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THE MICROSCOPIC VASCULAR PATTERN OF THE RUMINAL WALL IN *OVIS ARIES*

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SUMMARY

The microscopic vascular pattern of the ruminal wall of the sheep was studied by means of an India ink injection method followed by clarification in methyl salicylate. Both the epithelium and the tunica muscularis receive blood from a submucosal arterial plexus. Venules arise from the lower regions or bases of the papillae as well as from an inter-muscular plexus. These join the submucosal venous plexus. The sub-epithelial capillary flow is from the tips of the papillae toward their bases. Submucosal arterio-venous anastomoses were identified in serial sections.

INTRODUCTION

Ellenberger & Günther (1908) described the microscopic structure of the ruminal wall, but almost disregarded its vascular pattern. The vascular pattern of the intestine, however, was described by Pfuhl & Plenk (1932) and by Bloom & Fawcett (1962). Dobson *et al.* (1956) fully described the histology of the ruminal wall of the sheep with special emphasis only on its epithelium and sub-epithelial capillary network. The macroscopic blood supply of the rumen was dealt with by Happich (1961) whereas Nickel, Schummer & Seiferle (1960) and Sisson (1953) described the rumen anatomy fully. Consequently, although much information has been obtained on the physiological, anatomical and histological aspects of the rumen, little is known about the nature of its microcirculation. The object of this work then is to elucidate this particular aspect.

METHOD

The rumen of a sheep was removed intact immediately after slaughter. Without delay a solution of 0·85 per cent (w/v) sodium chloride, containing 0·5 per cent (w/v) ammonium oxalate as an anticoagulant and 0·2 per cent (w/v) sodium nitrate as vascular dilator, was injected into the right and left ruminal arteries (Lillie, 1953). Injection was continued at a low pressure (to prevent capillary rupture) until all the blood vessels had been thoroughly flushed out. Subsequently India ink was injected until it returned from the ruminal veins.

Sections of the ruminal wall approximately 5 cm square were fixed in 10 per cent (v/v) formalin for 24 to 48 hours. These blocks were then gradually dehydrated by immersing them for at least six hours in each of increasing concentrations of ethyl alcohol. Beginning with a 35 per cent (v/v) solution, concentrations were increased by 5 per cent at a time to 70 per cent. This was followed by 80 per cent, 96 per cent and two changes in 100 per cent alcohol. Thereafter methyl salicylate was used for clearing.

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Vertical sections were subsequently prepared, approximately 0·5 mm thick, and mounted in methyl salicylate. Horizontal sections of approximately one cm^2 were similarly mounted. Camera lucida drawings proved more suitable than photographs for obtaining greater focal depth.

Serial sections at 15μ were prepared and stained with haematoxylin and eosin to establish the presence of arterio-venous anastomoses.

Observations

The large, macroscopically visible blood vessels are situated just below the serosa in the longitudinal and coronary grooves of the rumen. While macroscopically still visible, they are seen to penetrate the tunica muscularis at markedly thinner areas. At the junction of the inner and outer layers of the tunica muscularis, these larger vessels give rise to small radicles.

On reaching the submucosa the arteries form a plexus in its deeper regions, next to the inner muscular layer. From this plexus arteries branch off towards the epithelium as well as to the tunica muscularis. The epithelial arteries have a characteristic arrangement. A single artery is found passing up the centre of a papilla. At its tip it passes into the capillary plexus which is characteristic in that it forms a long-meshed network arranged parallel to the long axis of the papilla with shorter cross connections (Fig. 3). This follows the general plan of the " proprial protrusions " arranged as longitudinal grooves and ridges interlocking with those of the epithelium. (The term " proprial protrusions " is used here to indicate the papillary body, homologue to the dermal papillae of the skin. Such a term is deemed necessary to avoid confusion with the term papillae, as the structures in the rumen are commonly known.) The capillaries, therefore, lie mainly in the sub-epithelial connective tissue.

The capillary plexus between papillae is in the form of a round-meshed network conforming to the patterns of the proprial protrusions at these sites.

Arteries from the submucosal plexus penetrate the inner muscle layer to form a plexus between the two layers of the tunica muscularis. From this arterial plexus arterioles supply the tunica muscularis (Fig. 1). The capillary network of the tunica muscularis forms a long-meshed network parallel to the direction of the smooth muscle fibres (Fig. 1).

