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Vasa Vasorum within the Media of Bovine Mesenteric Lymphatics (39723)

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In lower animals, particularly amphibia, the flow of lymph is maintained by rhythmically beating lymph hearts. Although there are no lymph hearts in the mammal, all lymphatics other than terminal capillary networks contain smooth muscles in their wall (1). It has been noted that mammalian lymphatics, at least in certain species and in certain areas, showed spontaneous active contractions which were capable of promoting lymph propulsion (1). Recently, the present authors have succeeded in recording membrane action potentials from bovine mesenteric lymphatics simultaneously with phasic contraction waves which had one-to-one correspondence to the action potentials. The present electron microscopic study was undertaken to elucidate the motor activity of lymphatic smooth muscles from the structural point of view. It was found that blood capillaries are distributed within and among the smooth muscle layers.

Materials and methods. Segments of mesenteric lymphatics, 2–3 cm in length, were dissected from the fresh mesenterics of recently slaughtered cattle and fixed in a 4% glutaraldehyde solution. Small pieces were then cut for embedding. After fixation in osmium tetroxide and dehydration in alcohol, the tissue blocks were embedded in epon. All sections were cut with the LKB Ultrotome, and the electron microscopy was done with the Hitachi MU-11A. The sections were stained double with lead citrate and uranyl acetate.

Results and discussion. Figure 1 is a transverse section of bovine mesenteric lymphatics at magnifications of 700 diameters to demonstrate the general organization of the lymphatic wall. Smooth muscles, which lined the walls very thickly, could be distinguished in three layers, i.e., the internal longitudinal, intermediate circumferential, and external longitudinal. The outermost layer was much thicker than the other two. There existed few elastic fibers and a vast number of collagen fibers underneath the endothelial lining and among the smooth muscle layers. Such a triplicate disposition of lymphatic smooth muscles has never been noticed except in an observation by Moriwaki on human leg lymphatics (2).

In addition, blood capillaries were found not only in the adventitia but also within and among the smooth muscle layers. Three arrowheads in the figure indicate the locations at which blood capillaries were found. They were identified as blood capillaries by the presence of basement membrane and the configuration of endothelium (Fig. 2). Occasionally erythrocytes were also found in the lumen.

The walls of lymphatic vessels have been known to be supplied by a rich network of nutritive blood vessels located exclusively in the adventitia (1). The present electron microscopic observation revealed that blood capillaries, along with collagen fibers, entered deep into the well-developed smooth muscle layers of bovine mesenteric lymphatics. The distribution of blood capillaries in lymphatic walls may be much more widespread than has so far been believed. The presence of vasa vasorum within the media may reflect the relatively high oxygen requirements of the lymphatic smooth muscles and the relatively low oxygen supply from the lymph flowing through the lymphatic vessel. An ample supply of oxygen will be required to maintain rhythmic contractions, which act as a driving force for the propulsion of lymph.

The oxygen requirements of arterial smooth muscles can be supplied from the blood in the lumen until the wall becomes too thick to be nourished without vasa vasorum. The critical thickness, that renders diffusion from the vessel's own lumen insufficient, has been estimated to be between 0.9 and 1.0 mm for human aortic walls (3). Wolinksy and Glagov (4) found that vasa vasorum within the media were present in

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FIG. 1. Transverse section of bovine mesenteric lymphatic wall ×700. The top is the endothelial side. Well-developed smooth muscles are arranged in three layers, i.e., the internal longitudinal, intermediate circumferential, and external longitudinal. The outermost layer is much thicker than the other two. A large number of collagen fibers exist underneath the endothelial lining and among the smooth muscle layers. Blood capillaries are found at the locations indicated by arrowheads.

