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SOME ANATOMICAL STUDIES ON THE VASCULATURE OF THE DIAPHRAGM IN GOAT

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SUMMARY

The arterial blood supply and venous drainage of the diaphragm in goat was conducted on sixteen specimens. The results revealed that the arterial supply of diaphragm in goat mainly come from the musculophrenic and dorsal intercostal arteries in addition to small twigs from the cranial epigastric, lumber and celiac arteries. The results also revealed that the venous drainage of the diaphragm drained mainly to the caudal vena cava through right and left phrenic veins in addition to small tributaries to musculophrenic and cranial epigastric veins. The distribution of arteries and veins in diaphragm were described in detail and results were discussed with that of the other domestic animals.

INTRODUCTION

In the time that the goat considered as a good field for conducting research, in addition to the importance of the diaphragm as the main muscle of respiration, there is a lack of descriptive knowledge about its blood supply. These reasons encourage us to investigate in detail the distribution of the blood vessels of the diaphragm hoping that the findings obtained will be of value and add some new anatomical and surgical information.

MATERIAL AND METHODS

The research was carried out on sixteen healthy goats of different age and sex from the farm of the Faculty of Veterinary Medicine Beni-Suef.

The goats were treated by an intravenous injection of 5000 IU sodium heparin (Declampo and Ginther, 1973) to avoid blood coagulation and then after the animals cauthanatized and bled through the common carotid artery. The blood vessels thoroughly flushed with warm normal saline.

The injection mass used adopted by (Tomsett and Wakely, 1965) as follows: 60 % gum milk latex emulsion in ammonium hydroxide, colored red (with carmine) for arteries, and blue (with ultramarine blue) for veins.

Six specimens injected through the common carotid artery (after ligation of the abdominal aorta at the level of 4th lumber vertebra) for studying the arteries. Four specimens injected through the caudal Vena cava by canulation after its exit from the diaphragm for studying the veins. The rest of the specimens was injected through both previous routes for demonstration the arteries and veins of the diaphragm.

Injection was done by hand syringes till both arteries and veins does not accept any more mass.

The specimens were preserved in 10 % formaline before dissection was performed.

The nomenclature used in the following description is that adopted by Nomina Anatomiea Veterinaria (1994) as well as Ragab (1980).

RESULTS

I. ARTERIES

A. Musculophrenica:

The musculophrenic artery (1/1, 2/1 – 3/1) arises from the internal thoracic artery at the level of costochondral junction of the 5th rib as one of its two terminal branches. It directs caudo-laterally between the diaphragm and thoracic wall till the level of cranial border of the 8th rib where it perforates the costal part of the thoracic surface of the diaphragm and then runs caudo-dorsally on its abdominal surface medial and parallel to the costal arch till the caudal border of the 10th rib where it continues dorsally as 10th ventral intercostal artery.

The musculophrenic artery releases 4-7 Rr phrenici, only 3-4 of them are fairly large branches directed dorso-medially in the pars costalis of the diaphragm terminate at the musculo-tendinous attachment, while the rest are short branches and arborised in the ventral aspect of the pars costalis of the diaphragm without reaching the musculo-tendinous attachment.

A. Epigastrica cranialis:

The cranial epigastric artery releases phrenic branch (1/3 – 2/3) at the level of the sternal attachment of the costal cartilage to the 7th rib. The phrenic branch passes caudo-medially to arborise in the sternal part of the diaphragm.

Aa. Intercostales dorsales:

The dorsal intercostal arteries (1/6 – 2/6 – 3/3) release 4 (rarely 3) phrenic branches (1/7– 2/7-3/5) from the last two or three dorsal intercostal arteries as well as from the dorsal costoabdominal artery (2/8 – 3/4). Each phrenic branch

detached from the dorsal intercostal artery at its lower fourth; and passes dorso-medially in the texture of the pars costalis of the diaphragm where it distributes in its upper half.

A. Phrenica caudalis:

The caudal phrenic artery represented by many branches of different origins and grouped into dorsal and ventral.

