausible that the knowledge surrounding the irrigation of the said gland is of utter importance to provide subsidies for the reproduction and the related areas. Thus, it has been sought to provide a description of the irrigation of the said gland in female subjects of the swine species.

II. MATERIALS AND METHODS

Seven crossbred sows (*Sus scrofa domesticus*) - with different body weights (weighing from 40kg to 50kg), and prior to puberty, with a mean age of three months, originated from pig farms in the municipal unit of Patos de Minas - MG, Brazil - were used. The pigs were obtained after natural death at the very farm and were subsequently forwarded to the Laboratory of Animal Anatomy of the University Center of Patos de Minas, where they were initially cleaned and identified.

For the marking of the arterial system of each animal, an incision was made in the dorsal third of the chest wall, between the third and the fifth intercostal space, with identification of the descending thoracic aorta, the brachiocephalic trunk, and the left subclavian artery. after insulation of the same, the said vessels were subjected to the procedure of cannulation with urethral catheter and filled with a 50% latex-based aqueous solution (Artecola® –Altamira Indústria e Comércio de Látex) stained with specific pigment (Suvinil® Tintas e Pigmentos – latex paint dye). The fixation was carried out by means of intramuscular, subcutaneous, and intracavitary injections of 10% formaldehyde aqueous solution (Chemco® – GEIII formaldehyde solution) prior being immersed in receptacles containing the same solution, where they were kept in for 15 days.

An incision in the mean third of the neck was made saiming to commencing the dissection at the level of the trunk for access to the internal thoracic arteries, after the opening of the thoracic transverse muscle. These vessels were followed, as they extended towards the abdominal cavity - where, from the xiphoid cartilage of the xiphoid process of the sternum, the arteries in question pass on to being referred to as the cranial superficial epigastric arteries - and branched off to the thoracic and cranial abdominal mammary glands, in direct and indirect branches. For the dissection of the arteries in the inguinal and caudal abdominal teats, the access took place from the external iliac artery, at the root of each pelvic limb. This artery followed underneath the pubis, at which point it branched off the pudendal epigastric trunk artery which, after a short path, gave rise to the caudal epigastric and the external pudendal arteries. From the external pudendal artery, the superficial caudal epigastric artery was branched off, which would be then followed until the end of the same, in direct and indirect branches to the mammary glands.

In four animals, prior to the vessels' being filled with latex aqueous solution, the Barium sulfate contrast (radiopaque) was bilaterally injected from the cannulation with urethral catheter in the internal thoracic arteries and the internal and external pudendal arteries. The animals were forwarded to the sector of diagnostic imaging of the Veterinarian Clinic Center which belongs to the same academic institution, where they would then be subjected to radiographic examination in the ventral dorsal and right and left oblique positions, whilst facilitating the identification of the arterial distribution.

A schematic drawing of the artery branching spread out towards the mammary glands was made. The statistical analysis adopted was simple descriptive, with verification of the presence or the absence of arteries spreading out towards the thoracic, the abdominal, and the inguinal teats, as well as the average of branches produced by the same.

The anatomic nomenclature for designation of the structures is in accordance with the International Committee on Veterinary Gross Anatomical Nomenclature [12]. The work had been approved by the Ethics Committee for the Utilization of Animals of the University Center of Patos de Minas – UNIPAM, under the protocol number 13/17.

III. RESULTS

It was observed a mammary complex composed by the seven teats in each antimere, separated by the intermammary groove, disposed at the level of the ventral medial line. Those teats are disposed bilaterally and in an asymmetric fashion, from the ventral region of the thorax, at the level of the seventh rib, to the inguinal region.

All of the mammary glands would receive a direct arterial branch and varying numbers of indirect branches. The direct branches were identified and designated in accordance with the name of the irrigated teat (Fig. 1).

