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SOME MORPHOLOGICAL STUDIES ON THE DIAPHRAGM OF THE FERRET (Mustela furo)

(With 5 Figs.)

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بعض الدراسات المورفولوجيه للحجاب الحاجز لابن مقرض

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لقد أجري هذا البحث لدراسة الصفات المورفولوجيه والمدد الدموي والعصبي للحجاب الحاجز لابن مقرض واستخدم في اجراؤه احدى عشر حيوانا من كلا الجنسين من حيوان بن مقرض تم الحصول عليه من صحراء أبو رواش وصحراء الصالحيه . أعدمت الحيوانات ثم حقنت بالمطاط الأحمر والأزرق بعد تثبيتها بمحلول الفورمالين ١٠٪ . وجد أن الساق اليمنى للحجاب الحاجز ينشأ من أجسام الفقرات القطنيه من الثانيه الى الرابعه بينما تنشأ الساق اليسرى من أجسام الفقرتين القطنيتين الثانيه والثالثه ثم تنقسم الى جزئين وحشي وأنسي . ويتواجد الفرجه الأبهريه بين جزئي الساق اليسرى، بينما يتواجد الفرجه المرئيه بين ساقي الحجاب الحاجز . ويتمثل الجزء الوتري المركزي للحجاب الحاجز بثلاث خطوط رفيعه تتصل ببعضها البعض عند مركز الحجاب الحاجز وبجوار ثقبة الوريد الأجوف الخلفي . ويتصل الجزء الضلعي للحجاب الحاجز الأنسي بالغضاريف الضلعيه من العاشر الى الرابع عشر . ينشأ الرباط التاموري الحجابي من الغشاء التاموري عند مستوى الفرضه ما بين البطينيه للقلب ويمتد موازيا للسطح الصدري للقص وينتهي في السطح الأمامي للحجاب الحاجز . يتلقى الحجاب الحاجز المدد الدموي من خلال الشريان الحجابي الأمامي والأفرع الحجابيه للشرايين ما بين الضلعيه من العاشر الى الثالث عشر . ويحدث التصريف الوريدي عن طريق الوريد الحجابي الأيمن والأيسر اللذان يصبان في الوريد الأجوف الخلفي وكذلك الوريد الذي يصرف ساقي الحجاب الحاجز ويفتح على الوريد الفرد بالاضافه الى الأورده البين اربيه من العاشر وحتى الثالث عشر . وينشأ العصب الحجابي من الجزوع السفليه للأعصاب العنقيه الشوكيه الخامسه والسادسه والسابعه .

SUMMARY

The right crus of the ferret's diaphragm originated from the bodies of the second, third and fourth and the left crus from the bodies

of the second and third lumbar vertebrae. The latter crus was divided into medial and lateral crura, where the aortic hiatus was located between them. The oesophageal hiatus was situated between the two crura. The tendinous center of the diaphragm was represented by three narrow lines in the form of Y shape. The costal part of the diaphragm was attached to the medial aspect of the 10th to 14th costal cartilages. The pericardiophrenic ligament extended from the pericardium at the level of the interventricular notch of the heart and passed caudally in the form of a cord to join the thoracic surface of the diahragm. The diaphragm was supplied through A phrenica cranialis and Rr.Phrenici of the 10th to 13th Aa. intercostales dorsales. It was drained through Vv. phrenicae dextrum et sinistrum, in addition to 10th to 13th Vv. intercostales and a branch which drained the lumbar part then joined V. azyyos. The phrenic nerve was originated from the ventral branches of the 5th, 6th and 7th cervical spinal nerves on both sides.

INTRODUCTION

The anatomy of the wild animals was not attracting the attention of the investigators. The ferret was selected for this work as a small wild animal.

The diaphragm of the different animals had already been investigated by various authors, but no available literature was obtained about this subject in the ferret. The thoracic cavity seemed to be two thirds of the whole length of the trunk and the diaphragm of this animals is nearly pure muscular in structure. Therefore, the anatomy of this structure in the ferret was studied to form an idea about its morphology, vascularization and innervation and comparing these results with those of the other domestic and wild carnivores.