1. Dorsal caudal phrenic Aa. (4B/9):

The artery represented by two or three fine twigs originated from the 1st and/or 2nd right lumber arteries in addition to a small twig from the celiac trunk. It passes cranio-ventrally to be distributed to the lumber attachment of the diaphragmatic crura and the dorsal extension of its tendinous center.

2. Ventral caudal phrenic A.(4B/5):

It is one or two branches originate either from the celiac or from both celiac and left gastric Aa respectively. The main branch (4B/5) directed cranially reaching to the abdominal surface of the diaphragm to divide into dorsal (4B/6) and ventral (4B/7) rami. The R. dorsalis distributed in the dorsal part of the diaphragmatic crura. While R. ventralis passes ventrally to the left part of the right crus around the hiatus oesophagous.

II- VEINS

V. Phrenica dextra:

The right phrenic vein (5/2 - 6/2) originates from the right side of the vena cava caudalis where it passes inside the cavel formen, at the level of caudal border of the 8th rib. It proceeds laterally across the central tendinous part of the right side of the diaphragm till the musculo-tendinous junction where it inclines dorso-laterally in the costal part of the right side of the diaphragm to anastomose with the 10th dorsal intercostal vein. During its course the right phrenic vein gives off medial and lateral sets of branches. The lateral set (5/9 - 6/9) are 5-7 long veins passed ventro-laterally and anastomosed with the ventral intercostal veins from 7th - 9th. The medial set (5/10) are 2-3 small and short branches drain the area dorsal to the right phrenic vein.

In two out of the examined cases the right phrenic vein, as reaches the musculo-tendinous junction at the level of the 8th rib, it divides into strong dorsal branch (1/9) and smaller ventral one (1/10). The dorsal branch behaves as that of the undivided right phrenic vein. The ventral branch passes cranioventrally to anastomose with the costo-sternal branch. During its course the ventral branch gives two lateral branches to drain the ventral area of the right costal part and anastomose with the 7th ventral intercostal vein.

R. sternocostalis dextra:

The right sternocostal vein is small branch originates from the right phrenic vein as it passes in the central tendinous part (6/8). In three out of the examined cases, the right sternocostal vein originates from the ventral aspect of the right side of the Vena cava caudalis (5/8). It proceeds cranio-ventrally in the central tendinous and sternal part of diaphragm to anastomose with the cranial epigastric vein to drain the sternal part of the diaphragm and adjacent tendinous & costal parts.

Rurim medialium dextrum:

The right crural vein (1/12 - 5/4 - 6/4) originates from the right side of the Vena cava caudalis dorsal to the right phrenic vein either single or represented by two branches originate independently from the dorsal aspect of Vena cava caudalis (6/4). The vein proceeds dorsally in the right crus of the diaphragm passing to the left crus dorsal to hiatus oesophagous to the anastomosed withthe small left one. During its course, it gives off 2-4 small branches to drain the right crus. One of these branches directed dorsally to be distributed inthe lumber part of the diaphragm around the hitus aorticus and anastomoses with the Rr. crucium lateralium.

V. phrenica sinstra :

The left phrenic vein (5/3 – 6/3) originates from the left side of the Vena cava caudalis on a level caudal and dorsal to the origin of the right one. The vein is weaker than the right one, it passes laterally crossing the central tendinous part, before reaching the left musculo-tendinous junction, where it divides into a large dorsal and a small ventral branch.

R. dorsalis :

The dorsal branch (5/5 – 6/5) directs dorsolaterally reaching the musculo-tendinous junction and then continues dorsally in the dorsal aspect of the left costal part where it anastomoses with the 10^{th} or 11^{th} dorsal intercostal vein. During its course, the dorsal branch gives off 3-5 lateral branches (6/10) to the left costal part of the diaphragm and they anastomose with 8^{th}, 9^{th} and may be 10^{th} ventral intercostal veins.

R. ventralis :

The ventral branch (5/6 – 6/6) is smaller than the dorsal one. It passes in the musculo-tendinous junction till reach to the sternal part of the diaphragm where it distributes and anastomoses with a branch from the cranial epigastric vein (Fig. 6). The vein releases 3-4 laterally small branches to the ventral aspect of the left costal part of the diaphragm.

