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Full Length Article

Anatomical and radiographical studies on the arterial supply of the udder in goat and their surgical importance

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ABSTRACT

The present study aimed to show the arterial blood supply of the udder of the Egyptian native breed of goat (Baladi goat) to be used as a guide during mastectomy and other surgical interferences. The study was carried out on the udder of twelve apparently healthy adult female Egyptian Baladi goats. Four goats were used for mastectomy, one specimen was used for radiography and the other specimens were subjected to gum-milk latex injection to clarify the origin, course and distribution of the main arteries supplying the udder. The results revealed that the udder of goat was supplied by the external pudendal artery and dorsal labial and mammary branch of the ventral perineal artery. The course of the external pudendal artery through the inguinal canal before reaching the base of the udder, as well as that of the dorsal labial and mammary branch of the ventral perineal artery in the perineal region, were briefly described to determine the appropriate site for ligation of these vessels before mastectomy. Moreover, the arterial interconnection between the two halves of the udder was emphasized to be highlighted during unilateral mastectomy. Vascular ligation of the main blood vessels supplying the udder on the basis of the anatomical description provided less traumatic surgery and reduced the severity of the blood loss.

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1. Introduction

Recently, goats became an important aspect of animal production in Egypt; they are considered as a source of meat, milk and hide (Hamed et al., 2009). There is a growing awareness in many countries for using the goat as efficient animals for milk production (Abu et al., 2013). The ability of goats to produce high-quality milk has been associated with increased susceptibility to udder diseases (Abu-Samra et al., 1988; Smith and Roguinsky, 1977). Mastectomy is indicated for treatment of gangrenous mastitis, chronic suppurative mastitis and udder abscessation and fibrosis (El-Maghraby, 2001; Noordsy, 2013; Youssef, 1999). Nevertheless, mastectomy is a high-risk procedure due to the potential of massive blood loss (Smith and Sherman, 2009). Consequently, vascular ligation is a major consideration during surgical removal of the enlarged and highly vascularized mastitic udder.

Many research have been done for demonstration of the udder vasculature in ruminants, however, little of them were referred to application of these anatomical facts during surgical interference. The present study gave a detailed description of the arterial system of the udder in goat and highlighted the course of these arteries to provide an accurate site for their ligation before mastectomy, in a trial to control the expected massive blood loss.

2. Materials and methods

2.1. *Animal specimens*

The present study was carried out on apparent healthy adult Egyptian Baladi female goats (n = 12, age 2–5 years, weight 18–27 kg) which were purchased alive from animals' markets in Beni-Suef Governorate. Mastectomy was done in four goats at the surgery clinic in Faculty of Veterinary Medicine, Beni-Suef University.

2.2. *Dissection of the specimens*

Seven fresh cadavers were injected with the embalming solution through the common carotid artery (2% Formalin 40%, 2% concentrated liquid phenol, 20% Ethyl alcohol 95%, 6% Glycerin and 70% water), then the specimens were kept in formalin 10% for 7 days. The abdominal aorta in all dissected specimens was injected with gum-milk latex, colored red (Rotring ink®). The caudal vena cava in six specimens was injected with gum-milk latex, colored blue (Rotring ink®). The blood vessels were secured and the whole cadavers were preserved in formalin 10% for 3–4 days. The specimens were eviscerated and carefully dissected in both sides for demonstration of the origin, course and ramification of the arteries supplying the udder (Hildebrand, 1968).

2.3. *Preparation of radiographic images*

The mercury was used as a contrast medium for radiography of the arteries in one specimen. The parameters used were 50 K. volt and 70 mAs. The system of films and screen used was C.R. AGFA.

The nomenclatures in this study were adopted according to Nomina Anatomica Veterinaria (2012) and the available literatures.

3. Results

The udder of goat was supplied by the external pudendal artery, as well as the dorsal labial and mammary branch of the ventral perineal artery.

3.1. *Pudenda externa*

The external pudendal artery was detached from the pudendoepigastric trunk and passed caudally with slight inclination ventrally over the inguinal ligament for about 3 cm. It left the abdominal cavity through the deep inguinal ring about 3.3 cm cranioventral to the cranial border of the pubis in accompany with the satellite vein and branches of the genitofemoral nerve, then it emerged from the superficial inguinal ring through the aponeurosis of the external abdominal oblique muscle to be continued in a flexuous course as a mammary artery (Fig. 1).