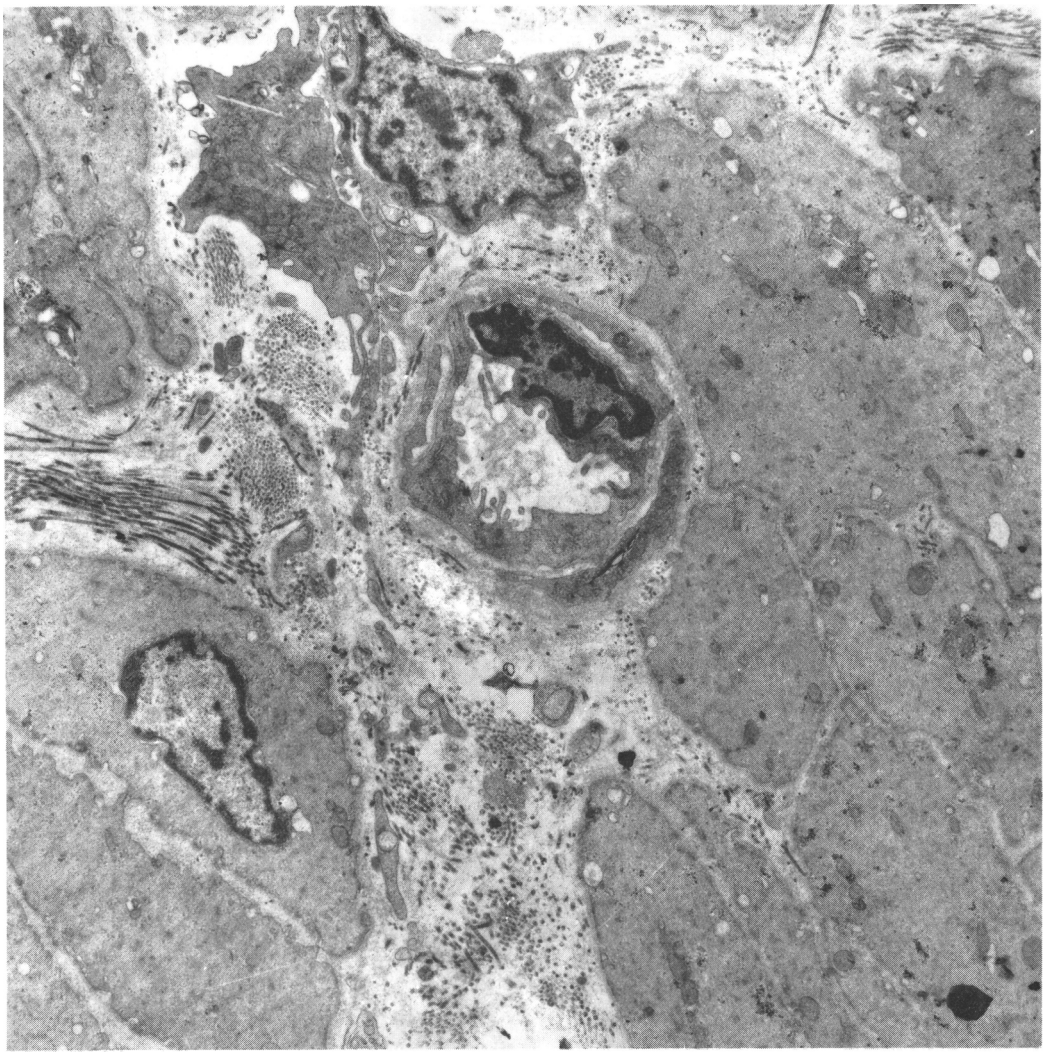

FIG. 2. Transverse section of a blood capillary found within the external longitudinal smooth muscle layer ×1540. The endothelium has many pedicles which protrude into the lumen.

mammalian aortae which had more than 29 elastic laminae but not in those which had less elastic laminae.

The amount of oxygen in lymph and the rate of flow in lymphatics are extremely low compared with those in arterial blood and in arteries (5). Hence, it may be comprehensible from the teleological point of view that the presence of blood capillaries within the well-developed smooth muscle layers is essential for bovine mesenteric lymphatics to maintain vigorous spontaneous activity. We have also found blood capillaries within the smooth muscle layers of the canine ureter and portal vein which were known to have spontaneous rhythmic contractility. No blood capillary has been found in the media of bovine mesenteric arteries.