MATERIAL and METHODS

Eleven ferrets of both sexes were obtained from Abo-Rwash and El-Salhea deserts. The animals were anaesthetized with chloroform and bled via the common carotid artery, then injected with 10% formalin solution. Six of these animals were injected by red coloured latex with carmine through the common carotid artery, while the other animals were injected blue

coloured latex with ultramarine via the femoral vein.

The nomenclatures used were that adopted by Nomina Anatomica Veterinaria (1983).

RESULTS

I- Morphology of the diaphragm (Figs. 1,2,3 & 5):

The diaphragm appears dome-shaped, convex towards the thoracic cavity. It reaches the level of the 9th costal cartilage. The abdominal concave surface of the diaphragm is nearly occupied with the liver. The diaphragm appears as pure muscular with three tendinous lines which represents the centrum tendineum. The muscular part can be differentiated as usual into pars lumbalis, costalis et sternalis.

(1) Pars lumbalis: It consists of two unequal muscular crura (Crus dextrum et sinistrum), the right crus is larger than the left one. The origin of these crura is fleshy in structure. The right crus originates from the bodies of the 2nd, 3rd and 4th lumbar vertebrae, while the left one from the 2nd and third lumbar vertebrae. The left crus is divided into smaller Crus mediale sinistrum and larger Crus lateralis sinistrum forming the hiatus aorticus which lies opposite to the first lumbar vertebra. The hiatus oesophageus is fleshy and loosely attached to oesophagus, it is located ventral to hiatus aorticus between Crus mediale sinistrum and Crus dexturm. The muscular fibers of the two crura of the diaphragm radiating in a fan-shaped mannar where they insert in the right and left tendinous lines.

(2) Pars costalis: It comprises of five muscular digitations which interdigitates with M. transversus abdominis and is attached to the medial aspect of 10th to 14th costal cartilages. The muscular fibers radiate in a cranio-medial direction towards the three lines of Centrum tendineum. The costal part joins the lumbar part dorsally to form the vetral boundary of Arcus lumbocostale.

(3) Pars sternalis: It is represented by two muscular bundles seperated from each other by median tendinous line of centrum tendineum. It originates from each side of the medial aspect of 10th costal cartilage very close to xyphoid cartilage. The fibers rum vertically along the median tendinous line to be attached.

(4) Centrum tendineum: It is represented by three tendinous narrow bands or lines or limbs that meet at the center of the diaphragm in the form of (Y) shaped mannar. Dorsally the right and left bands and median one

ventrally. The former two bands reach the dorsal border of the diaphragm and the median band runs ventrally towards the xyphoid cartilage to be attached.

Foramen venae cavae is located in the right side close to the point of meeting of the three tendinous lines and it is surrounded by a fibrous ring.

The pericardiophrenic ligament oppears as a fibrous band originates from the pericardium at the level of the interventricular notch of the heart and extends caudally to connect with the median tendinous band of the diaphragm.

II– Vascularization of the diaphragm:

(A) Arterial supply (Fig. 2):

The diaphragm is supplied through A.phrenica cranialis and Aa. intercostales dorsales.

1. A. phrenica cranialis: It is a considerably large artery detached from the ventral aspect of the aorta slightly to the left during its course in the hiatus aorticus at the level of the last thoracic vertebra. It passes cranioventrally to the cleft between the two parts of the left crus supplying them and gains the point of meeting of the three teninous lines where it divides into three branches that pass in the three tendinous lines. The two branches which run in the right and left lines supply the lumbar part and the dorsal area of the costal part. The third branch which descends in the median tendinous line suply the costal and sternal part of each sides.

2. Aa. intercostales dorsales X, XI, XII and XIII: Each of these intercostal arteries sends a phrenic branch at the level of the costal arch to suply the periphary of the costal parts of the diaphragm.