The external pudendal (mammary) artery could be detected at the superficial inguinal ring where it was covered by the skin of the inguinal region and lateral suspensory lamina; this area of the superficial inguinal ring (Fig. 2) was located between the medial aspect of the thigh and the base of the udder (about 6–7 cm craniodorsal to the caudal aspect of the base of the udder). Based on this anatomical description, the external pudendal artery could be ligated during mastectomy through 5 cm skin incision which made about 6–7 cm (four fingers breadth) craniodorsal to the caudal aspect of the base of the udder; the pulsation of the external pudendal artery was detected and the lateral lamina at this level was bluntly incised and reflected (Fig. 3a). The external pudendal vessels were bluntly dissected from the surrounding fascia and they were double ligated (Fig. 3b); care should be taken to avoid damaging of the genitofemoral nerve.

The mammary artery (Figs. 4/1 and 2 and 9/3 and 4) directed ventrally with slight inclination cranially reaching the caudal third of the base of the udder just rostral to the mammary lymph node, where it was divided into cranial and middle mammary arteries. During its course, the mammary artery gave ventral labial, caudal basal and caudal mammary arteries, as well as branches to the mammary lymph node.

3.1.1. *Ramus labialis ventralis*

The ventral labial artery was one of the collateral branches of the mammary artery having a different origin in the same specimen; it either originated from the medial aspect of the mammary artery before its bifurcation (Fig. 5/8) or from the medial aspect of the middle mammary artery (Fig. 5/7). It ran caudomedially along the medial border of the mammary lymph node, then it continued subcutaneously in the perineal region, where it received the dorsal labial and mammary branch of the ventral perineal artery (Fig. 10/14).

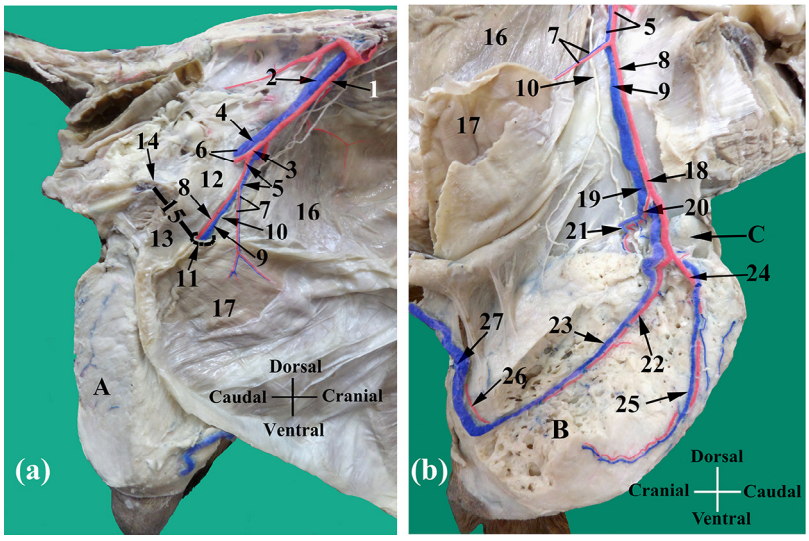

Fig. 1 – A photograph of dissected abdominal and pelvic cavities (a) and inguinal region (b) of the goat showing the origin and course of the external pudendal vessels; 1- External iliac artery, 2- External iliac vein, 3- Deep femoral artery, 4- Deep femoral vein, 5- Pudendoepigastric trunk, 6- Medial circumflex femoral vessels, 7- Caudal deep epigastric vessels, 8- External pudendal artery, 9- External pudendal vein, 10- genitofemoral nerve, 11- Deep inguinal ring, 12- Inguinal ligament, 13- Pre-pubic tendon, 14- Pubis, 15- Distance between 11 and 14, 16- Internal abdominal oblique muscle, 17a- Rectus abdominis muscle (after reflection of the inner rectal sheath), 17b- Reflected rectus abdominis muscle and its outer rectal sheath, 18- Mammary artery, 19- Mammary vein, 20- Caudal basal artery, 21- Caudal basal vein, 22- Cranial mammary artery, 23- Cranial mammary vein, 24- Middle mammary artery, 25- Middle mammary vein, 26- Cranial superficial epigastric artery, 27- Cranial superficial epigastric vein.

