Postcava structure in elephant and rhinoceros

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(With 4 figures in the text)

The mammalian postcava is vulnerable to lumen diminution or collapse under sudden increase of intra-abdominal pressure. Against such collapse its dorsal wall receives an extrinsic protection from the abdominal parietes. Its ventral wall, however, develops an intrinsic protective mechanism in the form of a specialization of its histological architecture. This specialization is most readily noticeable in large-bodied mammals and details of it are given for four such forms, viz., Asiatic elephant (*Elephas*), Sumatran rhinoceros (*Didermocerus*), Black rhinoceros (*Diceros*) and White rhinoceros (*Ceratotherium*).

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Introduction

According to their location in the body the veins of mammals exhibit certain differences in the histological structure of their walls. These differences depend basically upon the relative amount of intra-mural unstriped muscle present and upon a recognizable tunica media resulting from the disposition of this muscle. The relative amount of muscle present in a vein wall is determined largely by the topography of that vein and by the environmental forces to which it is consequently subjected—the muscle tissue being supportive and protective to the circulating venous blood. Hence in superficially disposed veins (e.g. subcutaneous limb veins) intra-mural muscle is more abundant than in deeply-situate veins, which derive an extrinsic support from adjacent muscle-groups and other structures: where such extrinsic support is itself all-sufficient (e.g. intra-cranial veins) the vein-wall may be wholly devoid of muscle tissue (e.g. meningeal and cerebral veins, dural sinuses). In the largest systemic veins the muscle content of the tunica media tends to be minimal and the thickest of the vein-wall coats to be the tunica adventitia, composed basically of collagen and elastic tissue. Such topographico-functional modifications of vein-wall structure are well recognized for the human subject, less so for most other mammals, whose internal environment is nevertheless subject to the operation of comparable vasculo-dynamic forces.

For purely functional reasons the human postcava (vena cava inferior) shows a ventral wall appreciably thicker than the dorsal. In larger-bodied mammals this difference is

obtrusively exaggerated, the postcava dorsal wall remaining histologically unremarkable but the ventral wall being notably hard, unyielding and enormously thickened. The specialized condition of the postcava ventral wall is here described for the Asiatic elephant (*Elephas maximus*) and for the Sumatran rhinoceros (*Didermocerus sumatrensis*), the Black rhinoceros (*Diceros bicornis*) and the White rhinoceros (*Ceratotherium simum*).

Material and methods

Macroscopic examination of the postcava wall was made both in the fresh state and after formalin fixation, in the following specimens:—

Asiatic elephant   (*Elephas maximus*)—7 years ♂: adult ♀: aged ♀
Indian rhinoceros   (*Rhinoceros unicornis*)—15 years ♂: 20 years ♂
Sumatran rhinoceros (*Didermocerus sumatrensis*)—13 years ♀
Black rhinoceros   (*Diceros bicornis*)—2–3 years ♂
White rhinoceros   (*Ceratotherium simum*)—3 years ♂

Microscopic examination was made of the wall of the infra-hepatic postacava in the aged Asiatic elephant specimen and the Sumatran, Black and White rhinoceros specimens. Portions of formalin-fixed postcava wall were paraffin-wax embedded and sectioned at a thickness of 10 μm: the sections were stained by haemotoxylin-eosin, by Weigert and van Gieson, by celestin blue and by Verhoff's stain.

Observations

In each specimen examined the fresh postcava manifested a peculiar and characteristic toughness, firmness and rigidity, with a consistency forcibly recalling that of lead piping. These characteristics were referable to the postcava ventral wall, seen to be many times thicker than the dorsal wall, which presented the customary features of any large vein. The disparity in thickness and physical properties between the postcava ventral and dorsal walls was so great as to suggest a marked difference of composition between the two, which subsequent histological examination showed to be the case. The inferance that, in all the forms examined, the postcava ventral wall followed a common pattern of construction, was likewise substantiated by such examination.