In one case, the left phrenic vein (1/11) crossing the central tendinous part, reaches the musculo-tendinous junction where it inclines dorsally without division behaves as the dorsal branch of the divided vein. The ventral branch, represented by 3-4 tributaries, originates from the ventral aspect of the parent vessel (1/11) independently to

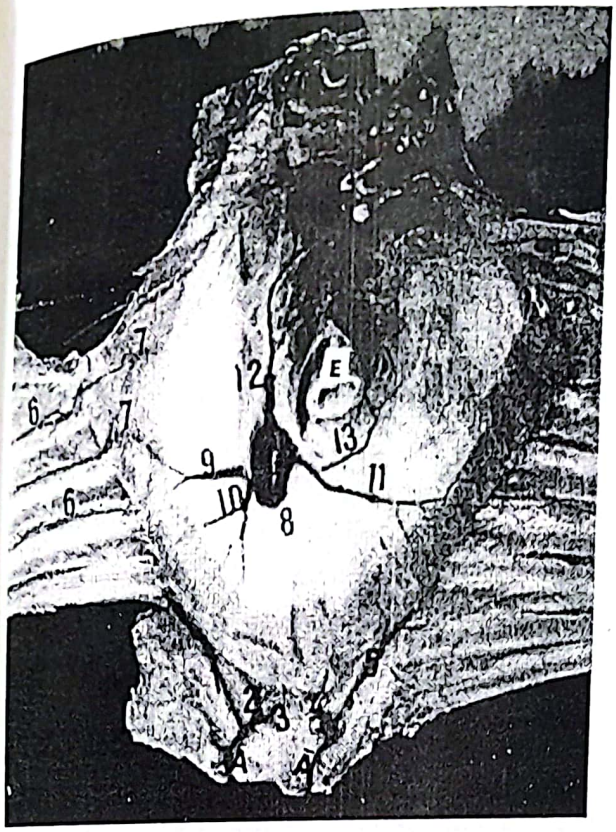

Fig. (1) : Photographic representation showing the arterial supply and venous drainage of the diaphragm of goat; (thoracic view).

E. esophagus .

AA. thoracica internae (right & left).

1-A. musculophrenica dextra.

2-A. epigastrica cranialis dextra.

3-A. R. sternalis.

4- A. epigastrica cranialis.

5- A. musculophrenica sinistra.

6-Aa. intercostales dorsales.

7-Rr. phrenici.

8-Vena cava caudalis.

9-R. dorsalis of V. phrenica dextra.

10-R. ventralis of V. phrenica dextra.

11-V. phrenica sinistra.

12-R. crurium medialium sinistrum.

13-R. crurium medialium dextrium.

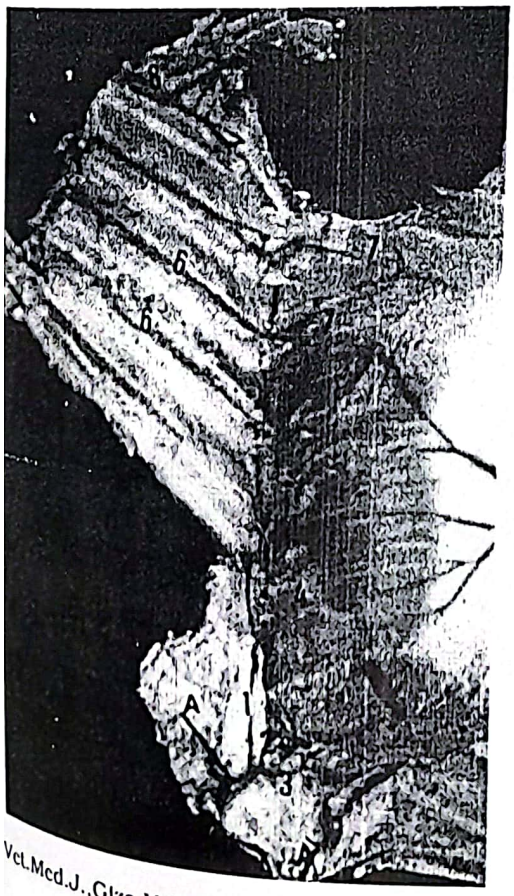

Fig. (2) : A close up of the right side of photograph (1):

A.A. Thoracica internae (right & left).