In the submucosa very few capillaries are to be seen.

The serosa has no visible capillary plexus of its own but seems to be supplied from the network of the outer muscle layer.

The sub-epithelial capillary network is drained by veins arising from the network at the bases of the papillae as well as directly from the inter-papillary areas (Fig. 1). Where the papillae are long and large, a vein may arise from the lower half of the papillae (Fig. 3). These veins join the submucosal venous plexus.

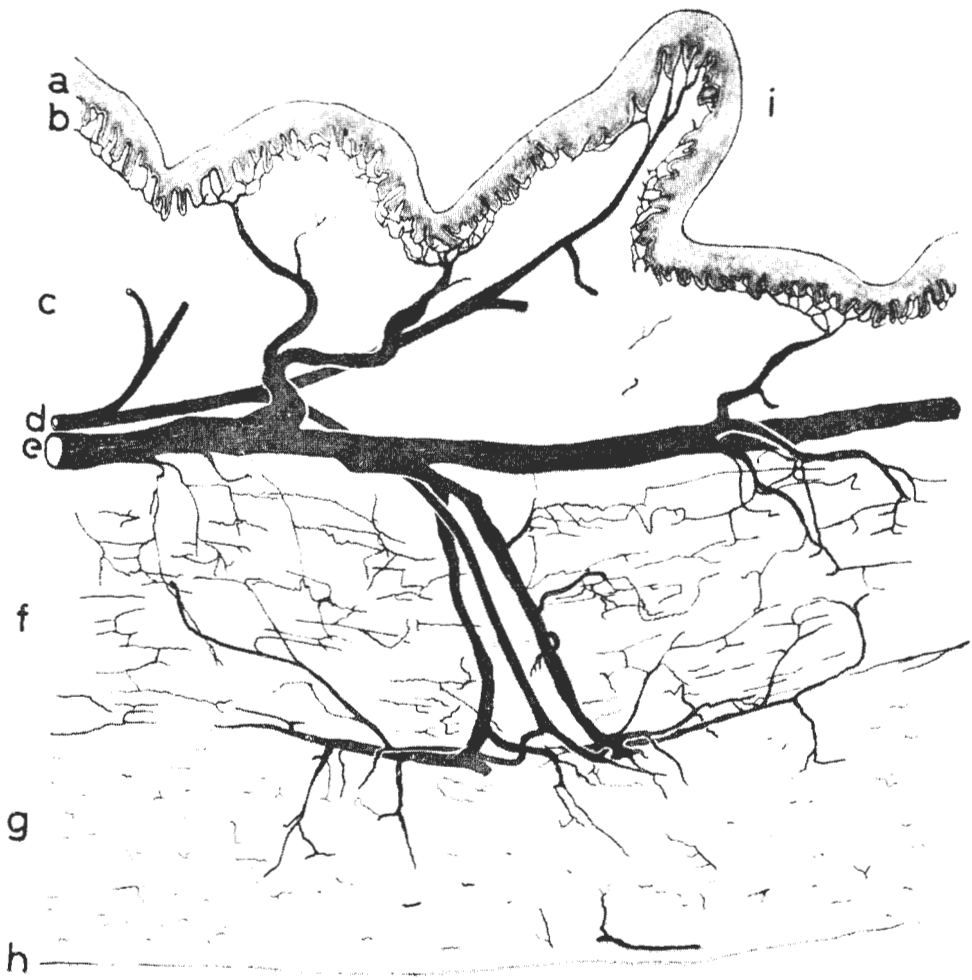

FIG. 1.—Semi-schematic camera lucida drawing compiled from a series of sections. a. Epithelium; b. Sub-epithelial capillary network; c. Submucosa; d. Artery; e. Vein; f. Inner muscular layer; g. Outer muscular layer; h. Serosa; i. Papilla