Asiatic elephant (*Elephas maximus*). Aged ♀

The fresh postcava showed a dorsal wall of normal vein consistency, averaging some 2 mm in thickness: In contrast the ventral wall was of firm, unyielding (almost uterine) consistency and averaged some 10 to 20 mm in thickness. Microscopically this ventral wall displayed the following features: The tunica intima had lost its endothelium. A distinct tunica media was unrecognizable and this canonical layer was apparently incorporated into the tunica adventitia. This adventia was composed of collagen, elastic tissue and unstriped muscle, collagen predominating and elastic tissue being quantitatively minimal. The abundant muscle tissue was disposed, not in simple longitudinal and transverse layers, but as a latticework of muscular fasciculi—consisting of relatively large, discrete, longitudinally disposed fasciculi, mutually connected by oblique (probably spiral) fasciculi and by some inner circular fasciculi; longitudinal and oblique bundles predominated (Fig. 1). Some of the advential muscle content extended into the postcava surroundings. The advential muscle was provided with a notable profusion of vasa vasorum, both arterial and venous.
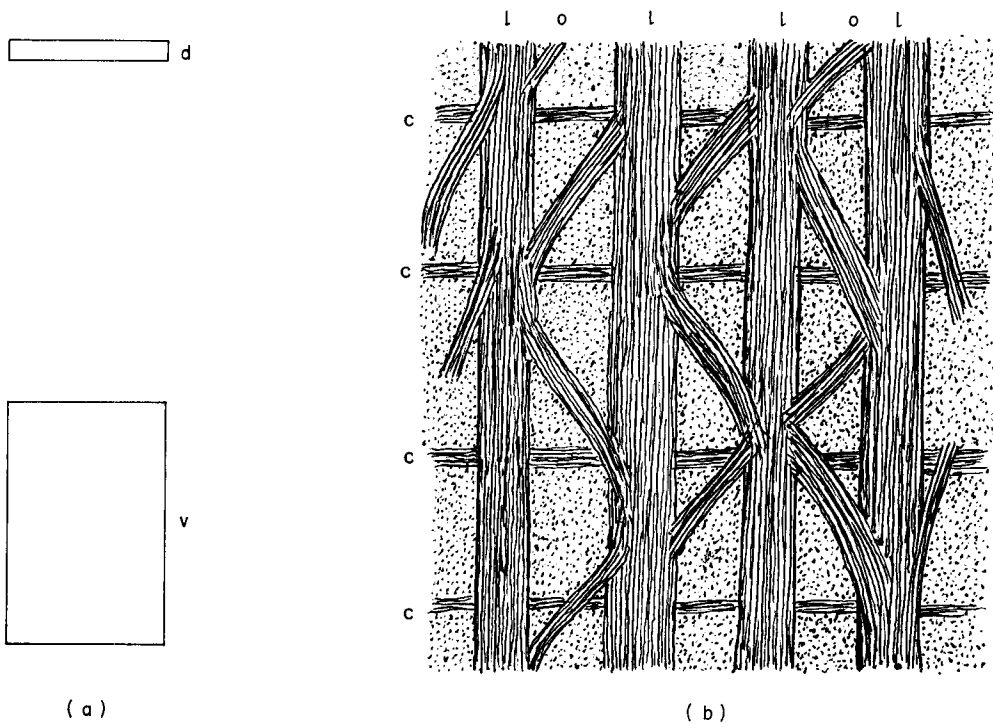
FIG. 1. *Elephas maximus*—postcava. Showing (a) the relative thicknesses of dorsal (d) and ventral (v) walls, (b) ventral wall adventitia with longitudinal (l), oblique (o) and circular (c) muscle fibres and collagen/elastic matrix (stippled). Diagrammatic.

Sumatran rhinoceros (*Didermocerus sumatrensis*). 13 years ♀

The fresh (unfixed) postcava was hard and rigid, as was also the portal vein. Histologically the tunica intima was compact and normal in all respects. The tunica media was somewhat diffuse in composition and relatively thin: it contained some innermost longitudinal muscle and in addition a very small amount of circularly arranged muscle. The tunica adventitia was composed basically of collagen and elastin in about equal proportion, in which matrix were disposed enormous numbers of longitudinally arranged plain muscle fasciculi (Fig. 2). These parallel fasciculi were discrete and closely packed and collectively represented a relatively enormous quantity of muscle tissue: they abounded in vasa vasorum, both arterial and venous.

