

THE LYMPHATIC DRAINAGE OF THE PERICARDIAL SPACE IN THE DOG

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ABSTRACT

The purpose of this study was to characterize definitively the lymphatic drainage system of the pericardial space in the dog. The reports on this subject, based on dissection experiments and acute dye injections, remain controversial, and our own previous studies have been incomplete. Seventeen dogs were studied using a radiographic technique. Micropulverized barium sulfate instilled into the pericardial sac was followed with serial chest x-rays in seven dogs with intact cardiac lymphatics, in seven dogs after section of the cardiac lymphatic drainage node (the cardiac lymph node) in the right upper mediastinum, and in three dogs after resection of cardiac drainage lymphatic nodes in the left upper mediastinum.

These studies revealed that the lymphatic drainage of the pericardial space is via (a) the principal coronary lymphatic which drains from the left ventricular muscle and passes to the right upper mediastinum via the cardiac lymph node, (b) the lesser coronary lymphatic which drains the right ventricular muscle and passes to the left upper mediastinum, and (c) bilateral internal mammary (parasternal) lymphatic chains.

These observations are important in planning experimental approaches to the effects of impairment of lymph drainage from the pericardial space. An understanding of the lymph drainage from the pericardial space may prove significant to understanding fibrotic reactions within it and the pathologic mechanisms of such entities as constrictive pericarditis.

Studies dating back to the mid-1700's have explored the anatomy of the lymphatics draining the heart ventricles of various animal species, including particularly the dog and man. There have been many such studies (1-6), and it is now established that the major lymph channel from the heart is the principal coronary lymphatic (1), which drains primarily the left ventricle. This channel passes behind the pulmonary artery and the aorta, and then travels cephalad to enter the consistently placed cardiac lymph node which lies between the superior vena cava and the innominate artery. From the cardiac lymph node, one or more lymphatics pass up to enter the right lymphatic duct. There is also a lesser coronary lymphatic, which drains primarily the right ventricle (5), passes to the left upper mediastinum

via one or more nodes there and then ascends to the thoracic duct.

Though the lymphatic drainage from the cardiac ventricles has been elucidated, few studies have explored the lymph flow from the pericardial space. Because it would not be possible to approach this problem with anatomical dissections, we elected to use a radiographic technique.

MATERIALS AND METHODS

We studied 17 dogs, divided into three experimental groups. Anesthesia was accomplished for all the animals with intravenous sodium pentobarbital and ventilation was maintained through an endotracheal tube using a Harvard ventilator. The chest was opened through a median sternotomy incision. The pericardial sac was left intact, and through it, using a 27 gauge needle, 0.3ml of T1824 Evans blue dye was injected into the free wall of both the right and left ventricle. This dye, almost immediately taken up by the lymphatics, visualized the lymphatic channels draining the injected areas and the regional lymph nodes to which they ascended.

Group I (seven dogs) had no surgical interference with the lymphatic drainage system from the heart. Group II (seven dogs) had resection of the right upper mediastinal lymph node (cardiac lymph node) and all adjacent lymphatics stained with dye. Group III (three dogs) had resection of the left upper mediastinal nodes and adjacent lymphatics that stained with dye. Though we originally planned to study more animals in this group, we believed that the results rendered this unnecessary.

After the blue dye injections and the surgical interventions, the remainder of the experimental procedure was the same for all the animals. Five to 10ml of air was injected into the most superior portion of the pericardial sac

through a 27 gauge needle, and then three (3.0) ml of a micropulverized barium sulfate (Damancy Co., Ltd., Sloughbucks, England) suspension in saline was injected into the air bubble through a 22 gauge needle. The consistency of the micropulverized barium sulfate suspension was prepared so that it required moderate force to push it through this size needle. The air bubble technique was developed to prevent leakage of the barium suspension through the puncture hole in the parietal pericardium (7). The particle size of the micropulverized barium sulfate varied from 0.1 to 1.0 micron in diameter.

After it was established that there was no backleak of barium sulfate through the needle puncture site in the parietal pericardium, the chest was closed using standard methods. Postoperatively, the dogs were given intravenous fluids and pain medication as indicated. In a few of the dogs, antibiotics were given because of beginning wound infection. All the dogs received humane care in compliance with the "Principles of Laboratory Animal Care" formulated by the National Society for Medical Research and the "Guide for the Care and Use of Laboratory Animals" prepared by the National Academy of Sciences and published by the National Institutes of Health (NIH Publication No. 80-23, revised 1978).