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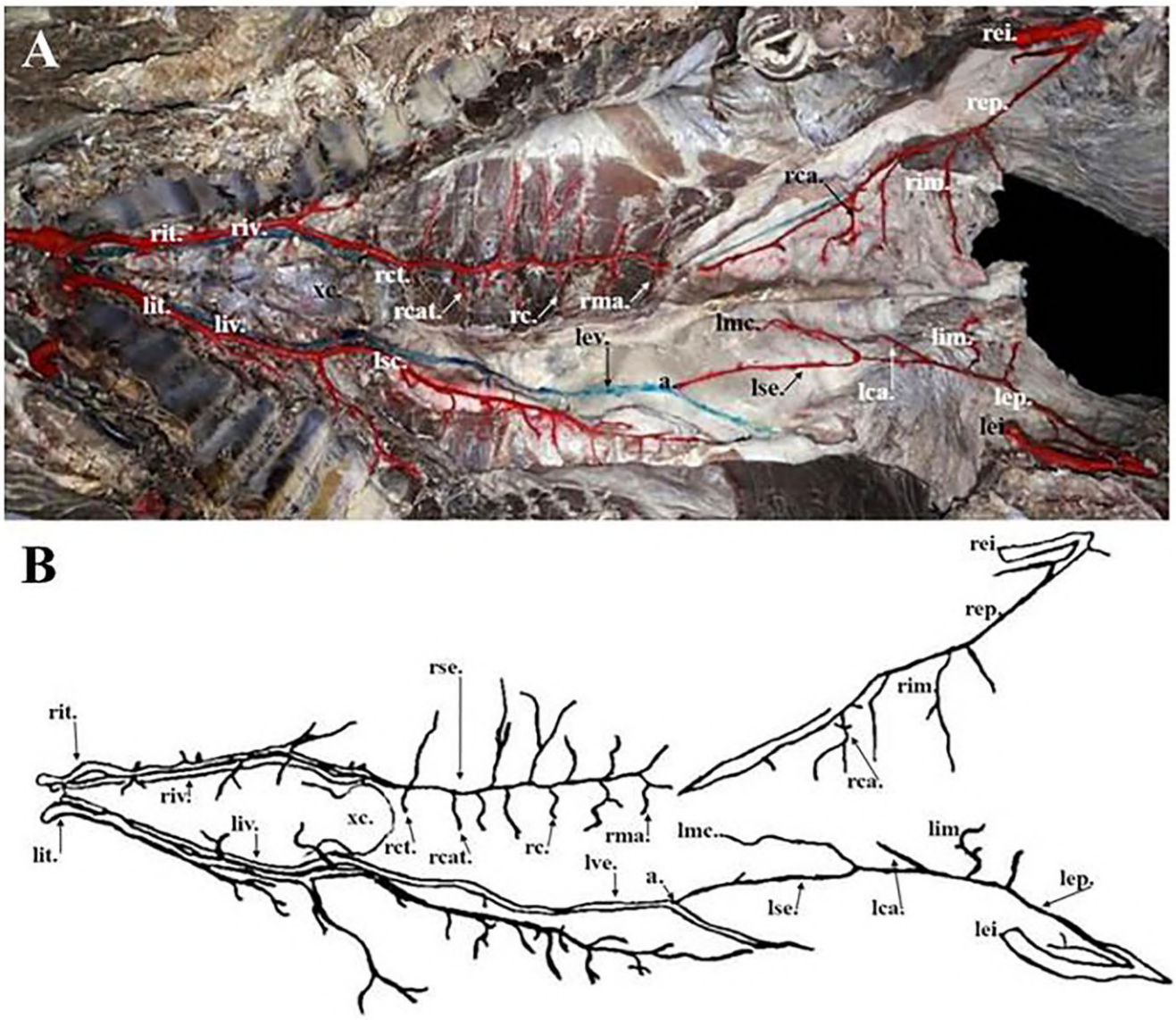