This histological arrangement held good for the ventral wall only of the postcava, the dorsal wall displaying no departure from the standard pattern of vein wall structure.

Black rhinoceros (*Diceros bicornis*). 2–3 years ♀

The postcava wall, hard and unyielding, was 8 to 10 times thicker ventrally than dorsally. Histologically the ventral wall showed a normal tunica intimia, succeeded immediately (in the absence of any recognizable tunica media) by an enormously thick and muscular tunica adventitia, comprising a compact series of plain muscle longitudinal fasciculi in a matrix of collagen and elastin (Fig. 3). In thickness the adventitia averaged 5 mm, this dimension
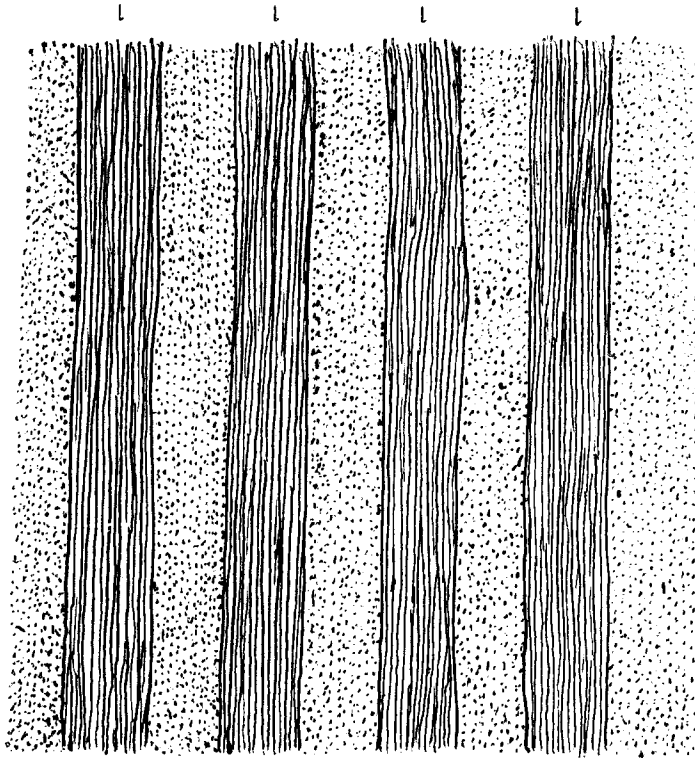
FIG. 2. *Didermocerus sumatrensis*—postcava. Showing longitudinal muscle fasciculi (l) and collagen/elastic matrix (stippled) of ventral wall adventitia. Diagrammatic.

diminishing from 8 mm cranially to some 4 mm caudally, where the contiguous aorta wall had a thickness of 2·5 mm. The fascicular muscle fibres were somewhat larger than unstriped muscle fibres in general and rather smaller than ordinary striped muscle fibres: they displayed a considerable degree of "ballooning" from vacuolation of their cytoplasm and their centrally disposed nuclei were often situate within a vacuole. The obtrusive muscularity of the adventitia was confined to the postcava ventral wall, and was absent from the walls of postcava tributaries (e.g. renal veins).

If the vacuolation of these postcava adventitial fibres be attributed to postmortem change it is remarkable that no comparable change was observable in the most superficial fibres of the gut wall. And even on the assumption that post mortem vacuolation could effect an increase of muscle fibre size to as much as twice the normal, it remains that a postcava ventral wall thickness of 4 mm is nevertheless excessive.

The pericaval tissue present was histologically similar to the adventitia of the postcava ventral wall, consisting of plain muscle fasciculi and intervening strands of connective tissue. In some places the pericaval muscle fibres evidenced "ballooning" from cytoplasmic vacuolation and their nuclei were situated within perinuclear vacuoles: in other places, however, no such vacuolation was observable and the pericaval muscle fibres presented a more typical histological appearance. Among the pericaval fasciculi lay a considerable quantity of diffuse, extra-vascular pigment—probably melanin.

White rhinoceros (*Ceratotherium simum*). 3 years ♀

The postcava was as hard and rigid on palpation as iron piping.