Chest x-rays of each dog were taken immediately postoperatively and then at three week intervals for three months. The drainage lymph nodes usually visualized radiographically within one month of surgery. In four of the dogs in Group I, only lateral chest x-rays were taken, while all of the other dogs studied had both lateral and ventrodorsal x-rays. All of the animals were sacrificed with a dog euthanasia solution containing sodium pentobarbital and sodium phenytoin as the active ingredients at three months after surgery. After a standard complete autopsy, the hearts were studied grossly and microscopically.

Table 1
Summary of Experimental Results

Group No.	I*	II**	III***
No. of Dogs	7	7	3
Micropulverized barium sulfate injected into the pericardial sac	7	7	3
Visualization of cardiac lymph node	6 [#]	0	2
Visualization of left upper mediastinal lymph nodes	3	6	1
Visualization of internal mammary chain and/or nodes	7	2	2

*Micropulverized barium sulfate injected into the pericardial sac.

**Same as Group I, plus resection of right upper mediastinal (cardiac) lymph node.

***Same as Group I, plus resection of nodes in left upper mediastinum (the resection was incomplete in one of this group).

[#]We know that the cardiac lymph node was visualized in two of the dogs that had ventrodorsal chest x-rays, and it is likely it was the posterior mediastinal node seen in the four dogs that had only lateral chest x-rays.

RATIONALE FOR EXPERIMENTAL APPROACH

In previous studies (6,7), we were able to demonstrate that micropulverized barium sulfate instilled into the pericardial sac visualized the principal coronary lymphatic drainage system. Occasionally, we also saw an opacified node without connecting lymphatics in the high retrosternal region on lateral x-rays. It appeared, therefore, that other drainage pathways, perhaps less active, also functioned at least part of the time. In the present study, we elected to obstruct what we considered the major lymphatic drainage system, namely, that via the principal coronary lymphatic up to the cardiac lymph node, to see if other drainage pathways became apparent. Using the same reasoning, we also decided to make the study more complete by obstructing the lymphatic drainage system which ascends to the upper reaches of the thoracic duct (the lesser coronary lymphatic).

The radiographic technique is one that we have successfully used in the

past, though in the present study we made the barium sulfate suspension more viscous than we had done before, to put more material in the pericardial sac. Though the use of micropulverized barium sulfate has the disadvantage of being slow in visualizing the lymphatic system, it is retained in the lymphatics and allows for accurate interpretation. Other markers, such as Evans blue dye (T1824), are of no value in such a study. If instilled into the pericardial sac, The T1824 blue dye diffuses rapidly and pickup by lymphatics is tenuous. Kluge and Ongre (9), also depended on a radiographic technique for their studies in the rat, successfully using thorium dioxide.

RESULTS

The postmortem examinations, and the gross microscopic studies of the hearts revealed no intercurrent pathology that might have affected the results. In every instance, micropulverized barium sulfate was found in the pericardial sac, usually more towards the base of the heart. In one dog in

Group II, the parietal pericardium was thicker than normal at necropsy, and appeared villous and somewhat shaggy. Because the x-ray findings in this dog were consistent with the others studied, it is included in the overall results (Table 1).

Group I

All seven of the dogs showed radio-opaque upper mediastinal lymph node collections on lateral chest x-rays (Fig. 1). In one of the three dogs in

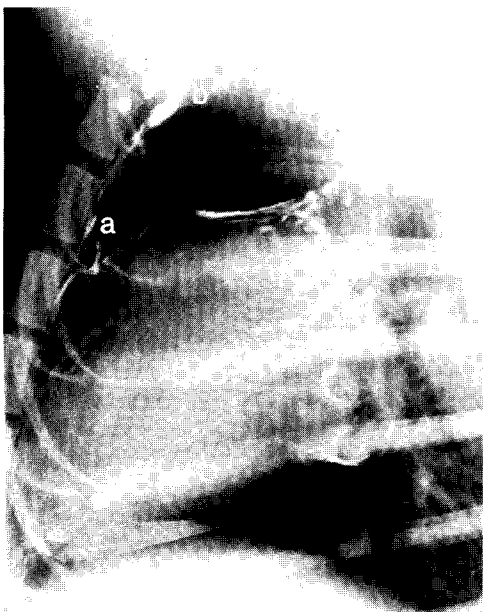


Fig. 1. Lateral view. Coronary lymphatic drainage intact. Flecks of micropulverized barium sulfate are seen within the pericardial sac. The internal mammary (parasternal) lymphatic chain (a) is well seen ascending to high parasternal nodes (b). The cardiac lymph node (c) is visualized, though overlap from left upper mediastinal nodes is likely.