1-A. musculophrenica.

2- A. epigastrica cranialis.

3- R. sternalis.

4- Rr. phrenici A. musculophrenica.

5- Aa. intercostales dorsales.

6- Rr. phrenici.

7-A. costoabdominalis dorsalis.

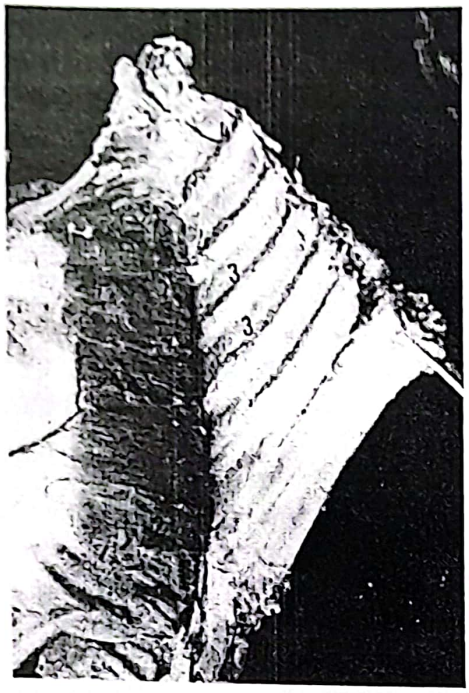

Fig. (3) : A close up of the left side of photograph (1):
A. Thoracica interna.
1-A. musculophrenica.
2-Rr. phrenici of (1).
3-Aa. intercostales dorsales.
4-A. costoabdominalis dorsalis.
5-Rr. phrenici of (3).

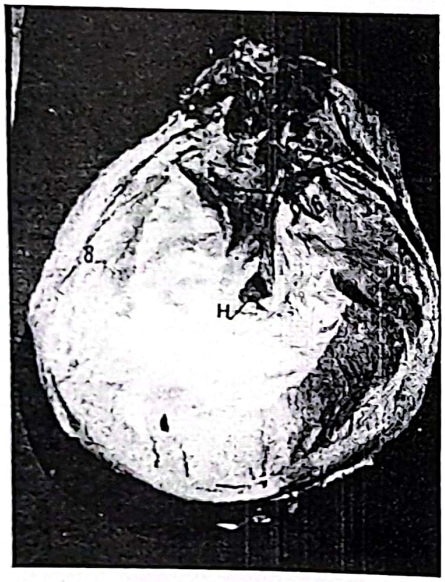

Fig. (4A) : Photographic representation showing the arterial supply of the crura of the diaphragm (abdominal view).
H. Hiatus esophagus.
1. Aorta abdominalis.
2. Common trunk of A. celica and A. mesenterica cranialis.
3.A. mesenterica cranialis.
4.A. celica.
5. Aa. phrenici caudales.
6. A. gastrica sinistra.
7.A. musculophrenica.
8.Rr. phrenici of Aa. intercostales dorsales.

Fig. (4B) : A close up of photograph (4A):
G. Hiatus aorticus.
1. Aorta abdominalis.
2. Common trunk of A. celica and A. mesenter
cranialis.
3.A. mesenterica cranialis.
4.A. celica.
5. A. phrenica caudalis.
6. dorsal branch of (5).
7. ventral branch of (5).
8. Aa. lumbales.
9. Rr. phrenici of (8).

Fig. (5) : Photographic representation showing the venous drainage of the diaphragm in goat (thoracic view).

H. Hiatus esophagus.
1. Vena cava caudalis.
2. V. phrenica dextra.
3. V. phrenica sinistra.
4. R. crurium medialium dextrum.
5. R. dorsalis of (3).
6. R. ventralis of (3).
7. R. crurium medialium sinistrum.
8. R. sternalis.
9. lateral branches of (2).
10. medial branches of (2).
11. V. musculophrenica.
12. V. epigastrica cranialis.
13. Rr. Phrenici of (11).

