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THE LYMPHATIC DRAINAGE OF THE LEFT VENTRICLE IN THE YUCATAN MINIPIG

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ABSTRACT

The gross anatomy of the cardiac lymphatic system draining the left ventricle was studied in 15 Yucatan minipigs and 2 regular swine. The findings confirm that the drainage pathways are similar to those of man and dog. After a coloring marker is injected near the apex of the left ventricle, one or more lymphatics are seen to ascend towards the left atrial appendage. Where there is more than one ascending lymphatic, they typically join before or at the left atrial appendage. This principal lymphatic then passes beneath the appendage and travels behind (dorsal to) the pulmonary artery and aorta to the right side of the mediastinum. From here, the lymphatic passes cephalad along the left border of the superior vena cava to enter the cardiac lymph node between the superior vena cava and the trachea.

The pig is a useful animal model for experimental atherosclerosis (1) and the Yucatan minipig is particularly useful for study of experimental coronary artery atherosclerosis (2). We previously hypothesized that the cardiac lymphatic system plays an integral role in the development of coronary atherosclerosis (3). In preparation accordingly for investigating coronary atherosclerosis in the Yucatan minipig, we examined its cardiac lymphatic anatomy of which only scant information exists.

MATERIALS AND METHODS

Thirteen Yucatan minipigs and 2 young regular swine (10 males and 5 females) obtained from the Charles River Company (Charles River Laboratories, Inc., Wilmington, MA) were studied. The pigs (BW 16.6 to 26 kg) were operated shortly after arrival in the laboratory. The two swine and three of the Yucatan minipigs were operated upon as "acute" experiments; the other minipigs were operated upon as preparatory to studying coronary atherosclerosis.

The animal care complied with the "Principles of Laboratory Animal Care" and the "Guide for the Care and Use of Laboratory Animals" (NIH Publication No. 80-23, revised 1985). Each animal was operated upon in the Center for Animal Resources at the Northwestern University Medical School. Strict aseptic precautions were maintained in the chronic experiments. Anesthesia was uniformly induced with Ketamine 15 mg/K, Xylazine 1.0 mg/K, and atropine 0.05 mg/K given IM, followed by Brevital mg 11/K given intravenously. After endotracheal intubation, anesthesia was maintained with halothane (0.5 to 1.5 percent) administered via standard anesthesia equipment. The heart was exposed via a sternal-splitting incision. An invariably thin pericardium was then incised longitudinally to make a pericardial sling. In the acute experiments, India ink diluted 1:1 with saline