The postcava dorsal wall showed no departure from customary vein constitution: it had a median thickness of 1·5 mm, whereas the opposed ventral wall showed a thickness of some 8 mm. Longitudinal and transverse sections of this ventral wall revealed the presence of a normal tunica intima, the absence of any well-differentiated tunica media and the immediate surrounding of the intima by an exaggeratedly muscular tunica adventitia. This thick, tough, rigid adventitial coat was composed of an enormous number of stout, parallel, longitudinal plain muscle fasciculi set in a matrix of collagen plus a little elastic tissue (Fig. 4).

The longitudinal muscle fasciculi were mutually connected by oblique (possibly spiral) fasciculi, producing a branched or latticework appearance. Individual fasciculi ranged in size from 180 to 325 μm, the latticework interstices from 50 to 225 μm in diameter: within the fasciculi individual muscle fibres pursued a sinuous course. Thus the entire tunica adventitia of the postcava ventral wall was essentially a specialized, much-elongated muscular network. This muscle formation was abundantly supplied with both arterial and venous vasa vasorum, the smallest of which were traceable into (or from) the individual fasciculi.
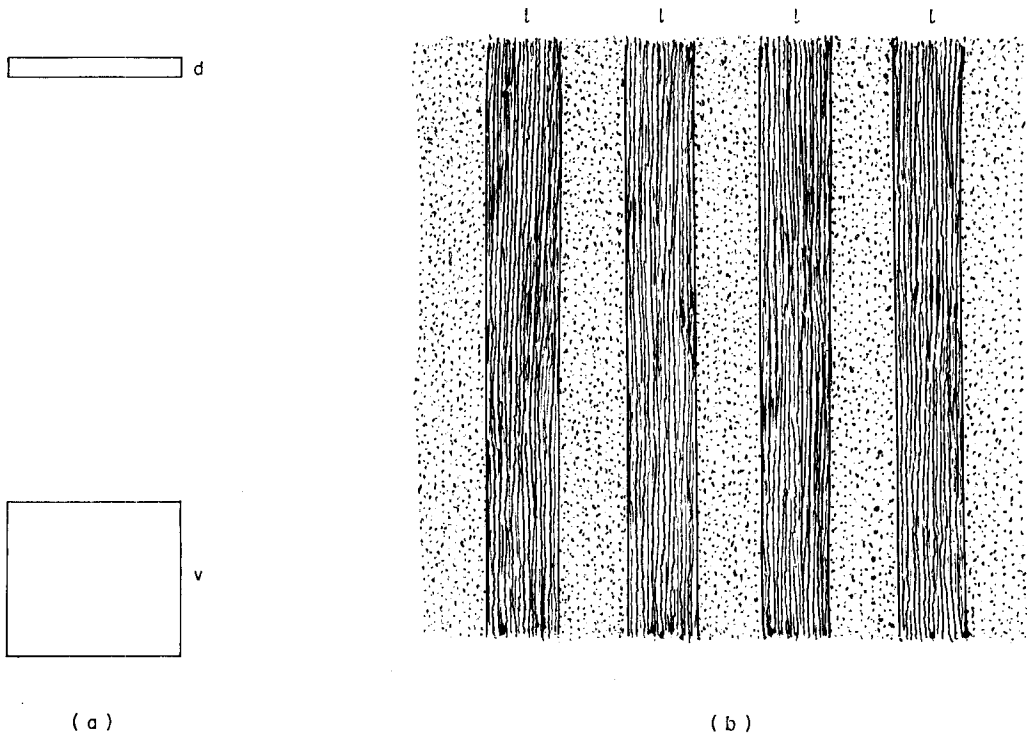

