Direct arteriovenous connections and the intermediate circulation in dog spleen, studied by scanning electron microscopy of microcorrosion casts

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Summary. The exact nature of the circulatory pathways in dog spleen, particularly with reference to the intermediate circulation and the possible existence of direct arteriovenous connections, has been studied by scanning electron microscopy (SEM) of microcorrosion casts. A new casting procedure was developed in which minimal amounts of material were injected into contracted spleens, thus filling preferentially the faster channels for flow. Extensive filling of the red pulp was thereby avoided, leaving an open view of blood vessels and their connections. The depth of focus of the SEM, incomparably greater than those of transmission electron or light microscopes, enabled vascular pathways to be traced over considerable distances.

Using this approach, we have obtained clear evidence for abundant connections between arterial capillaries and venous sinuses (i.e., “closed” circulation). Typically, the terminal arteriole bifurcates repeatedly, in quick succession, giving rise to as many as twelve short capillaries, each leading directly to at least one sinus. However, an “open” circulation also exists, inasmuch as the majority of all capillaries end in the marginal zone around lymphatic nodules. In the dilated spleen, direct connections to sinuses are rarely visible but endings in the red pulp are found, in addition to those going to the marginal zone.

Key words: Dog spleen – “Closed” vs. “open” circulation – Arteriovenous connections in spleen – SEM of microcorrosion casts

The exact nature of the “intermediate circulation” of the spleen, that part of the splenic microcirculation between the end of the arterial capillaries and the start of the venous channels, remains to this day a confusing issue. The question of an “open” versus a “closed” circulation, i.e., whether the arterial blood flows first into the reticular spaces of the red pulp or directly into the venous sinuses (“primordial veins” in the case of non-sinusal spleens) has been studied by many investigators, using a wide variety of approaches, but with conflicting results.

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Attempts by use of light microscopy over more than half a century have employed, predominantly, histological sections of splenic tissue; transillumination of the organ in vivo and the examination of vascular corrosion casts have also played an important part. The controversy came into sharp focus with the radically divergent results of Knisely (1936) and MacKenzie et al. (1941), both obtained by the same transillumination procedure. Part of the discrepancy may have been due to lack of an adequate recognition of species differences (sinusal vs. non-sinusal spleens) but later workers, using a refinement of this technique, also failed to reach agreement (Peck and Hoerr 1951; Parpart et al. 1955). Similarly, studies of fixed sections of splenic tissue examined by light or transmission electron microscopy (TEM) produced conflicting results. In sinusal spleens some workers saw only direct connections of arterial capillaries with venous sinuses (e.g., Pictet et al. 1969, using rats; Tischendorf 1969, using human and other sinusal spleens), while others found capillary openings primarily into the red pulp and only rarely, if at all, direct connections with sinuses (e.g., Snook 1950, using rat, dog, guinea-pig, rabbit, and human spleens; Weiss 1962, 1964, using rat and rabbit spleens). From an examination of vascular casts Lewis (1957) concluded that the intermediate circulation in spleens of cat, rabbit, dog, sheep, and man is exclusively “open”. On the other hand, Ohta (1957) and Ohta et al. (1958) found evidence for the coexistence of both “open” and “closed” circulation in casts of rabbit, dog, goat, rat, mouse, and human spleens, whereas in spleens of cat, pig, and cattle the circulation proved to be entirely “open”.

From the point of view of tracing vascular pathways in three dimensions all the foregoing methods, employing light microscopy or TEM, suffer from the limitation of a very small depth of focus. In the case of TEM the problem is compounded by the need for extremely thin sections. These difficulties have been overcome by the advent, during the last decade, of the scanning electron microscope (SEM) with its incomparably greater depth of focus and the ease of preparation of stereo-paired images. Even so, the conflict of “open” versus “closed” circulation has continued. Most workers examining splenic tissue using SEM have found evidence for only an “open” circulation, in human (Fujita 1974; Irino et al. 1977, 1978) and dog spleens (Suzuki et al. 1977). However, in the hen spleen Miyamoto et al. (1980) found only a “closed” circulation. The results of recent attempts by use of SEM of vascular casts are similarly divided. Murakami et al. (1973) found evidence for exclusively a “closed” circulation in spleen of the rat, whereas Irino et al. (1977) observed only “open” pathways in the human spleen. Barnhart and Baechler (1974), Barnhart and Lusher (1976) and Barnhart et al. (1976) saw pathways, in their casts of human and dog spleens, suggesting the existence of both “open” and “closed” circulation.

Why is there still controversy? The beautiful SEM pictures of arterial capillary endings in the red pulp, provided by Suzuki et al. (1977) and Irino et al. (1977), are a clear demonstration of the existence of an “open” circulation. These workers, and many others, have not found evidence for a closed circulation. However, one should not use the “argument from silence” to conclude that a closed circulation does not exist. In our opinion, the evidence presented so far for a closed circulation has, at best, been less than convincing, partly because of the rarity with which direct connections of arterial capillaries with venous sinuses have been found in any given preparation.