*Figure 1 – **(A)** Dorsal views of the ventral walls of the thoracic and of the abdominal cavities and of the inguinal region of a crossbred sow; **(B)** Schematic of the arterial distribution to the mammary glands of sow. Left internal thoracic artery (lit.), right internal thoracic artery (rit.), left superficial cranial epigastric artery (lsc.), right cranial thoracic mammary artery (rct.), right caudal thoracic mammary artery (rcat.), right cranial abdominal mammary artery (rc.), right medial cranial abdominal mammary artery (rma.), left external iliac artery (lei.), right external iliac artery (rei.), left external pudendal artery (lep.), right external pudendal artery (rep.), left inguinal mammary artery (lim.), right inguinal mammary artery (rim.), left caudal abdominal mammary artery (lca.), right caudal abdominal mammary artery (rca.), left medial caudal abdominal mammary artery (lmc.), left superficial caudal epigastric artery (lse.), xiphoid cartilage of the xiphoid process of the sternum (xc.), left superficial cranial epigastric vein (lev.), left internal thoracic vein (liv.), right internal thoracic vein (riv.), and anastomosis between the indirect branch of the left superficial caudal epigastric artery and the left superficial cranial epigastric vein (a.).*

The cranial thoracic, the caudal thoracic, the cranial abdominal, and the medial cranial abdominal mammary glands are irrigated by the direct and indirect branches of the superficial cranial epigastric arteries, which are the direct continuation of the internal thoracic arteries - these being visualized with significant calibers and with no spread of direct and indirect ramifications to the mammary glands.

Apart from the indirect branches, the right cranial thoracic mammary gland received the direct branch described as homonymous to the teat it irrigates (right cranial thoracic mammary artery). Irrigating the left

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cranial thoracic mammary gland, the left cranial thoracic mammary artery and other indirect branches stemming from the same artery were noticed.

The direct branches of the superficial cranial epigastric arteries - termed right and left caudal thoracic mammary arteries - converged to the right and left caudal thoracic mammary glands. It has also been noticed that, at the level of the cranial region of the abdomen, the cranial abdominal mammary glands are found in each antimere, wherein the right and left cranial abdominal mammary arteries are observed - these also derived from the right and left cranial epigastric arteries, respectively.

The right and left medial cranial abdominal mammary glands are irrigated by direct branches from the superficial cranial epigastric arteries, termed right and left medial cranial abdominal mammary arteries. Nevertheless, they also receive indirect branches from the superficial caudal epigastric arteries.

The medial caudal abdominal, the caudal abdominal, and the inguinal mammary glands are irrigated by direct and indirect branches from the superficial caudal epigastric arteries, which are the continuation of the external pudendal arteries, which have not produced either direct or indirect branches towards the teats. The direct branches have been termed in accordance with the mammary gland which sustained the blood support.

Initially, there had been visualization of the direct stemming of the right and left inguinal mammary arteries, which provide blood support to the right and left inguinal mammary glands, respectively. To the right and left caudal abdominal mammary glands, the right and left caudal abdominal mammary arteries were respectively observed. In the right and left medial caudal abdominal mammary glands, there has been observation of the right medial caudal abdominal mammary artery towards the right teat, and of the left medial caudal abdominal mammary artery towards the left teat.

The presence of arterial-venous anastomosis was observed in all of the dissected animals, among the indirect branches of the superficial caudal epigastric arteries with the superficial cranial epigastric vein.

By means of the contrast radiography technique, there has been visualization of the arteries described and of the actual path run by the same in order to facilitate blood supply to the mammary glands in the thoracic, the abdominal, and the inguinal regions. It was also possible to compare the calibers of these vessels revealing that the superficial cranial epigastric arteries have diameters that are larger than those of the superficial caudal epigastric arteries (Fig. 2 and 3).