The ventral labial branch detached 2–3 small branches to supply the caudomedial aspect of the mammary gland and surrounding skin. Moreover, it gave an anastomosing branch to join the middle mammary artery (Fig. 5/10).

3.1.2. *Ramus basalis caudalis*

The caudal basal branch (Figs. 5/11 and 9/11) considered a second collateral branch which detached separately from the lateral aspect of the mammary artery about 0.2–0.3 cm dorsolateral to the origin of the ventral labial one. Only in one specimen, it originated by a common stem with the caudal mammary artery (Fig. 7). The caudal basal branch proceeded craniolateral to the mammary lymph node on the lateral aspect of the base of the udder about 2.5 cm lateral to the cranial mammary artery, then it anastomosed with the most rostral part of cranial mammary artery (Fig. 5/12). Through its length, the caudal basal branch detached about 4–5 small parenchymal branches (Fig. 6/6) to be distributed in the lateral aspect of the mammary gland.

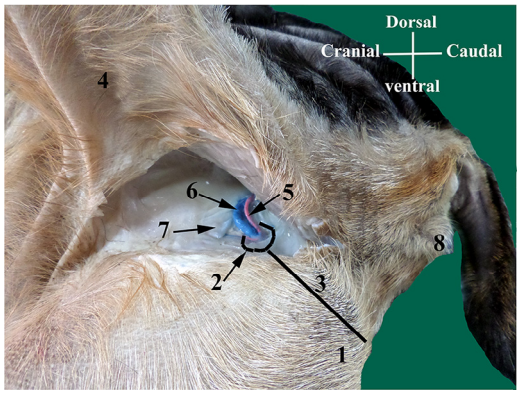

Fig. 2 – A photograph of female goat in a lateral recumbency showing the external pudendal vessels at the superficial inguinal ring; 1- Caudal aspect of the base of the udder, 2- Superficial inguinal ring, 3- Distance between 1 and 2, 4- Medial aspect of the thigh, 5- External pudendal artery, 6- External pudendal vein, 7- Lateral suspensory lamina, 8- Vulva.

About 2 cm from its origin, the caudal basal branch detached cutaneous and caudal sinus branches. The cutaneous branch (Figs. 7/7 and 9/12) ran rostrolaterally to be ramified in the skin of the dorsolateral aspect of the udder. The caudal sinus branch (Figs. 7/8 and 9/13) passed, rostroventrally supplying the caudal aspect of the lactiferous sinus through 3–4 fine sinus branches before its bifurcation into small cranial and large caudal branches; the cranial one (Figs. 7/9 and 9/14) continued cranioventrally to be ramified in the craniolateral aspect of the arterial papillary plexus. While, the caudal branch (Figs. 7/10 and 9/15) passed caudoventrally, where it received an anastomosing branch from the caudal mammary artery (Fig. 7/11), and then it ramified in the caudal aspect of the arterial papillary plexus at the base of the teat.

3.1.3. *Mammaria caudalis*

The caudal mammary artery (Fig. 6/3) was detached from the external pudendal artery as a collateral small branch just before its bifurcation and about 0.5 cm cranial to the origin of the caudal basal branch. It ran cranioventrally on the caudal aspect

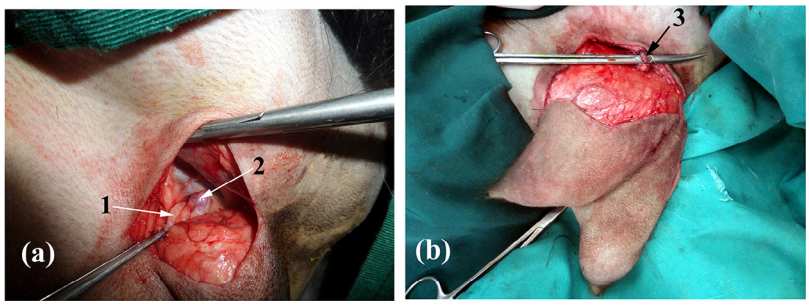

Fig. 3 – A photograph showing skin incision at the base of the udder and reflection of the lateral suspensory lamina (a1) for detection of the external pudendal vessels (a2) and then they double ligated (b2).

of the udder until it was terminated in the arterial plexus at the base of the teat (Fig. 7/6). Along its course, this artery gave about 2–3 small parenchymal branches (Fig. 6/7) which ramified in the caudal aspect of the mammary gland; it also gave a branch to the mammary lymph node (Fig. 6/5).