(B) Venous drainage (Fig. 3):

1. Vv. Phrenicae: The diaphragm is drained through Vv. Phrenicae dextrum et sinistrum which join the both sides of caudal vena cava during its course in the caval foramen.

(a) V. phrenica dextrum: It drains the central area of the right costal part through 2–3 tributaries.

(b) V. phrenica sinistrum: It is formed by the union of three branches just before joining the caudal venae cava. These branches pass in the three tendinous lines. The right and left branches pass in the corresponding tendinous lines to drain the neighbouring lumbar and dorsal costal partion. The third courses in the median tendinous line and drains the ventral portion of the costal parts on both sides by several tributaries as well as two

tributaries drain the sternal part and ascend to join the main branch of the median tendinous line. The latter two branches are considered as lines of demarkation between the sternal and costal parts.

2. Vv. interostales dorsales X, XI, XII and XIII: These veins receive a fine phrenic twigs that drain the periphary of the costal part.

3. Vena azygos: The two crura of the diaphragm are drained by 2–3 fine twigs that unite to form a considerable large branch that passes on the abdominal surface of the right crus and joins the right Vena azygos at the level of the 2nd lumbar vertebra.

III– The innervation (Figs. 2, 4 & 5):

1. Nn. phrenicae: Each of the right and left is formed by contributions from the ventral branches of the 5th, 6th and 7th cervical spinal nerves. The root which is derived from the 5th cervical spinal nerve is small radicle passes caudally to join the root of the 6th cervical spinal nerve near its origin.

N. phrenicus dexter: It gains the thoracic cavity along the right side of the cranial vena cava then courses on the right atrium and continues caudally along the caudal vena cava within plica venae cavae to reach the thoracic surface of the diaphragm.

N. phrenicus sinister: It enters the thoracic cavity on the left side of the cranial vena cava then passes over the left atrium and runs between the left pulmonary artery and the left bronchus. It contineus caudally in the post cardiac mediastinum to gain the diaphragm.

Upon reaching the diaphragm each of the right and left phrenic nerves soon trifuracte at an acute angle into R. costalis and R. sternocostalis. The former branch ascends to the corresponding part of the crura where it terminates. The R.costalis supplies the dorsal portion of the costal part. The R.sternocostalis descends ventrally and terminates in the ventral half of the costal part and the sternal part.

2. Nn. Intercostales X, XI, XII et XIII: These nerves detach fine branches at the costal attachment of the diaphragm. They are distributed in the costal part of the diaphragm.

DISCUSSION

The caudal attachment of the ferret,s diaphragm which was represented by the commencement of the origin of the crura is at the 2nd lumbar vertebra, whereas the convexity of the diaphragm reached the level of

the 9th costal cartilage and the caudal attachment of the costal part from 10th to 14th costal cartlage. This position was unique among the other domestic and wild animals. These leads to increase the capacity of the thoracic cavity which is occupied by the relatively large lungs to face the high respiratory, oxidative and metabolic requirements of the ferret as an active and hunting animal.

The caudal level of the origin of the crura at the level of 2nd lumbar vertebra in the ferret is similar to that of the cat (TAYLOR and WEBER, 1969), rat (HABEL and STROMBERG, 1976) and rabbit (RAGAB, 1987) for the left crus only.

Moreover, MCLURE, et al. (1973) in cat, St. CLAIR (1975) and EVANS and CHRISTENSEN (1979) in dog reported that the beginning of origin of the two crura from the 3rd lumbar vertebra.

The caudal level of the convexity of the ferret,s diaphragm simulated what has been recorded by SELIM and KHIDR (1988) in fox. But in the latter animal the convexity reached the level of the 11th intercostal space. However, AHMED et al. (1984) in rabbit reported that this convexity reached the level of the 6th rib.