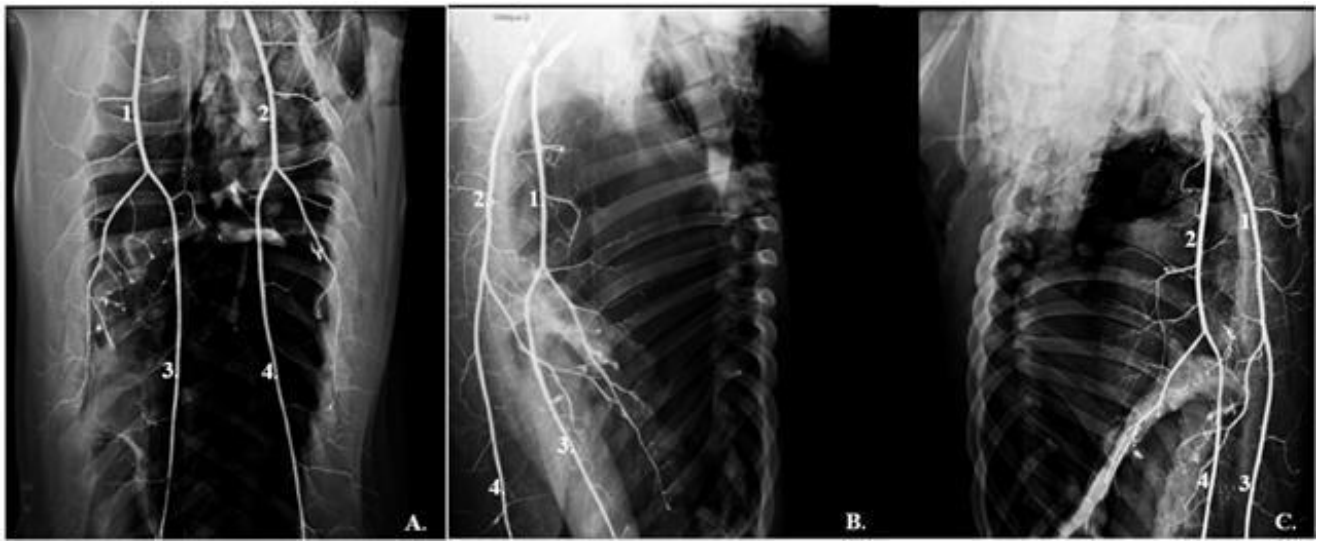

*Figure 2 - Contrast radiographs of the thoracic cavity of sow, in ventral dorsal positioning **(A)**, right oblique **(B)**, and left oblique **(C)**, Being: right internal thoracic artery (1), left internal thoracic artery (2), right superficial cranial epigastric artery (3), and left superficial cranial epigastric artery (4).*

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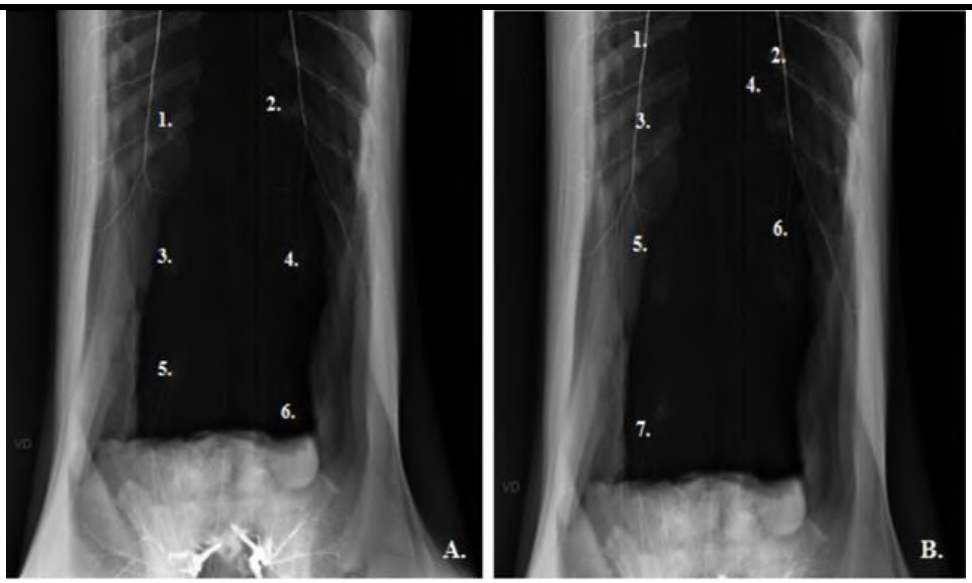

Figure 3 - Contrast radiographs of the caudal third of the thoracic cavity, of the abdominal cavity, and of the cranial third of the pelvic cavity of sow, in ventral dorsal positioning. ***(A)*** *Right medial cranial abdominal mammary gland (1), left medial cranial abdominal mammary gland (2), right medial caudal abdominal mammary gland (3), left medial caudal abdominal mammary gland (4), right caudal abdominal mammary gland (5), and left caudal abdominal mammary gland (6).* ***(B)*** *Right superficial cranial epigastric artery (1), left superficial cranial epigastric artery (2), right medial cranial abdominal mammary artery (3), left medial cranial abdominal mammary artery (4), right medial caudal abdominal mammary artery (5), left medial caudal abdominal mammary artery (6), and right caudal abdominal mammary artery (7).*