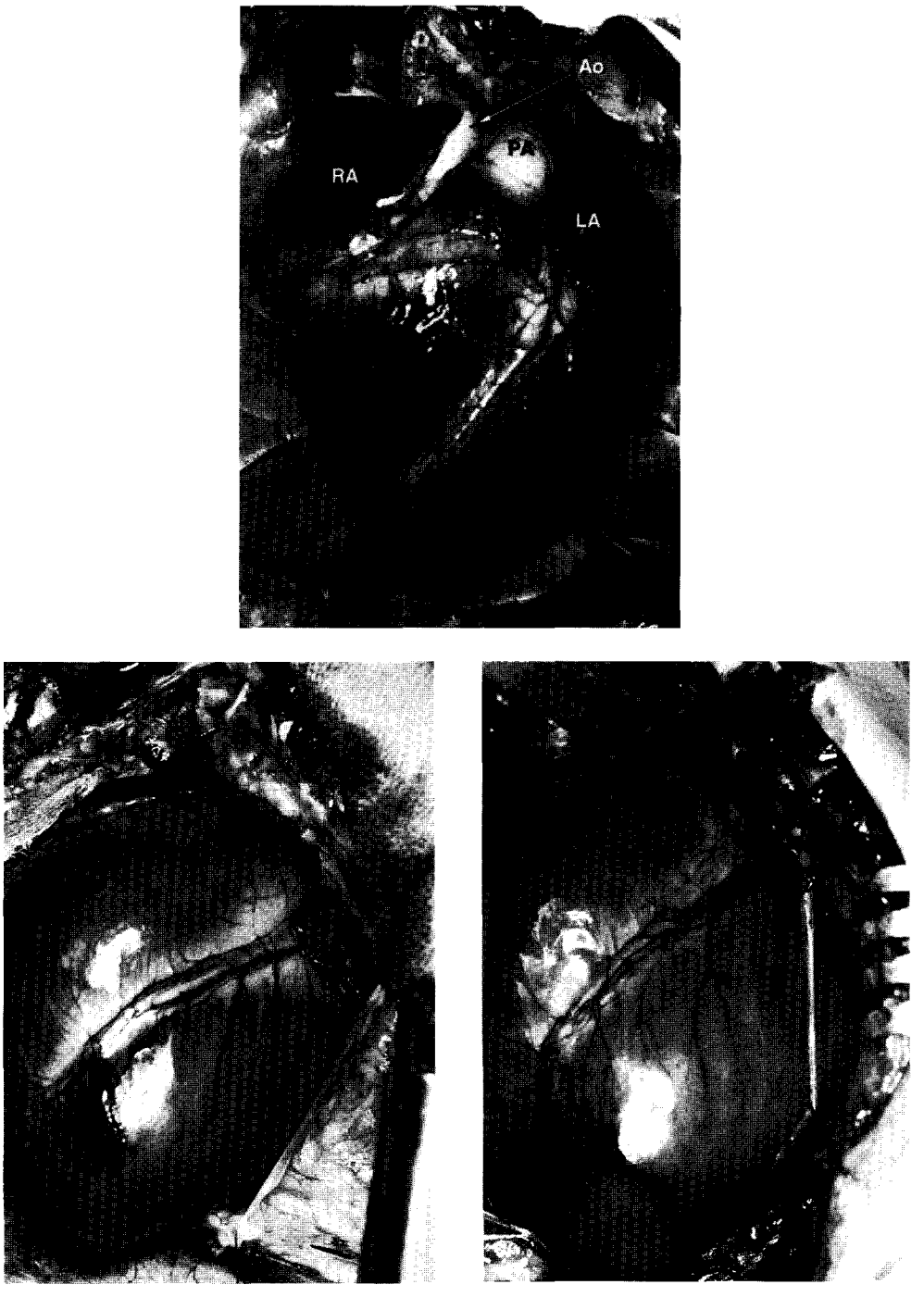

Fig. 1. Top—The relationship between the anteriorly placed main pulmonary artery (PA), the aorta (Ao) and the right (RA) and left atrial (LA) appendages that abut on either side. Lower Left — Two major lymphatics arise from the site of India ink injection into the left ventricle. Both lymphatics ascend upward and pass beneath the left atrial appendage. Lower Right — Two major lymphatics arise from the site of India ink injection into the left ventricle. As they ascend towards the left atrial appendage, they crisscross over the anterior descending coronary artery.

solution was used as a marker for the lymphatic pathways; in the chronic experiments, T1824 blue dye (Evans) diluted 1:1 with saline solution was used as the marker. Approximately 0.5 ml of either coloring matter was injected subepicardially at one or two sites in the apex of the left ventricle. Photographs were taken of the ascending lymphatics, and then mediastinal dissections were performed to visualize the mediastinal lymphatic drainage pathways. In the acute studies, the animals were killed with a lethal intravenous dose of sodium pentobarbital. In the chronic studies, the pericardium and chest incisions were closed using standard techniques.

RESULTS

Certain aspects of the minipig heart and great vessel anatomy merit emphasis. The superior vena cava is consistently large. The atrial appendages are large and prominent and abut the anterior pulmonary artery on either side *(Fig. 1, top)*. The aorta is markedly posterior, and is covered on its ventral aspect by the superior vena cava and the right atrial appendage. Although these are anatomical variants from that of man and dog, the cardiac lymphatic anatomy is nonetheless remarkably similar to these species (4).