FIG. 3. *Diceros bicornis*—postcava. Showing (a) relative thicknesses of dorsal (d) and ventral (v) walls, (b) longitudinal muscle fasciculi (l) and collagen/elastic matrix (stippled) of ventral wall adventitia. Diagrammatic.
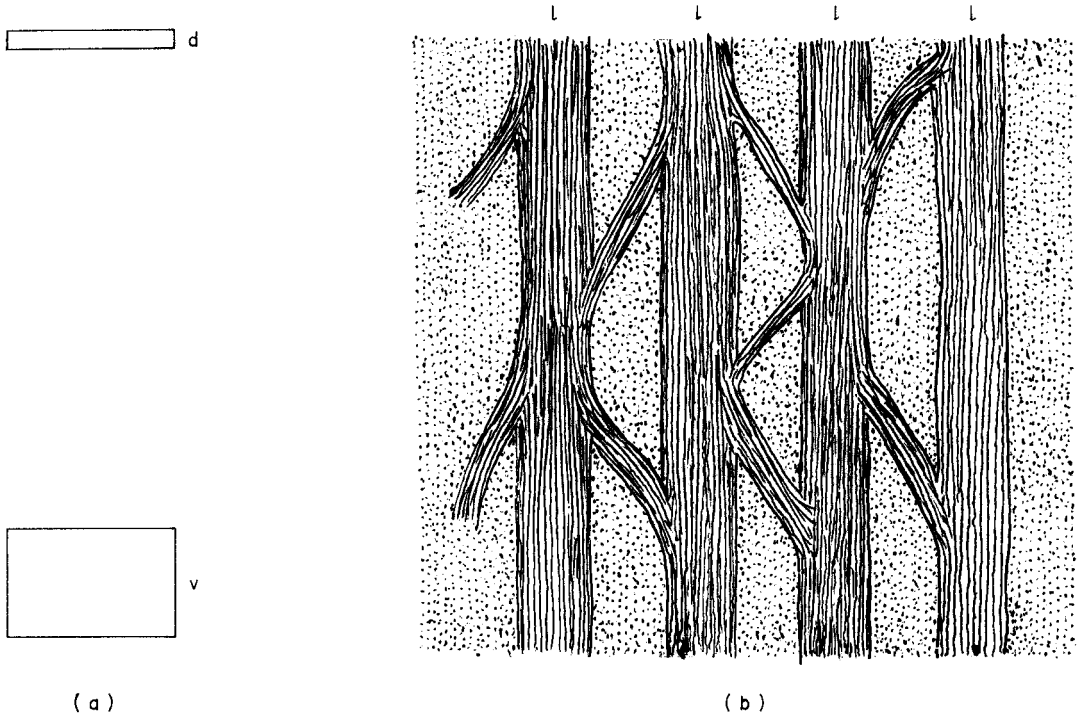
FIG. 4. *Ceratotherium simum*—postcava. Showing (a) relative thicknesses of dorsal (d) and ventral (v) walls, (b) the longitudinal (l) and annectant muscle fasciculi and the collagen/elastic matrix (stippled) of the ventral wall adventitia. Diagrammatic.

Commentary

Being the principal return channel for venous return from the hind-limbs and trunk, the mammalian postcava requires some permanent provision against collapse of its walls with consequent diminution or obstruction of its lumen. Such collapse is likely to ensue from sudden rise of intra-abdominal pressure, to which the postcava ventral wall is particularly vulnerable. Protection against potential wall collapse may be either extrinsic or intrinsic. The postcava dorsal wall receives substantial extrinsic protection from the vertebral column. The postcava ventral wall develops instead an intrinsic protection mechanization by means of a specialization and augmentation of its mural musculature.

The observations recorded above render it clear that, at least in the large-bodied forms studied, this specialization is an excessive 'muscularization' of the tunica adventitia, involving the development therein of an abundance of substantial muscle fasciculi, arranged in either palisade or lattice formation. This quantitative increase of intra-mural muscle necessitates a correlated augmentation of the matricial collagen and elastic—the total modification of structure being responsible for the postcava physical characteristics of toughness and rigidity. It accounts also for the suppression (or extreme diminution) of any tunica media in the postcava histological picture.

The specialized muscularity of the postcava ventral wall described here for certain elephant and rhinoceros forms may well be nothing more than a particularly obtrusive

manifestation of a standard response to the vasodynamics of environment common to mammals in general, as further enquiry may demonstrate. And it may be not unreasonably assumed that the advential specialization noted for the rhinoceros genera *Didermocerus*, *Diceros* and *Ceratotherium* will be found to obtain also in the genus *Rhinoceros*.