IV. DISCUSSION

In swine farming, it is important to know more about mammary glands to understand why the cranial glands are larger than the caudal - that factor being an aggravation in the uniform development of the piglets [11]. The circulatory system of this tissue, with all of its main vessels and ramifications, calls for a high level of knowledge, due to its significance on account of being responsible for carrying the nutrients, the hormones, and the oxygen in order for a matrix sow to produce milk [13].

In relation to the number of teats found, it is in accord with that which had been described by Frandson, Wilke and Fails [14], who reported that, for domestic swine, the normal number of teats is seven pairs - the first pair being found immediately caudal to the junction between the sternum and the costal arch, whereas the last pair is found in the inguinal region. Getty [15] describes a distribution similar to that of bitches, this being in two rows, which König and Liebich [13] have reported to be parallel to the ventral medial line of the trunk, being separated by the intermammary groove. They are thus distributed: 2 thoracic pairs, 4 abdominal pairs, and 1 inguinal pair; being adhered by fat tissue to the wall, surrounded by elastic and connective tissue [17]. Supranumerary teats may be found among normal teats, although such occurrence had not taken place in this study. In average, the sows present 2.5 teats beyond the average number of their litters [14].

The distribution of the left and right mammary complexes follows that established by König and Liebich [13], in which they are not found at the same transversal plane but, rather, are distributed in an alternate fashion to facilitate access to the piglets, when the female is in lateral decubitus. These authors moreover describe that each of those complexes has two or three mammary units and that, in each of the same, an individualized orifice is open at the end of the papilla. In this study, no pathology has been observed to affect the mentioned glands analyzed.

The description pertinent to the irrigation of the mammary glands in this species chosen for the study is scarce, while Dyce et al. [18] report that the local blood supply of the mammary glands of sows is performed from the internal thoracic, the superficial cranial epigastric, and the superficial caudal arteries.

Frandson et al. [14] characterize that the caudal distribution is performed by the superficial caudal epigastric artery and that the cranial pairs receive blood from the branches of the superficial cranial epigastric arteries - besides specifying that the same do link dorsally to the abdominal mammary glands. However, the superficial cranial and caudal epigastric arteries end in direct and indirect branches for the blood supply of the

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teats - the aforementioned communication not being maintained.

König and Liebich [13] portray that the responsible for the irrigation of the cranial abdominal and thoracic mammary complexes is a single punching branch that originates from the internal thoracic artery, termed the mammary branch of the superficial cranial epigastric artery, and that branches emerging from the external pudendal artery - described as mammary branches of the superficial caudal epigastric artery - irrigate the caudal and the inguinal abdominal teats. Nevertheless, multiple direct branches (described as mammary arteries) and indirect branches have been observed, which stem from the cranial and the caudal epigastric arteries and distribute to the entire mammary complex. Still in contradiction, these authors report that segmental ventral intercostal branches of the internal thoracic artery may convey blood to the thoracic glands.

In bovine females, König and Liebich [13] have described a caudal blood distribution originating from the same branches observed in sows, though with a different ending for their ramifications. The mains artery that irrigates the udder is the external pudendal which, after crossing the inguinal ring, converges caudally until the base of that gland, whilst bifurcating in the cranial mammary and the caudal mammary arteries which cranially perform an anastomosis with the superficial caudal epigastric artery, being in continuation with the superficial cranial epigastric artery. Caudally, the ventral labial branch of the internal pudendal artery is distributed to the udder - a ramification that is not observed in domestic swine.