The caudal attachment of the costal part of the ferret,s diaphragm was attached to the medial aspect of the 10th to the 14th costal cartilage. Meanwhile, AHMED, et al. (1984) in rabbit recorded that it was attached from the 7th to 11th rib. But RAGAB (1987) recorded that this part was attached to the last seven ribs in rabbit and last five ribs in cat.

With regard to the division of the crura, the present investigation revealed that the left crus only which was divided into medial and lateral portions. Similar opinion was recorded by NICKEL, et al. (1976) in dog. In contrast to these findings, AHMED, et al. (1984) and RAGAB (1987) in rabbit and SELIM and KHIDR (1988) in fox recorded that the right crus was divided into two portions. However, RAGAB (1987) in rabbit claimed that in one of the examined cases each of the two crura was divided into medial and lateral portions. But EVANS and CHRISTENSEN (1979) in dog and RAGAB (1987) in cat reported that the right crus was divided into Crus mediale and Crus laterale in addition to Crus intermediate.

The Centrum tendenium of the ferrets diaphragm was represented by three narrow lines forming Y-shape. A condition which was not observed in the other animals.

The hiatus aorticus in ferret was situated between the medial and lateral portions of the left crus. Similar results were given by RAGAB (1987)

in rabbit. On the other hand, MCLURE, et al. (1973) and RAGAB (1987) in cat, St. CLAIR (1975) in dog, HABEL and STROMBERG (1976) in rat and AHMED, et al. (1984) in rabbit recorded that the hiatus aorticus was formed between the two crura of the diaphragm.

The hiatus oesophogeus of the ferret was located on the left side of the median plane between the left medial and right crura of the diaphragm. These results were in the same line with the statements of HABEL and STROMBERG (1976), AHMED, et al. (1984) and RAGAB (1987) in rabbit. However the latter authors added that this hiatus was located at right side. The present study revealed that the hiatus oesophagus was fleshy and loosely attached to the oesophagus. Similar results were given by RAGAB (1987) in cat but he added that in the rabbit the ventral boundary of this hiatus was tendinous and firmly attached to the oesophagus. Accordingly the oesophageal prolaps was rare in rabbit.

The pericardiophrenic ligament which was observed during the present work was not described by any author in the available literature.

The ferret,s diaphragm was arterially supplied through the cranial phrenic artery and fine phrenic branches of the 10th to 13th intercostal arteries. That simulated the findings of AHMED, et al. (1984) in rabbit. The pericardiophrenic arteries which were detached from the corresponding supreme intercostal artery and were described by AHMED, et al. (1984) in rabbit could not be met with either in the present research or in the available literature. In the same respect, the caudal phrenic artery which was given off from the right renal artery in fox (SELIM and KHIDR, 1988), as well as the musculophrenic artery which was described by AHMED (1984) in rabbit and SELIM and KHIDR (1988) in fox could not be observed during the course of this work. BISCOE and BUCKNELL (1962) in cat recorded that the 8th to 13th intercostal arteries, branches from internal mammary arteries, as well as vessels from the branches of the abdominal aorta shared in the vascularization of the diaphragm. Either of these vessels was not observed in the present work.

The right and left phrenic veins joined the caudal vena cava during its passage within the diaphragm. Similar results were given by AHMED, et al. (1984) in rabbit and SELIM and KHIDR (1988) in fox. The phrenic tributary which drained the crura and joined V.azygos were not met with in the available literature.

The radicles of the phrenic nerve were derived from the 5th, 6th and 7th cervical spinal nerves. These findings simulated those of MILLER, et al.

(1964), GHOSHAL (1975) and SEIFERLE (1976) in carnivores, AHMED, et al. (1984) in rabbit and SELIM and KHIDR (1988) in fox and WILSON (1968) in rat and mice. Meanwhile, in cat it was derived form 5th and 6th cervical spinal nerves (HARRISON, 1964 and 1976, WILSON, 1968 and and DONNELLY (1972).