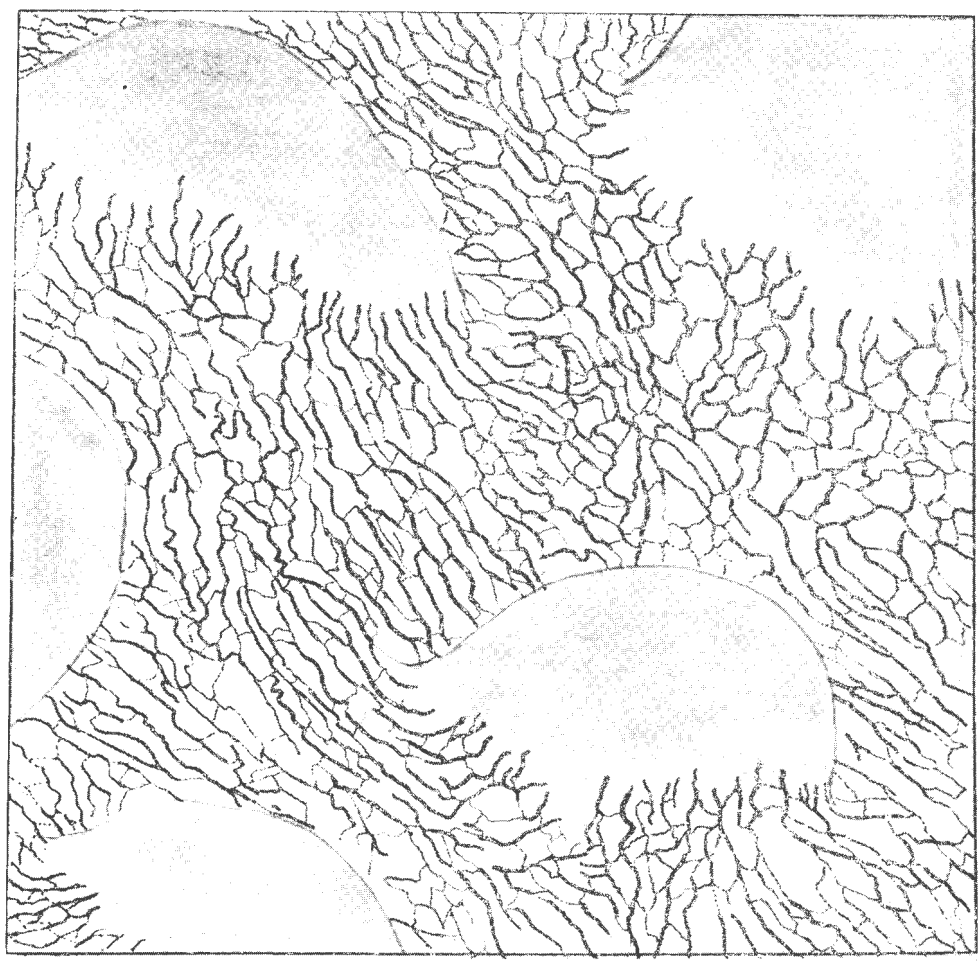

FIG. 2.—Camera lucida drawing of sub-epithelial capillary network. Due to the density of the epithelium on these papillae, the vessels are not visible

