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Regional differences in aorta of goat (*capra hircus*)

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Regional differences in the aortic wall are important in explaining the physicomechanical properties and disease distribution in this artery. The goat is a suitable model for studying cardiovascular disease, but the regional features of its aorta are scarcely reported. The purpose of the study was therefore to describe the regional differences in the wall of its aorta.

*Sixteen healthy adult male domestic goats (*capra hircus*) were euthanised with intravenous sodium pentabarbitone and specimens obtained from the ascending, arch, each vertebral level of descending thoracic, and various segments of abdominal aorta. The specimens were fixed in 10% formaldehyde solution and routinely processed for paraffin embedding. Seven micron thick sections were stained with Mason's Trichrome and Weigert Resorcin Fuchsin stains.*

Light microscopic examination revealed that the aortic wall consists of tunica intima comprising endothelium, subendothelial zone and internal elastic lamina, media, and adventitia. Endothelium comprises flat and round endotheliocytes. The population of round cells declines as the internal elastic lamina increases in prominence caudally. Tunica media in ascending, arch, and proximal thoracic aorta comprises two zones: namely a luminal elastic and adventitial musculo-elastic zone, in which muscle islands interrupt some elastic lamellae. These islands progressively diminish caudally until by the eleventh thoracic vertebra they are only patchy. Beyond this point and in the abdominal aorta they are absent and tunica media consists of regular concentric elastic lamellae. Tunica adventitia, on the other hand, increases in thickness and elastic fibre content caudally.

Regional variations exist in all three layers of goat aorta. The nature of these differences suggests that they are related to haemodynamic factors. Furthermore, the variations may form the basis for regional differences in physicomechanical strength and disease distribution along the aorta. (Folia Morphol 2010; 69, 4: 253–257)

Key words: goat, aorta, regional differences

INTRODUCTION

Regions of the aorta, namely: ascending, arch, descending thoracic, and abdominal, vary in their structure [1, 22] and susceptibility to disease. For instance, atherosclerosis and related aneurysms occur more commonly in the abdominal than in the thoracic aorta [13], while dissecting aneurysms and penetrating atherosclerotic ulcers seem to be more common in descending thoracic than in abdominal aorta [3, 4]. Understanding the regional structural differences may provide some insight into the basis of observed variations in predisposition of aortic regions to disease. Furthermore, knowledge of the histomorphological organisation of the different

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aortic regions may enhance understanding of its function and serve as a baseline for studying alterations that occur in aging and disease processes such as atherosclerosis and aneurysms [5]. The goat is a suitable model for studying vascular disease [14, 26]. There are, however, few reports on the regional features of its aorta [15], and existing reports concentrate mainly on the tunica media with very little mention of the tunica intima and adventitia. This study, therefore, aimed to describe the regional differences in the three layers of goat aorta.

MATERIAL AND METHODS

Aortae for this study were obtained from 16 male healthy domestic goats *(capra hircus)* aged between 6 and 24 months and weighing 10–60 kg, purchased from private livestock farmers in the outskirts of Nairobi. The animals were weighed then euthanised with an overdose of sodium pentabarbitone 20 mg/mL injected intravenously. The abdomen and thorax were opened by midline incisions, and the pericardium slit to expose the heart. To clear the blood, normal saline was introduced through the left ventricle and drained out through the right auricle. By the same means, the animal was fixed by gravimetric perfusion using 10% formaldehyde solution. Specimens taken from ascending, arch, each vertebral level of thoracic, pre-renal, renal, and post-renal segments were processed routinely for paraffin embedding and 7 μm sections stained with Weigert resorcin — fuchsin/Van Gieson stain for demonstration of elastic fibres, and with Mason's trichrome stain for collagen and cells. The proportion of tunica media occupied by muscle islands was determined by point counting on a quadratic lattice applied on stained slides at magnification 35× projected onto a television screen. The number of complete elastic lamellae was counted at four different areas on every fourth randomly selected slide and the average taken.