3.1.4. *Mammaria media*

The middle mammary artery was one of the terminal branches of the mammary artery. The large right middle mammary artery (Fig. 4/4) ran ventromedially along the medial suspensory ligament, where it received the small left one (Fig. 4/6), and then it continued to supply the medial aspect of both halves of the udder. However, in four out of the investigated specimens, the small right middle mammary artery (Fig. 5/4) crossed the medial suspensory ligament to be anastomosed with the large left one (Fig. 5/6). At the cranial aspect of the base of the udder, the middle mammary artery divided into two branches (Fig. 9/17) that joined the lateral sinus branch and papillary plexus of both sides.

Along its course, the middle mammary artery gave about 10–12 small parenchymal branches (Fig. 4/10) which passed through the medial suspensory ligament to supply the medial aspect of the glandular tissue and lactiferous ducts of both halves of the udder. A medial sinus branch (Figs. 4/9 and 9/16) was detached from the middle mammary artery about 2 cm from its origin; it passed cranioventrally supplying the medial aspect of the lactiferous sinus through 2–4 small sinus branches and it also gave 2–3 parenchymal branches to the mammary gland and lactiferous ducts. About 1 cm cranial to the origin of the medial sinus branch, a papillary branch (Fig. 7/13) was detached from the ventral aspect of the middle mammary artery only in one half of the udder; it passed cranioventrally to be terminated in the caudomedial aspect of the arterial plexus at the base of the teat.

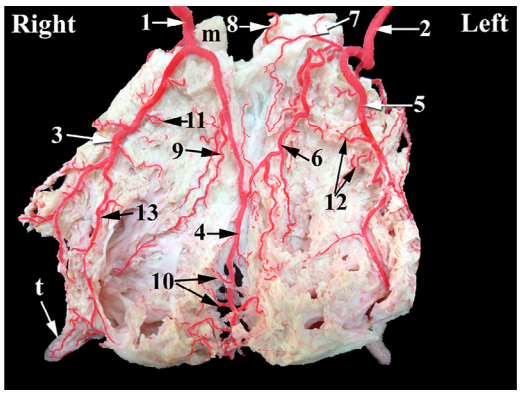

Fig. 4 – A photograph of dissected dorsal aspect of goat's udder showing the distribution of the mammary artery; m- Mammary lymph node, t- Teat, 1- R. mammary artery, 2- L. mammary artery, 3- R. cranial mammary artery, 4- R. middle mammary artery, 5- L. cranial mammary artery, 6- L. middle mammary artery, 7- Ventral labial branch, 8- Dorsal labial and mammary branch of the ventral perineal artery, 9- R. medial sinus branch, 10- Parenchymal branches of the R. middle mammary artery, 11- Parenchymal branches of the R. cranial mammary artery, 12- Dorsal branches of the L. cranial mammary artery, 13- Lateral sinus branch of the R. cranial mammary artery.