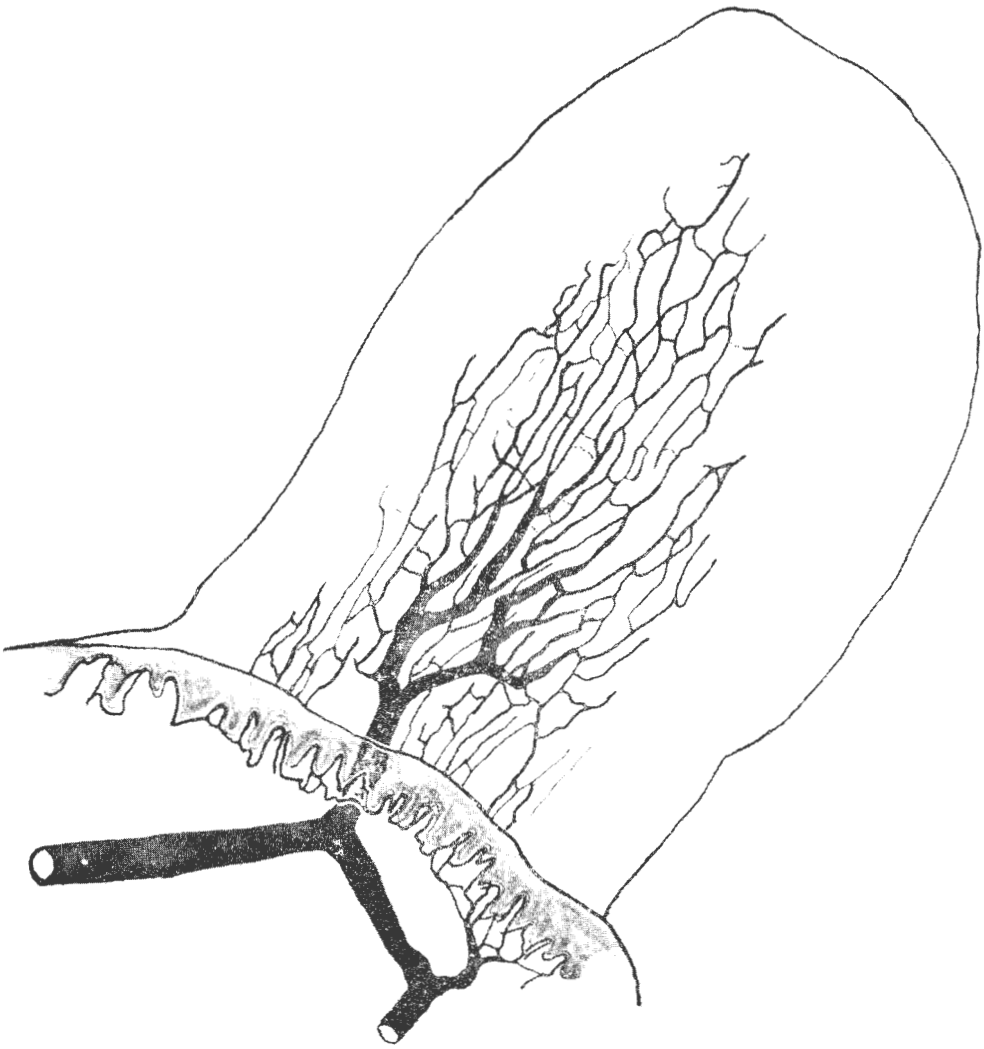

FIG. 3.—Camera lucida drawing of a large papilla showing the venous drainage

The capillary network from the tunica muscularis drains mainly into a venous plexus between the two muscle layers. From this plexus satellite veins accompany the artery to end in the submucosal plexus. Small veins and venules may drain directly from the inner muscle layer to the submucosal venous plexus, while from the outer muscle layer, venules drain into small subserosal veins.

On microscopical examination of the serial sections, an arterio-venous anastomosis was found at the base of a papilla. The presence of such anastomoses would explain why, after India ink injection, all arteries and veins are filled with ink, whereas the capillaries are only filled in some localized areas of about 20 cm diameter. The injection mass must have been short-circuited through some of the anastomoses.

Discussion

The fact that the larger arteries and veins penetrate the tunica muscularis where it is thinnest, will tend to obviate vascular occlusion during muscular contraction.

The general pattern of a vascular tree with a diminishing calibre of vessels and increasing number of vessels as the terminal area is reached, is modified here. Although arterioles to the tunica muscularis do leave the main vessels as they traverse the muscularis to reach the submucosa, it is the submucosal vascular system which forms the main distribution area to the tunica muscularis proximally and to the papillae distally. Similarly, direct venous drainage to a subserosal plexus does not occur, but again the submucosal plexus forms the main drainage area. The vascular system between the two layers of the tunica muscularis in turn forms a subsidiary supply and drainage area.

The sub-epithelial capillary network, as seen in the sections, receives blood only from the tips of the papillae and is drained from the bases and from the interpapillary regions. The direction of blood flow is thus from the tip towards the base of each papilla. This directional capillary flow would greatly facilitate exchange of metabolites between the blood and the ruminal contents, thus indicating the rumen to be a physiologically active organ. The sub-epithelial capillary network of the rumen and the enlarged surface area of the papillae compare admirably with the villi and capillary network of the duodenum and ileum, organs of undoubted physiologic activity.

Arterio-venous anastomoses are present in the submucosal vascular network, as in the rest of the digestive tract and these correspond to the haemodynamics of the alimentary blood circulation system.

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