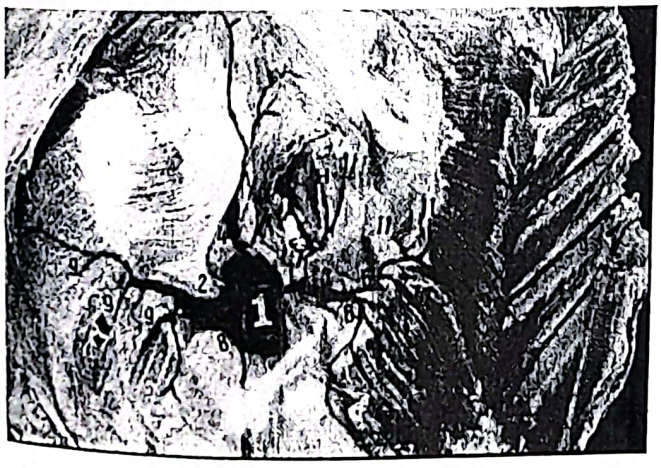

Fig. (6) : Photographic representation showing the venous drainage of the diaphragm in goat (thoracic view).

H. Hiatus esophagus.
1. Vena cava caudalis.
2. V. phrenica dextra.
3. V. phrenica sinistra.
4. R. crurium medialium dextrum.
5. R. dorsalis of (3).
6. R. ventralis of (3).
7. Rr. crurium medialium sinistrum.
8. R. sternalis.
9. lateral branches of (2).
10. lateral branches of (5).
11. Medial branches of (5).

be distributed in the ventral aspect of the left costal part of the diaphragm.

R. Crurium medialium sinistrum :

The left crural vein (1/13– 5/7– 6/7) represented by one or two small branches originate from the left phrenic vein as it passes in the central tendinous part of the left margin of the hiatus oesophagous. It proceeds dorsally to be anastomosed with a branch of the right medial crural vein. The vein drains the ventral aspect of the left crus of the diaphragm.

V. Musculophrenica :

The musculophrenic vein (5/11) gives off 4-5 phrenic branches originating either from the parent vessel or from the ventral intercostal veins from 7^{th} to 9^{th} or 10^{th} (5/13). These branches anastomose with the lateral branches of the phrenic vein in the right side while in the left side, the first two branches anastomose with ventral branch and the last 2 or 3 branches anastomose with the dorsal branch of the left phrenic vein.

V. Epigastrica cranialis :

The cranial epigastric vein (5/12) releases small twig just before it crosses the sternal part of the diaphragm. This twig proceeds caudo-dorsally in the sternal part of the diaphragm where it anastomoses with the sternocostal vein of the right side and with the ventral branch of the left phrenic vein.

Rr. Cruium lateralium :

Right and left small tributaries arise from the lumber vein. Each of them passes ventrally in the corresponding crus of the diaphragm where it anastomoses and anastomoses with the right medial crural vein.

DISCUSSION

I. ARTERIES

In the present investigation the musculo-phrenic artery arises from the internal thoracic artery at the level of the 5th intercostal space in contrast to the other observations. Raghavan and Chachroo (1964) in ox; Getty (1975) in sheep and goat and Selim (1979) in camel agreed that the musculo-phrenic artery originated at the level of the 7th costal cartilage while Getty (1975) stated that the artery originated at the level of 7th intercostal space in ox and at the level of 8th costal cartilage in horse and dog. On the other hand Ragab(1980) agreed with Georgy; Ragab; Osman and Labib (1982) that the musculo-phrenic artery originated, in donkey and buffalo, from the internal thoracic artery at the level of 6th intercostal space.

The cranial epigastric artery releases a sizable branch to the sternal part of the diaphragm in goat in agreement with observation of Evans and

Christensen (1979) in dog; Selim (1979) in camel and Georgy et al. (1982) in buffalo.

Our findings as well as that of Ghoshal (1975) in sheep; goat and dog and Evans and Christensen (1979) in dog stated that; the last 3 or 4 dorsal intercostal arteries shared in the arterial supply of the pars costalis of the diaphragm. In this respect, the observation of Ragab (1980) in donkey and Georgy et al. (1982) in buffalo passes in the same line with some differences in the number and origin of these phrenic branches.