this group studied with ventrodorsal x-rays, radio-opaque nodes were present only in the left upper mediastinum; in the remaining two dogs, radio-opaque nodes were seen in both right and left upper mediastinal regions. In all seven dogs, radio-opaque nodes were visualized high in the parasternal region in the lateral views, and in three of them,

internal mammary (parasternal) lymphatic chains draining to these nodes were also well-visualized (Fig. 1).

Group II

The seven dogs studied in this group all had lateral and ventrodorsal chest x-rays, and all had resection of the cardiac lymph node in the right upper mediastinum. Six dogs showed left upper mediastinal radio-opaque lymph nodes. In none of them did any radio-opaque right upper mediastinal nodes visualize. In two of this group, internal mammary (parasternal) lymphatic chains emptying into high parasternal nodes (as seen on the lateral chest x-rays) were also seen (Fig. 2).

Group III

Three dogs were studied in this group. In one of them, small localized clumps of barium were seen above the heart in the lateral view, but their location could not be determined in the ventrodorsal views. In one of the two remaining dogs, radio-opaque nodes were well seen in both the right upper and left upper mediastinal areas on the ventrodorsal x-rays. The finding of a node in the left upper mediastinum indicated an inadequate surgical resection. In two of the dogs in this group, high parasternal lymph nodes were seen on the lateral views, and in one dog the connecting internal mammary (parasternal) lymphatic chain was also visualized (Fig. 3).

DISCUSSION AND CONCLUSIONS

We can summarize the results as follows (Fig. 4):

(a) The lymphatic drainage of the pericardial space in the dog is to nodes in both the right and left upper mediastinum and via the bilateral internal mammary (parasternal) lymphatic chains.

(b) The high parasternal mediastinal nodes, which are visualized in

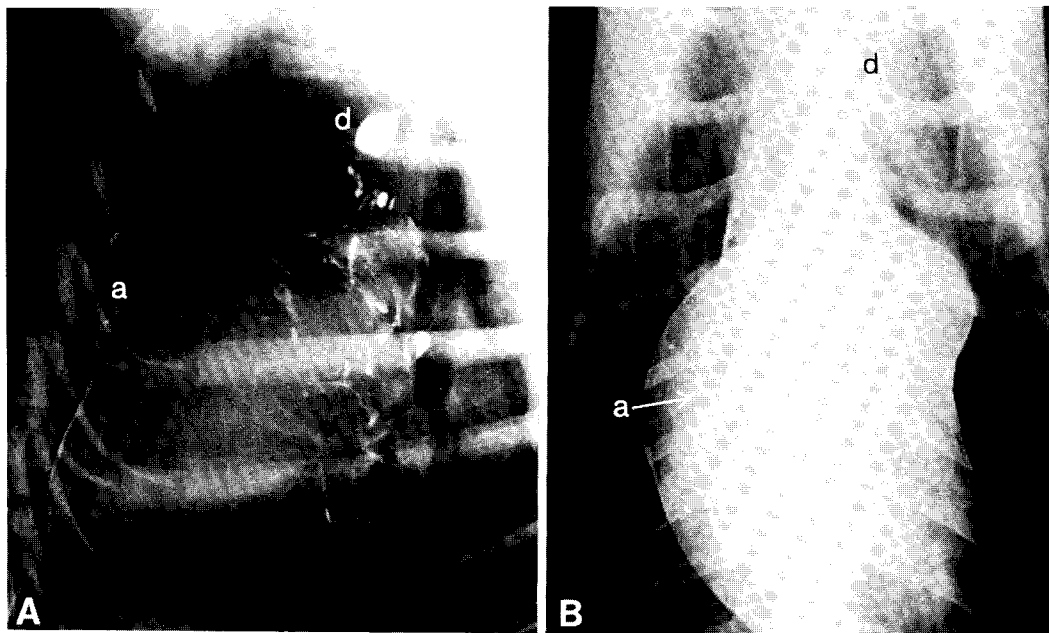


Fig. 2. A. Lateral view. The cardiac lymph node in the right upper mediastinum was resected. Micropulverized barium sulfate outlines the pericardial sac. An internal mammary (parasternal) lymphatic is opacified (a). A large posterior mediastinal node, undoubtedly in the left upper mediastinum, is seen (d). B. Ventrodorsal view. Micropulverized barium sulfate outlines the pericardial sac. The internal mammary (parasternal) lymphatic (a) is visualized on the right. A mediastinal node is seen to the left of the midline (d).