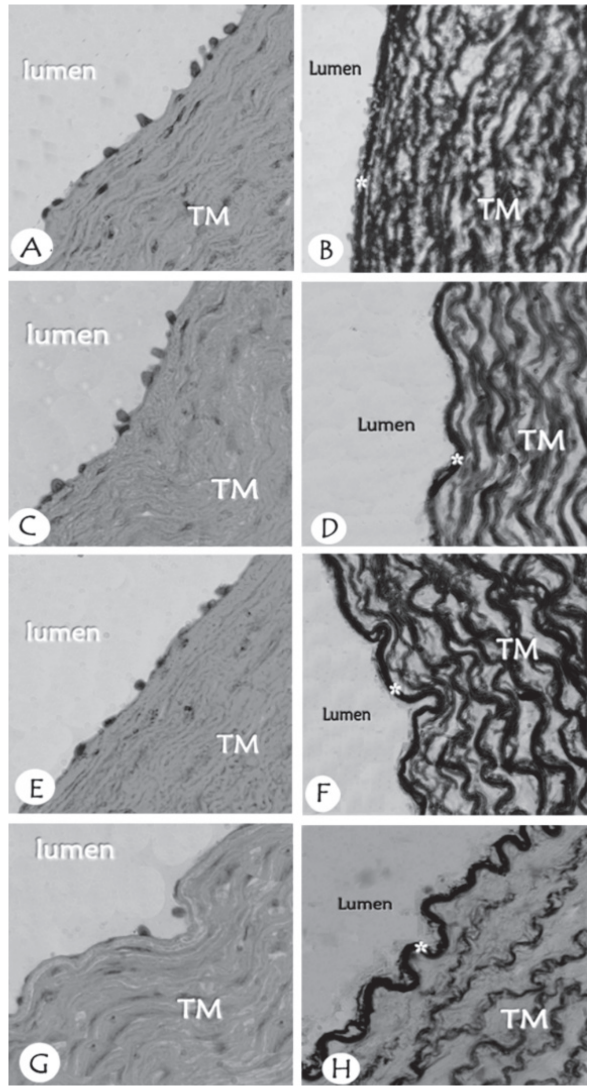

Figure 1. Regional variations in tunica intima of the aorta in the goat; TM — tunica media; **A, C, E, G.** Tunica intima and part of the media showing endotheliocytes (red). Mason's Trichrome stain ×400; **A.** Ascending aorta; **C.** Aortic arch; **E.** Middle thoracic aorta; **G.** Abdominal aorta. Note the caudal decline in frequency of round endotheliocytes; **B, D, F, H.** Tunica intima and luminal part of TM showing internal elastic lamina (stars). Weigert elastic stain ×400; **B.** Ascending aorta; **D.** Proximal thoracic aorta; **F.** Distal thoracic aorta; **H.** Abdominal aorta. Note the caudal increase in prominence and folding.

RESULTS

The aortic wall consists of tunica intima, media, and adventitia. Tunica intima comprises endothelium with squamous and round endotheliocytes, a subendothelial zone, and internal elastic lamina. The tunica media is made of concentric lamellae, some of which in the adventitial zone of proximal segments are interrupted by muscle islands. Tunica adventitia is a fibro elastic jacket. Regional variations in cellular morphology, fibre composition, and disposition have been observed in all three layers.

Regional variations in the tunica intima

The frequency of round endothelial cells shows progressive craniocaudal reduction until, in the abdominal aorta, they are only scattered (Figs. 1A, C, E, G). The internal elastic lamina in the ascending aorta and aortic arch is not readily distinguishable from the elastic lamellae of the tunica media (Fig. 1D). It increases caudally in prominence and degree of folding such that it is most prominent and folded in the abdominal aorta (Figs. 1B, D, F, H).

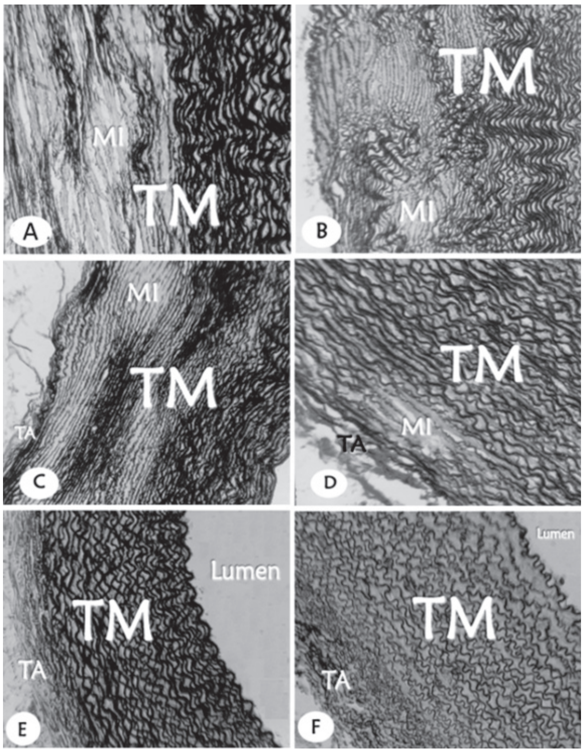

Figure 2. Regional variations in the tunica media of the goat aorta. Weigert elastic stain. ×100; MI — muscle islands; TM — tunica media; TA — tunica adventitia; **A.** Ascending aorta to show MI in the adventitial zone of the TM; **B, C.** Thoracic aorta at T7(B) and T9(C) to show MI in the adventitial zone of the TM; **D.** Thoracic aorta at T10, showing a small patch of MI in the adventitial third of the TM next to the TA; **E.** Thoracic aorta at T12 showing a homogenous TM without MI. Note the thin TA; **F.** Abdominal aorta showing a homogenous TM without MI. Note the thick TA.