Luiz and Miglino [19] describe that the present literature uses the irrigation of the mammary glands of bovine females as a standard for the other species - a fact that should be reviewed due to the peculiarities present in each species, as has been demonstrated for the swine as from this study. Upon their analyzing the irrigation of the mammary complex of goats, these authors have reported the similarities with the arterial supply in cows, whilst observing that the same is performed as from the external pudendal artery (this being the mains vessel), apart from two other sources of blood supply, also visualized by Magilton and Getty [20], Schmidt [21], Berg [22], Getty [15], Schummer et al. [23], Lahunta and Habel [24], and Dyce et al. [18]; which is an anastomosis of the ventral perineal artery, the dorsal labial branch, and the mammary branch to the ventral labial branch or the perineal, apart from the anastomosis at the level of the umbilical scar of the superficial caudal epigastric artery, which comes from the external pudendal artery, with branches from superficial cranial epigastric artery, originated from the internal thoracic artery.

Luiz et al. [25], whilst evaluating the blood supply of the mammary glands in 45 adult canines - crossbred and at different ages - (15 multiparous females, 15 nulliparous females, whilst those remaining were male), have been able to conclude that, in this species, the blood supply comes from the superficial cranial and caudal epigastric arteries - results that are similar to that which has been found in sows, hence those are the precursors in the blood distribution to the mentioned glands.

Still, according to Luiz et al. [25], the distribution to each gland takes place as flows: in the three groups analyzed, there had been the predominance of irrigation in a terminal direct fashion in the cranial thoracic and the cranial abdominal pair of teats; in the caudal thoracic teats, there had been greater incidence of a terminal direct type of distribution in nulliparous females whilst, in multiparous females and in males, an equivalence has taken place in regard of the indirect and the direct terminal irrigation in these pairs of mammary glands. In the caudal abdominal teats, there had been nearly absolute predominance of the indirect distribution - a mode of irrigation found in the inguinal glands of all animals from all of the groups assessed. In the swine females, all of the animals evaluated have expressed a direct mode of irrigation - these branches being termed mammary arteries - besides varying numbers of indirect branches.

Luiz et al. [26], whilst also describing the irrigation of the mammary glands in dogs, conclude for the presence of two arterial subdivisions found in all of the cases: a cranial complex arising from the internal thoracic artery, and another caudal complex which arises from the external pudendal artery; the same being found in sows.

Whilst evaluating the morphology of the mammary glands of six female adult subjects of coati (*Nasua nasua*), with one of them being in a nursing stage, Casals et al. [27] describe the teats of that species as being similar to those of the other animals which are part of the Procionidae family, apart from the domestic animals. In spite of the variation in regard of the number of pairs of glands, whilst presenting only three (one pair in the cranial abdominal region, another one in the caudal abdominal region and, finally, one pair in the inguinal region) - four pairs short from the sows - these have received ramifications from practically the same arteries: the superficial cranial epigastric artery and the superficial caudal epigastric artery. Bellatine et al. [28], after having dissected three adult females of South American Raccoon (*Procyon cancrivorus*), with no defined ages, observed the same arterial distribution reported.

As conceptualized by Han and Hurd [29], the contrast radiographic study achieves, as a purpose, the plotting of an outline between an organ or a system and

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the soft tissue surrounding the same, whilst the establishment of the size, the shape, the position, the localization, and the function of an organ.

Luiz, Miglino and Santos [26], whilst resorting to the aforementioned methodology, have attained a description in detail of the irrigation of the mammary glands in bitches, highlighting the localization and the quantity of arterial anastomoses of the mammary complex of the species with the neighboring territories, making it possible to establish the intersegmental limits and the relations with other organs, especially the skin.

In this perspective, better identification and understanding of the blood supply to the mammary glands of sows was possible, since the implantation of the contrast radiography proved efficient for the identification of the direct and indirect branches of these glands.

V. CONCLUSION

The mammary arteries responsible for the irrigation of the mammary glands in sows originate from the superficial cranial and the caudal epigastric arteries. The direct branches have been termed in accordance with the glands which they distributed to, and the indirect branches have presented variation in standard and size. The deployment of contrast radiography has revealed to be efficient for the identification of the direct and the indirect branches, whilst ensuring better visualization of the irrigation and a specific description for each mammary gland. It is worth to mention that the reduced caliber of the direct branches derived from the superficial caudal epigastric arteries corroborates with the information that the caudal mammary glands are smaller and that, as a consequence, they have lesser productive performance.

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