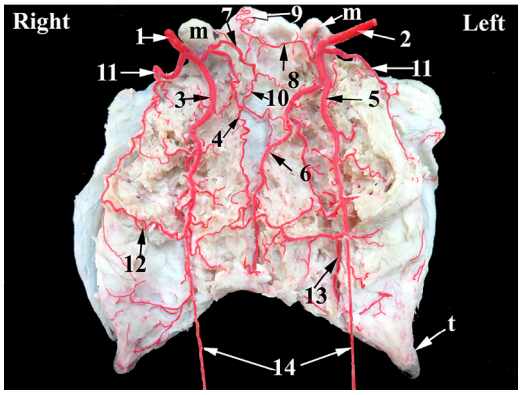

Fig. 5 – A photograph of dissected dorsal aspect of goat's udder showing different size and course of the middle mammary artery in five specimens; m- Mammary lymph node, t- Teat, 1- R. mammary artery, 2- L. mammary artery, 3- R. cranial mammary artery, 4- R. middle mammary artery, 5- L. cranial mammary artery, 6- L. middle mammary artery, 7- R. ventral labial branch, 8- L. ventral labial branch, 9- Dorsal labial and mammary branch of the ventral perineal artery, 10- Anastomosing branch of 7, 11- Caudal basal branches, 12- Caudal basal branch anastomosed with the cranial mammary artery, 13- Lateral sinus branch of 5, 14- Cranial superficial epigastric arteries.

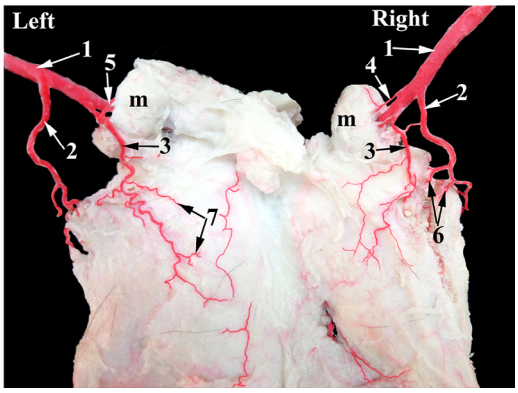

Fig. 6 – A photograph of dissected caudal aspect of goat's udder showing the origin of the caudal basal and caudal mammary branches; m- Mammary lymph node, 1- Mammary arteries, 2- Caudal basal branches, 3- Caudal mammary branches, 4- Branch to the mammary lymph node from the mammary artery, 5- Branch to the mammary lymph node from the caudal mammary artery, 6- Parenchymal branches of the caudal basal artery, 7- Parenchymal branches of caudal mammary artery.

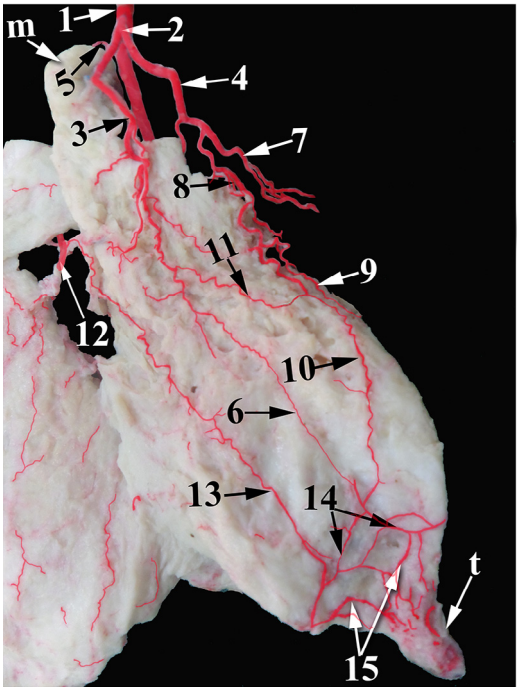

Fig. 7 – A photograph of dissected caudal aspect of the right half of the udder of goat showing the exceptional origin of the caudal basal and caudal mammary arteries; m- Mammary lymph node, t- Teat, 1- Mammary artery, 2- Common stem of caudal basal and caudal mammary arteries, 3- Caudal mammary artery, 4- Caudal basal branch, 5- Branch to the mammary lymph node, 6- Termination of the caudal mammary artery in the arterial papillary plexus, 7- Cutaneous branch of 4; 8- Caudal sinus branch, 9- Cranial branch of 8, 10- Caudal branch of 8, 11- Anastomosing branch of caudal mammary and caudal branch of caudal sinus branch, 12- Middle mammary artery, 13- Papillary artery of the middle mammary artery, 14- Arterial papillary plexus, 15- Papillary arteries.

3.1.5. *Mammaria cranialis*

The cranial mammary artery (Fig. 4/3 and 5) was considered the direct continuation of the mammary artery, where it passed cranially through the parenchyma of the udder in a superficial course than the middle one. Cranial to the base of the udder, it continued subcutaneously as cranial superficial epigastric artery (Fig. 5/14).