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LEGENDS OF FIGURES

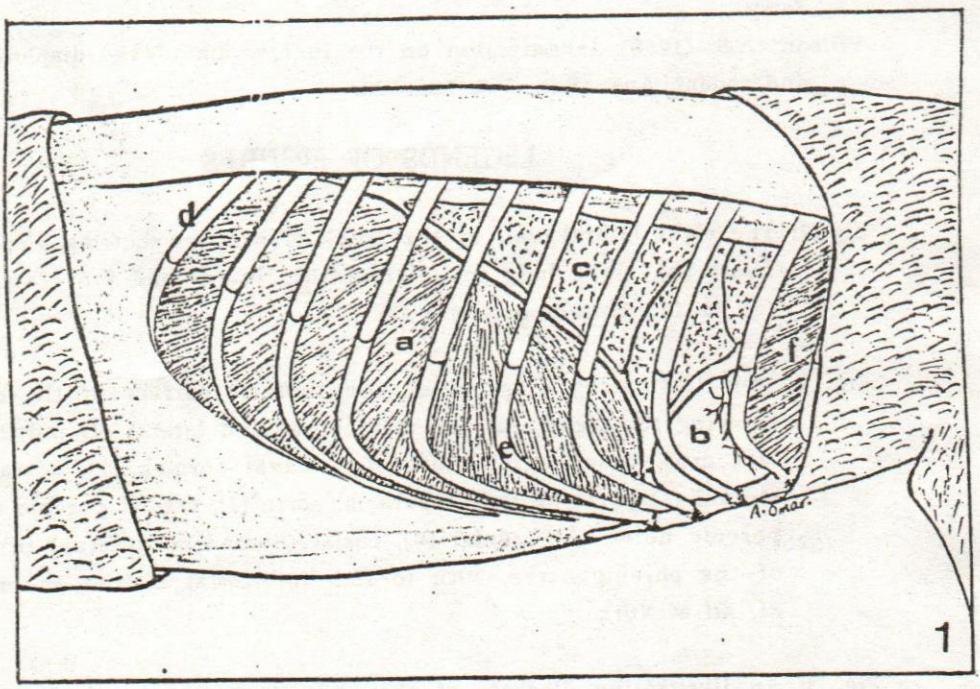
Fig. 1: The right lateral wall of the trunk of a ferret showing diaphragm (a), heart (b), right lung (c), last (14th) rib (d) and 9th costal cartilage (e). M. intercostalis extermus (f).

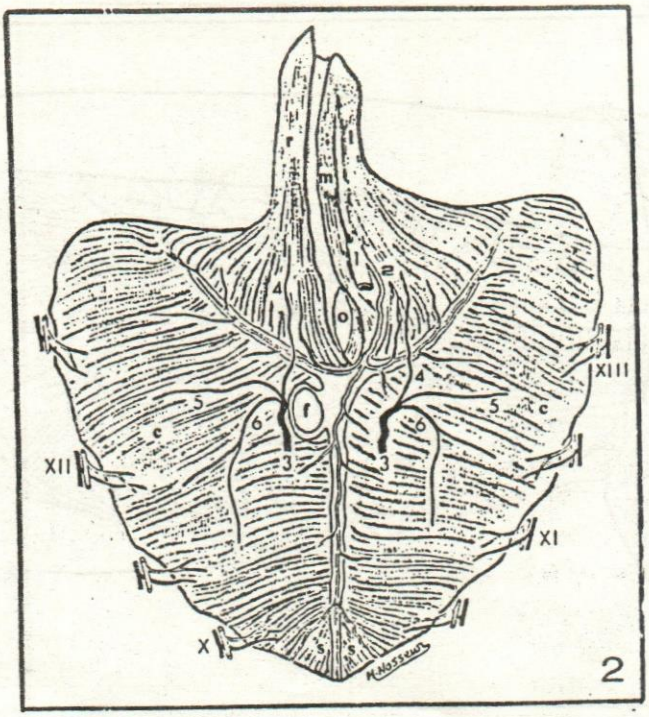
Fig. 2: An illustrating diagram of the thoracic surface of the diaphragm showing the right crus (r), medial (m) and lateral (l) portions of the left crus, oesophagial hiatus (o), caval formen (f), costal (c) and sternal (s) parts of the diaphragm, aorta (1), cranial phrenic artery (2), phrenic nerve (3), cranial (4), costal (5) and costosternal (6) branches of the phrenic nerve, 10th to 13th intercostal arteries and nerves (X, XI, XII et XIII).