the later chest x-rays after micropulverized barium sulfate is instilled into the pericardial sac, receive the internal mammary (parasternal) lymphatics.

(c) Though the specific pathways were not visualized, it is known (6) that the right upper mediastinal node (the cardiac lymph node) drains to the right lymphatic duct, and the left upper mediastinal node(s) drains to the thoracic duct. The right internal mammary (parasternal) lymphatic drains to the right lymphatic duct; the left internal mammary (parasternal) lymphatic drains to the thoracic duct.

How does the micropulverized barium sulfate leave the pericardial sac? Probably much of it leaves through the epicardial surface (the visceral pericardium) of the heart itself. Subepicardial lymphatics of the left ventricle would carry the barium to the principal coronary lymphatic, and then to the right lymphatic duct via the cardiac lymph

node in the right upper mediastinum. Subepicardial lymphatics of the right ventricle would carry the barium via the lesser coronary lymphatic to nodes in the left upper mediastinum and then to the thoracic duct. It is likely that small lymphatics that are seen at the base of the heart in the fat adjacent to the parietal pericardium also drain, via the lesser coronary lymphatic, to the left upper mediastinal nodes and the thoracic duct. We are not certain exactly where the internal mammary (parasternal) lymphatics pick up the barium that they carry to the parasternal nodes to the right and left of the upper sternum, and which then drain to the right lymphatic duct and thoracic duct, respectively.

The lymphatic drainage of the pericardial space in the dog is similar to that found in the white rat according to the work of both Miotti (8) and Kluge and Ongre (9), and it is likely