Along its course, the cranial mammary artery gave about 5–6 parenchymal branches (Fig. 4/11) to irrigate the glandular tissue of the dorsolateral aspect of the udder and about 3–5 dorsal branches (Fig. 4/12) to supply the glandular tissue and the lactiferous ducts. About 5–6 cm from its origin, the cranial mammary artery detached a lateral sinus branch (Figs. 8/4 and 9/18), which ran cranioventrally giving 3–4 small sinus branches to supply the lateral aspect of the lactiferous sinus; it also detached 2–3 small parenchymal branches to be ramified into the mammary tissue in this area. The lateral sinus branch deviated medially toward the base of the teat, then it divided into two papillary arteries which received the papillary branch of the middle mammary artery, as well as branches from caudal mammary, and caudal basal arteries forming an arterial circular plexus (Figs. 8/6, 9/19 and 10/15). From this plexus about 3–4 small papillary arteries (Figs. 8/7, 19/20 and 10/16) were detached to supply the teat.

3.2. *Ramus labialis dorsalis et mammarius*

The dorsal labial and mammary branch of the ventral perineal artery of the internal pudendal artery (Fig. 10/14) passed about 3 cm ventral to the vulva, then it continued subcutaneously in the perineal region for about 4 cm to be joined with the ventral labial branches of both sides at the caudomedial aspect of the base of the udder. This branch with its satellite vein was located subcutaneously in the perineal region (Fig. 11), so they could be ligated during mastectomy at the midway between the vulva and the caudal aspect of the base of the udder (Fig. 12), to avoid sever hemorrhage during the operation.

4. Discussion

The obtained results provided a brief anatomical description for the arteries supplying the udder in the Egyptian Baladi goats. The present data showed that the udder of the goat was supplied by the external pudendal artery and the dorsal labial and mammary branch of the ventral perineal artery matched the findings of Luiz and Miglino (2000) in the same animal, Schummer et al. (1981) in cow, Badawi et al. (1985) in buffalo and Konig and Liebich (2009) in ruminants. On the other hand, it is supplied only by the external pudendal artery in goat and ewe (Saleh et al., 1999; Schummer et al., 1981).

The flexuous course of the external pudendal artery that was reported in this study simulated the findings of Nickerson and Akers (2002) in ruminants and Budras et al. (2003) in cow; the latter authors attributed this flexuous course to allow the

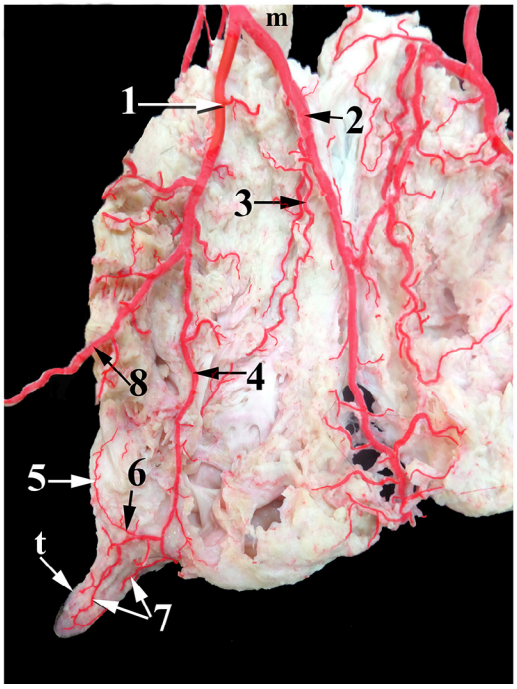

Fig. 8 – A photograph of dissected right half of Fig. 4 showing the arterial supply of its teat; m- Mammary lymph node, t- Teat, 1- Cranial mammary artery, 2- Middle mammary artery, 3- Medial sinus branch, 4- Lateral sinus branch, 5- Cranial branch of caudal sinus branch, 6- papillary Arterial circle, 7- Papillary arteries, 8- Cranial superficial epigastric artery.