Fig. 3: An illustrating diagram of the abdominal surface of the diaphragm showing right crus (r), medial (m) and lateral (L) parts of the left crus, oesophageal hiatus (o), caudal vena cava (v), costal (c) and sternal (s) parts of diaphragm, aorta (1), right phrenic vein (2) left phrenic vein (3), crural branch joined V.azygos (4) and 10th to 13th intercostal veins (X, XI, XII et XIII).

Fig. 4: The left lateral aspect of the trunk of a ferret showing diaphragm (a), heart (b), right lung (c) last (14th) rib (d) oesophagus (e), thoracic aorta (f), trachea (g), cranial vena cava (h), pulmonary trunk (i) brachiocephalic trunks (j) and left phrenic nerve (k).

Fig. 5: The right lateral aspect of the trunk of ferret showing diaphragm (a), heart (b), left lung (c), last (14th) rib (d), oesophagus (e), caudal vena cava (f), cranial vena cava (g), trachea (h) pericardiophrenic ligament (i), and right phrenic nerve (j). V.azygos (k) and trachea (1).

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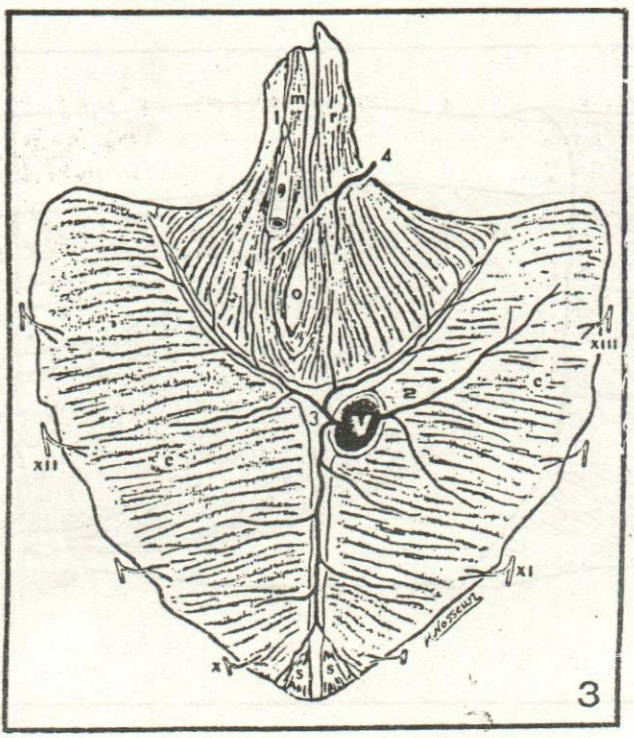
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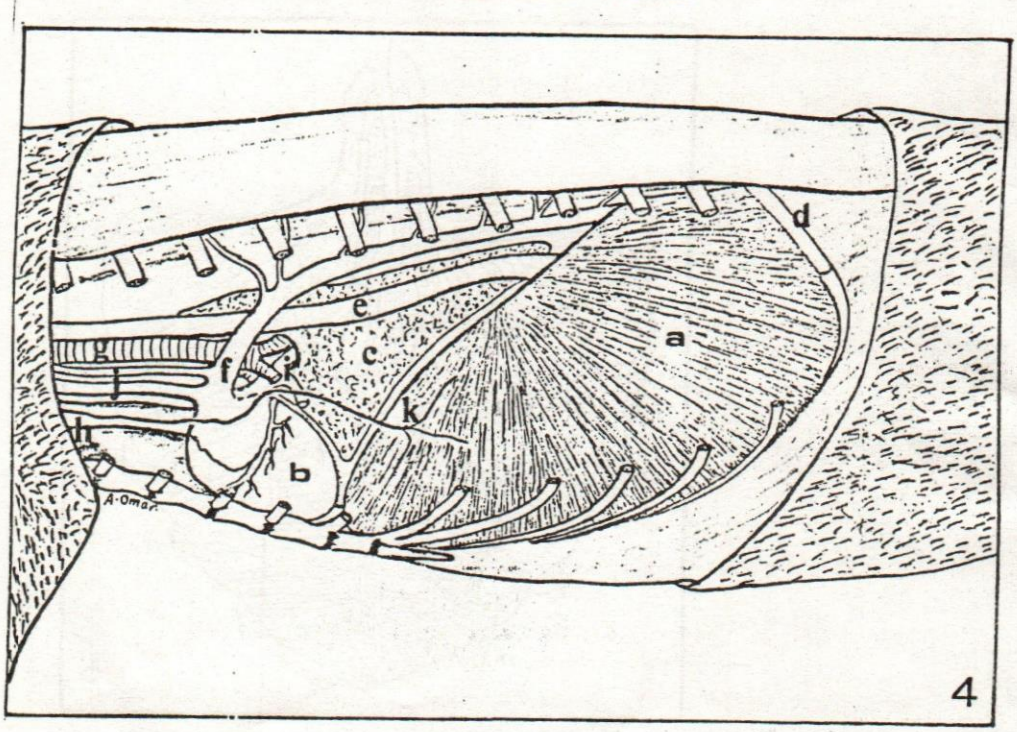