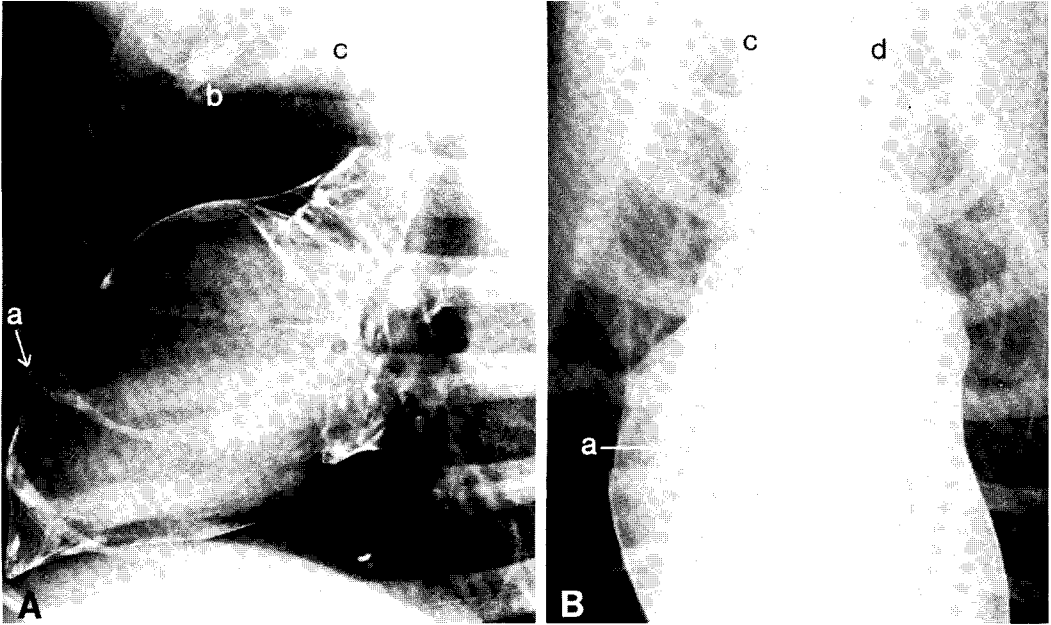


Fig. 3. A. Lateral view. A left upper mediastinal node was resected. Micropulverized barium sulfate outlines the pericardial sac. An internal mammary (parasternal) lymphatic (a) ascends to a parasternal node (b). Two posterior mediastinal nodes (c) are well seen. B. Ventrodorsal view. Micropulverized barium sulfate outlines the pericardial sac. The right internal mammary (parasternal) lymphatic (a) is seen. A right upper mediastinal node (cardiac lymph node) (c) is seen, as well as a left upper mediastinal node (d). Visualizing the latter indicates an inadequate surgical resection.

that the anatomy is similar in man. As has been noted elsewhere (6), it is surprising how consistent the principal coronary lymphatic anatomy is from one dog to another, and all evidence points to the fact that the anatomy is essentially identical in man. That such information is important in the evaluation of various types of experimental intervention in animals is apparent. It is our hypothesis that interference with, or overwhelming the capacities of, the lymphatic system draining the pericardial space predisposes to the laying down of fibrous tissue in response to such situations, for example, as blood in the pericardial sac. In addition, as is true in other areas of the body, we believe that interference with the lymphatic drainage system of the pericardial space predisposes to infection and inflammation. Such considerations are of significance in assessing the

pathology and clinical presentation of certain disease processes in man. Perhaps the classic example might be in constrictive pericarditis complicating tuberculosis, in which it is likely that the lymphatic drainage vessels and nodes here described are involved by the infectious process. We know that blood in the pericardial sac is usually absorbed without any residue, but that under certain poorly understood circumstances, trauma to the heart is followed with constrictive pericarditis. Another example of constrictive pericarditis that we do not understand is that following radiation therapy. Though our studies can only raise the question of a role of the lymphatic system draining the pericardial space in these and other clinical states, certainly they merit consideration and provide the anatomical basis for further experimental studies.

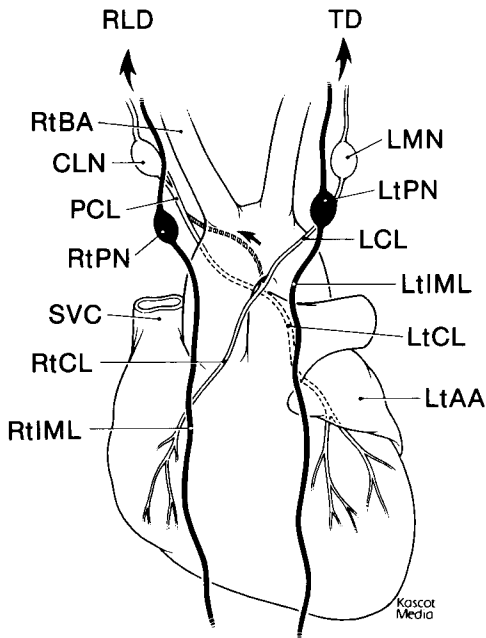


Fig. 4. A schematic drawing of the lymphatic drainage system of the pericardial sac in the dog. The left coronary lymphatic (LtCL) passes behind the pulmonary artery and the arch of the aorta, and ascends to the cardiac lymph node (CLN) as the principal coronary lymphatic (PCL). The right coronary lymphatic (RtCL) enters the principal coronary lymphatic system, as at the shaded vessel beneath the arrow, or ascends to the left mediastinal node(s) (LMN) as the lesser coronary lymphatic (LCL). The right internal mammary (parasternal) lymphatic (RtIML) drains to the right lymphatic duct (RLD), invariably via right parasternal nodes (RtPN). The left internal mammary (parasternal) lymphatic (LtIML) drains to the thoracic duct (TD), via left parasternal nodes (LtPn). SVC=superior vena cava; LtAA=left arterial appendage; RtBA=right branchiocephalic; PCL=principal coronary lymphatic; LtCL=left coronary lymphatic; CLN=cardiac lymph node; RLD=right lymphatic duct; LCL=lesser coronary lymphatic; LtCL=right coronary lymphatic; LMN=left mediastinal nodes; TD=thoracic duct; RtIML=right internal mammary (parasternal) lymphatic; RtPN=right parasternal nodes; LtIML=left internal mammary (parasternal) lymphatics; LtPN=left parasternal nodes.

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