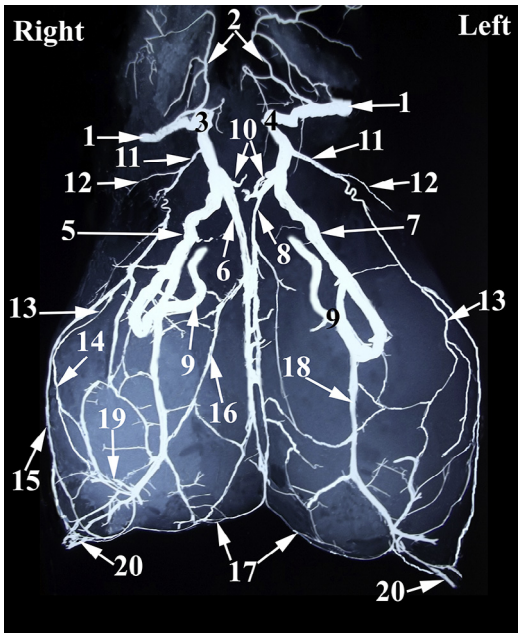

Fig. 9 – A radiographic image of the udder of the goat using mercury to show the distribution of the mammary artery; 1- Pudendoepigastric trunks, 2- Caudal deep epigastric arteries, 3- R. mammary artery, 4- L. mammary artery, 5- R. cranial mammary artery, 6- R. middle mammary artery, 7- L. cranial mammary artery, 8- L. middle mammary artery, 9- Cranial superficial epigastric arteries, 10- Ventral labial branches, 11- Caudal basal branches, 12- Cutaneous branch of 11, 13- Caudal sinus branches of 11, 14- Cranial branch of 13, 15- Caudal branch of 13, 16- Medial sinus branch of 6, 17- Termination of 6, 18- Lateral sinus branches of 7, 19- Arterial apillary plexus, 20- Papillary arteries.

lengthening of the blood vessels as the medial suspensory ligaments stretch to accommodate the distended udder. Moreover, the direct continuation of the external pudendal artery was referred as mammary artery as proved by Garrett (1988) and Seddek et al. (2013) in goat, Schummer et al. (1981) in goat and ewe, May (1971) in ewe and Damian et al. (2009) in cow.

Regarding the hemorrhage during surgical removal of the udder which is life threatening, vascular ligation of the main blood vessels supplying the udder is a major consideration to reduce the stress on the animal (El-Maghraby, 2001; Noordsy, 2013). The current investigation provided an appropriate site for ligation of the external pudendal vessels and dorsal labial and mammary branch of the ventral perineal vessels, in atrial to conduct a safe, quick and less expensive technique for mastectomy; it also reduced the severity of the blood loss. Moreover, ligation of these vessels could be used as an alternative technique for radical mastectomy especially in case of gangrenous mastitis in goat (El-Maghraby, 2001).

The division of the external pudendal artery in this study under investigation into cranial and middle mammary arteries was confirmed by the findings of Luiz and Miglino (2000) in goat and Badawi et al. (1985) in buffalo. On the other hand, it is divided into cranial and caudal mammary arteries in goat (Garrett, 1988; Seddek et al., 2013), ewe (May, 1971), cow (Damian et al., 2009; Konig and Liebich, 2009), she camel (Damian et al., 2009; Smuts and Bezuidenhout, 1987) and mare (Budras et al., 2009).

Our data came in agreement with the findings of the Badawi et al. (1985) in buffalo that, the external pudendal artery gave caudal basal, caudal mammary and ventral labial branches, as well as branches to the mammary lymph node. On the other hand, Saleh et al. (1999), in goat and ewe, denied the ventral labial branch, while the caudal basal branch that recorded in our findings couldn't be observed by Luiz and Miglino (2000) in goat.

Concerning the ventral labial branch in goat, it was originated either from the external pudendal artery or from the middle mammary one, and it anastomosed with the dorsal labial and mammary branch of the internal pudendal artery providing and additional arterial supply for the udder. Similar observations were reported by Luiz and Miglino (2000) in the same animal and Badawi et al. (1985) in buffalo.

The current investigation observed that the caudal basal branch terminated by anastomosing with the most rostral part of the cranial mammary artery. However, Saleh et al. (1999) in goat and ewe reported that, it joins with the lateral sinus branch. Moreover, our findings added that the caudal basal branch gave cutaneous and caudal sinus branches.