Fig. 1 (lower left and right) illustrate the characteristic patterns of the principal ascending cardiac lymphatic(s) draining the left ventricle. As shown, T1824 blue dye (Evans) or India ink depicts one or two principal ascending lymphatics in or near the interventricular groove. When two lymphatics ascend adjacent to the interventricular groove, they invariably join near or under the left atrial appendage. The principal ascending lymphatic then travels beneath the appendage and passes behind the pulmonary artery and aorta to the right side of the mediastinum. It then passes cephalad in the right mediastinum along the left side of the superior vena cava to enter a cardiac lymph node located between the superior vena cava and the right side of the trachea.

COMMENT

In 1966, Johnson and Blake (5) described the anatomical pathways of the cardiac lymphatics in pigs, dogs, and humans. Using primarily hydrogen peroxide to visualize the lymphatics, they concluded that the pig, like dog and man, had an extensive subepicardial and subendocardial network of lymphatics. They did not study the mediastinal drainage pathways of these cardiac lymphatics. In 1968, Lukaszewska-Otto et al (6) examined cardiac lymphatics and dehydrated specimens of man and pig after the injection of Paris or Berlin blue (oily suspensions of pigments used in painting) in chloroform. They observed that the ventricular subepicardial lymphatic network in man was more extensive than that in the pig and that the caliber of the lymph vessels was larger in the pig. Julien et al (7) described the cardiac lymphatic anatomy in Yorkshire pigs during studies of lipoprotein composition and transport in cardiac lymph. They injected T1824 blue dye (Evans) or Patent blue (2.5% saline solution) into the apical areas of the right and left ventricles to optimize visualization of these lymphatics. They found the same pathway of the principal ascending lymphatic(s) on the surface of the heart as we did, which also passed towards the left atrial appendage. In 10 pigs, they described an ascending lymphatic trunk in the right mediastinum on the dorsal side of the superior vena cava, which terminated in a cardiac lymph node between the superior vena cava and the trachea. In 5 other pigs, they found that the common ascending mediastinal lymphatic divided into two or three smaller lymph vessels, one of which passed to the left pretracheal lymph node. They also noted that efferent lymphatics from the cardiac lymph node passed cephalad or emptied into the left pretracheal node. It should be emphasized that these workers injected coloring markers into the right ventricle as well as the left and accordingly their anatomical findings included lymphatic drainage pathways from both ventricles.

Our findings in the Yucatan minipig confirm the description by Julien et al (7) in Yorkshire pigs. The cardiac lymph node in the right mediastinum was invariably the drainage pathway from coloring markers injected into the left ventricle. It would not, however, be surprising particularly in light of the findings by Julien et al (7) to find occasional connections to a left mediastinal node. Recognizing the particular anatomical features of the heart and great vessels in the minipig should make approaching the cardiac lymph system easier for future investigators. It is also noteworthy that the major right mediastinal lymphatic draining the left ventricle in the minipig is accessible as it is in the dog for cannulation before it enters the cardiac lymph node.

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REFERENCES

1. White, CJ, SR Ramee: Swine models of atherosclerosis. In: *Atherosclerosis and Arteriosclerosis: Human Pathology and Experimental Animal Methods and Models.* White, RA (ed.), CRC Press, Inc., Boca Raton, 1989, pp. 207-234.
2. Thorpe, PE, WJ Hunter III, XX Zhan, et al: A noninjury, diet-induced swine model of atherosclerosis for cardiovascular-interventional research. Angiology 47 (1996), 849-858.
3. Miller, AJ, A DeBoer, AS Palmer: The role of lymphatic system in coronary atherosclerosis. Medical Hypotheses 37 (1992), 31-36.
4. Miller, AJ: *The Lymphatics of the Heart.* Raven Press, New York, 1982.
5. Johnson, RA, TM Blake: Lymphatics of the heart. Circulation 33 (1966), 137-142.
6. Lukaszewska-Otto, H, S Zajac, A Kukwa, et al: The subepicardial lymphatic network of the heart in man and in the pig. Folia Morphologica 4 (1968), 391-392.
7. Julien, P, E Downar, A Angel: Lipoprotein composition and transport in the pig and dog cardiac lymphatic system. Circ. Res. 49 (1981), 248-254.

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