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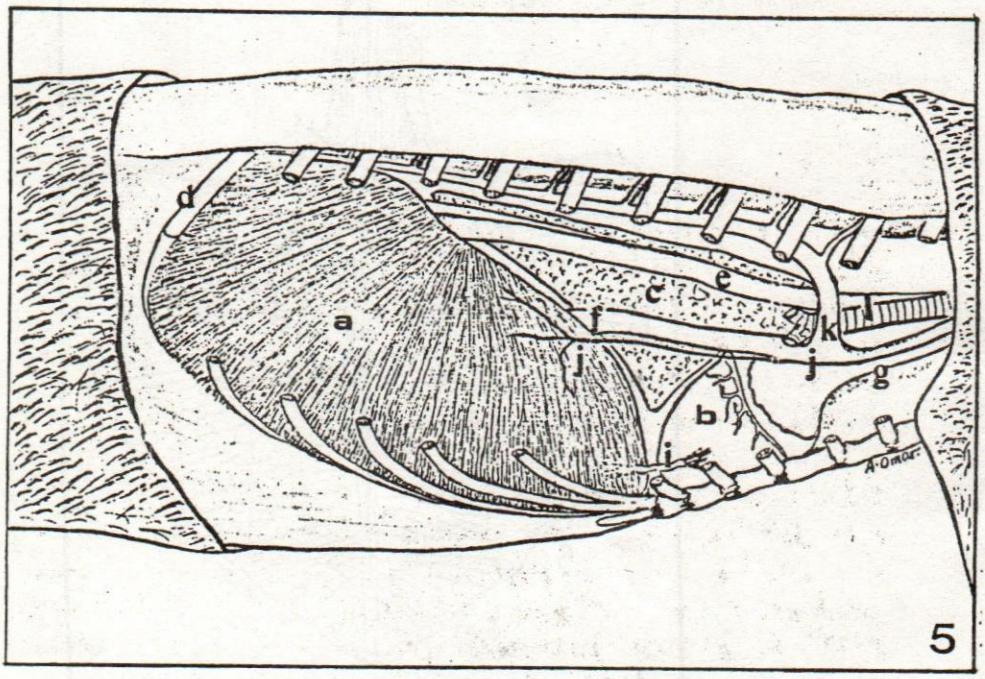

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