The current study as well as Schummer et al. (1981) in goat reported that the middle mammary artery gave medial sinus branch to supply the lactiferous sinus, meanwhile, Saleh et al.

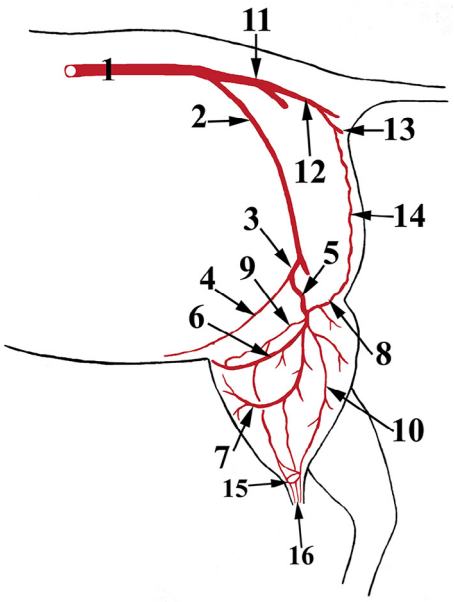

Fig. 10 – A diagram showing the arterial supply of goat's udder; 1- Abdominal aorta, 2- External iliac artery, 3- Pudendoepigastric trunk, 4- Caudal deep epigastric artery, 5- External pudendal (mammary), 6- Cranial mammary artery, 7- Middle mammary artery, 8- Ventral perineal artery, 9- Caudal basal artery, 10- Caudal mammary artery, 11- Internal iliac artery, 12- Internal pudendal artery, 13- Ventral perineal artery, 14- Dorsal labial and mammary branch of 13, 14- papillary Arterial circle, 16- Papillary arteries.

(1999) in the same animal observed the origin of this branch from the cranial mammary artery.

The anastomosing branches between the two halves of the udder should be ligated during partial mastectomy in goat (El-Maghraby, 2001; Hofmeyer, 1990). In this concern, the current investigation reported that one of the main branches of the external pudendal artery, the middle mammary artery, crossed the medial suspensory ligament to be joined with that of the

Fig. 11 – A photograph of a dissected perineal region of the goat showing the dorsal labial and mammary branch of the ventral perineal vessels (1 and 2) at the midway between the base of the udder (3) and the vulva (4).

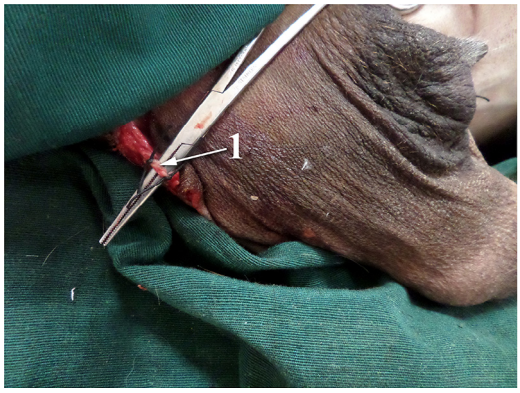

Fig. 12 – A photograph showing double ligation of the dorsal labial and mammary branch of the ventral perineal vessels (1).

other side. However, this connection is achieved by small anastomosing branches as observed by Luiz and Miglino (2000) in goat, Schummer et al. (1981) in ruminants and Damian et al. (2009) in cow. In contrary with Frandson et al. (2009) in ruminants who stated that no vessels pass through the medial ligament from one half to the other.

Regarding the arterial supply of the teat, the current study revealed that the arterial papillary plexus was formed by the two papillary arteries of the lateral sinus of the cranial mammary artery which received the papillary branch of the middle mammary artery, as well as branches from caudal mammary and caudal basal arteries. However, this plexus is formed by medial and lateral sinus branches as observed in goat and ewe (Saleh et al., 1999). On the other hand, Schummer et al. (1981) in goat reported that the teat is supplied by two papillary arteries from the medial sinus of the middle mammary artery, while Seddek et al. (2013) in the same animal observed that it is supplied by two papillary arteries from the caudal mammary artery.

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