Figure 3 demonstrates a longitudinal section of a lymphatic smooth muscle cell. A large number of mitochondria gathered in a cluster were seen on both sides of the nucleus along the longitudinal cell axis. Numerous glycogen granules were also found among and around the mitochondria. Numbers of micropinocytotic vesicles, which have recently been recognized as the preservation site of free calcium ions (6), were

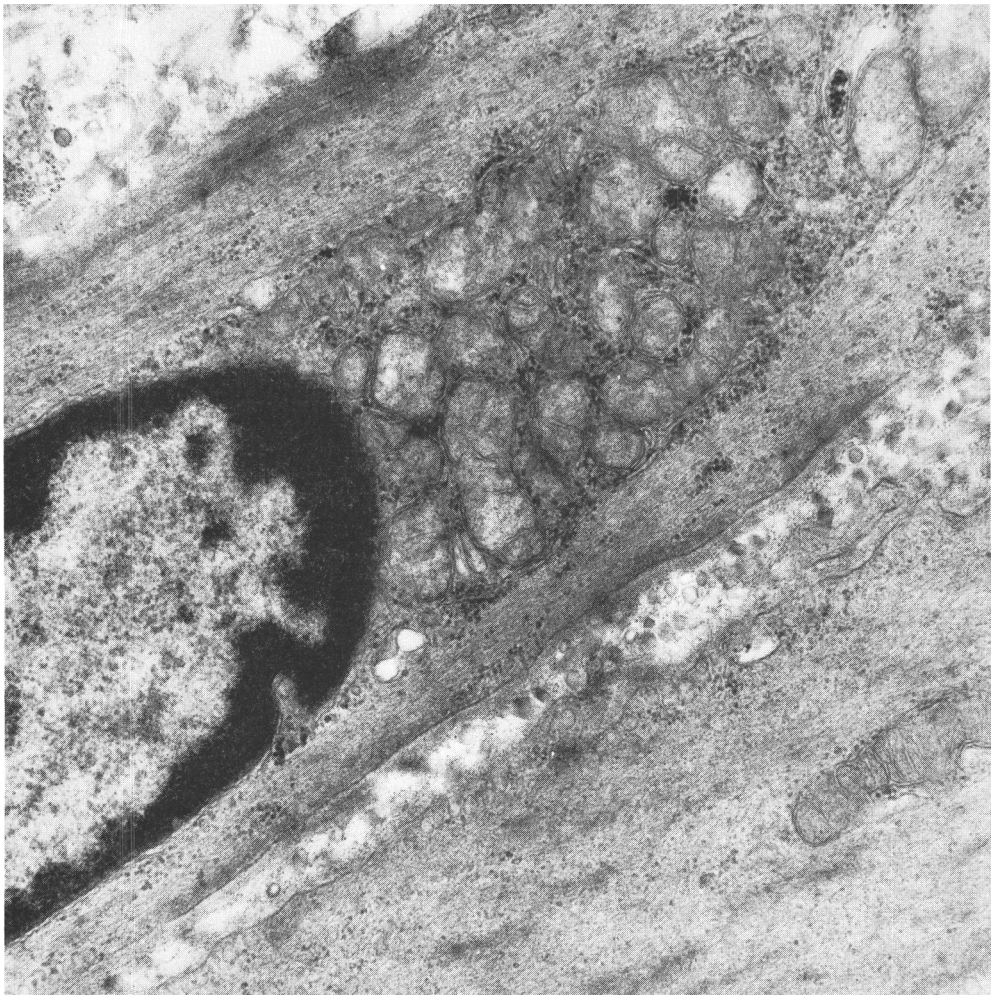

FIG. 3. Longitudinal section of a lymphatic smooth muscle cell ×7000. Mitochondria are clustered on one end of the nucleus along the longitudinal cell axis. A number of glycogen granules are seen among and around the mitochondria.

found together with mitochondria and glycogen granules in the vicinity of sarcolemma, not shown clearly in this figure. These structural features might be a morphological manifestation of the high metabolic activity required for spontaneous contractions of bovine mesenteric lymphatic smooth muscles. The high metabolic demand may be met by oxygen supply from the blood flowing through the blood capillaries distributed within the smooth muscle layers.

In the case of bovine mesenteric arteries and veins, only a few mitochondria were noticed around the nucleus of smooth muscle cells. No significant difference in other organellae was noted between lymphatic and vascular smooth muscle.

Summary. Smooth muscles in bovine mesenteric lymphatics were well-developed and arranged in three layers, i.e., the internal longitudinal, intermediate circumferential, and external longitudinal. The outermost one was much thicker than the other two. Blood capillaries were found within the smooth muscle layers as well as in the adventitia. These blood capillaries may be essential for maintaining vigorous rhythmic contractions of the lymphatic smooth muscles which act as a driving force for the

propulsion of lymph. The presence of numerous mitochondria and glycogen granules seemed to reflect a high metabolic activity of the smooth muscle cells.

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