In our research as well as in goat and sheep (Ghoshal, 1975) and in buffalo (Georgy et al., 1982). The pars lumbalis of diaphragm takes its arterial supply through the caudal phrenic arteries which grouped as dorsal (originated from the lumber arteries) and ventral (originated from the celiac and left gastric). Our findings stated that neither thoracic nor abdominal part of aorta shares directly in vascularization of pars lumbalis of the diaphragm in contrast to the observation of Ghoshal, (1975) in dog and Ragab (1980) in donkey.

II- VEINS

Review of the available literatures revealed that the phrenic veins, which drained into the caudal vena cava, is considered the main venous drainage of the diaphragm in different species of animals, in addition to small tributaries from the internal thoracic vein as well as from the lumber veins.

Our results as well as that of Ragab (1980) in donkey; Ghoshal (1981) in ox and Shehata; Ragab; Osman and Labib (1982) in buffalo stated that, The right and left phrenic veins are tributaries of the caudal vena cava as it passes through the caval foramen. In sheep (Ghoshal, 1981) mentioned that the right and left cranial phrenic veins originate from the caudal vena cava after it enters the abdominal cavity.

In goat, the left phrenic vein, was stronger than the right one and divided into dorsal & ventral branches while the right one did not do that, it gave medial and lateral sets of branches. Similar observations were recorded in donkey and buffalo by Ragab (1980) and Shehata et al., (1982) respectively. On the other hand, Ghoshal, (1981) mentioned that both right and left cranial phrenic veins in horse divided into a dorsal and a ventral branch, sometimes one of them only divides.

In our results, the sternal part of the diaphragm drained mainly via cranial epigastric vein and right sternocostal branch. Sometimes, additional branch to the ventral division of the left phrenic vein. These results are nearly similar to the observation of all the available literatures in domestic animals. The differences constricted in the origin of the right sternal vein. In this connection, our investigations agreed with that of Ghoshal,

(1981) in goat, sheep and ox that the right sternocostal vein detached from the right phrenic vein. On the other hand, Ragab (1980) in donkey and Shehata et al., (1982) in buffalo mentioned that the right sternocostal branch arose from the right face of the caudal vena cava a result which observed in two out of our examined specimens. All the aforementioned authors agreed that the left sternocostal branch (which inconstant in our results) arose from the left phrenic vein.

The present investigation agreed with the observation of Ragab (1980) in donkey; Ghoshal, (1981) in ox, sheep and goat and Shehata et al., (1982) in buffalo in that, the lumber part of the diaphragm were drained mainly to the right and left medial crural branches in addition to the lateral crural branches of the lumber veins. In goat as well as in ox and sheep (Ghoshal, 1981), the right medial crural vein arose from the caudal vena cava and the left one arose from the left phrenic vein. The later result differs from that of Ragab (1980) in donkey and Ghoshal, (1981) in goat. The former author stated that both right and left medial crural vein arose from the left phrenic vein while the latter author mentioned that, the right and left crural veins arose from the right and left phrenic veins respectively in addition to another right branch from the caudal vena cava.

Our results agreed with the results of Ghoshal, (1981) in ox, sheep and goat, that the lateral crural branches detached from the first lumber vein while in donkey (Ragab, 1980) it arose from the second lumber vein and from the 3rd lumber vein in buffalo (Shehata et al., 1982).

With exception of our observation in addition to that of Ragab, (1980) in donkey; Ghoshal, (1981) in dog and Shehata et al., (1982) in buffalo any of available literatures did not declare the rule of the musculophrenic vein in the venous drainage of the diaphragm. In goat 4-5 phrenic branches detached either from the musculophrenic vein or from the ventral intercostal veins,from 7^{th} to 10^{th} , which anastomosed with the branches of right and left phrenic veins. Nearly the same results recorded by Ragab, (1980) in donkey, while in buffalo (Shehata et al., 1982) mentioned that, the musclophrenic vein received 9-11 phrenic rami during its course.

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