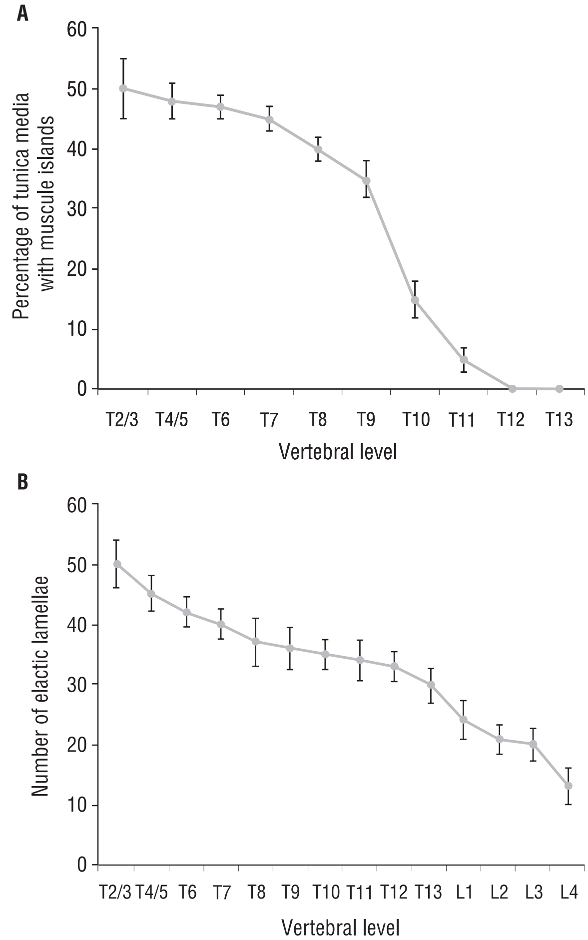

Figure 3. A. The percentage of tunica media of the goat aorta with muscle islands. Note the craniocaudal decline in muscle islands down to T12; **B.** The average number of elastic lamellae at various vertebral levels of the goat aorta. Note the craniocaudal decline in the number of lamellae.

Regional variations in the tunica media

Definite muscle islands in the adventitial zone of the tunica media are only found in the ascending aorta, aortic arch, and thoracic aorta down to T9 (Fig. 2A–C). At T10 and T11 irregular patches of muscle cells occupy only the outer one third of the tunica media (Fig. 2D). At T12–T13 and in the abdominal aorta the tunica media shows uniformly arranged elastic lamellae without any interruption by muscle islands (Figs. 2E, F). The proportion of tunica media occupied by muscle islands and number of concentric elastic lamellae decline caudally (Figs. 3A, B).

Regional variations in the tunica adventitia

The tunica adventitia displays a craniocaudal increase in thickness and elastic fibre content (Figs. 4A–D). In the ascending aorta, aortic arch, and proximal descending aorta, the tunica adventitia is thin and consists predominantly of collagen fibres with a few scattered elastic fibres running in different directions (Figs. 4A–C). In the abdominal region it is much more prominent, compact, and contains more elastic fibres than in the thoracic part (Fig. 4D).

DISCUSSION

Observations of the present study reveal that all three coats of the aortic wall display qualitative and quantitative regional variations.

Regional variations in the tunica intima

Endothelial morphology depends on the level of haemodynamic microstimulation [7, 8]. Accordingly, it is plausible that in the present study the higher number of round cells in the proximal segments of the aorta reflects the greater variability in microstimulation in these parts which receive the direct thrust of blood during systole. The internal elastic lamina is thick and folded simi-

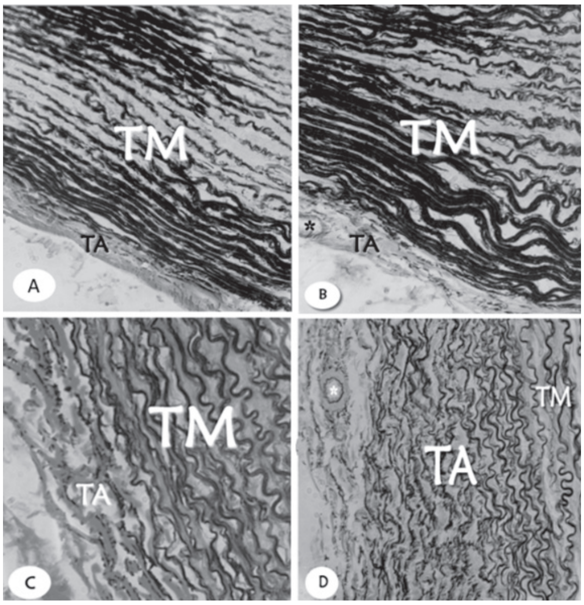

Figure 4. Regional variations in the tunica adventitia of the goat aorta: Weigert elastic stain, × 250; TA — tunica adventitia; TM — tunica media; **A.** Ascending aorta. Note that the TA is thin and predominantly collagenous; **B.** Proximal thoracic aorta. Note the few scattered elastic fibres (black) and a vasa vasorum (star) in the TA; **C.** Distal thoracic aorta. Note the increase in thickness and the definite amount of elastic fibres (black) in the TA; **D.** Abdominal aorta. Note the marked thickening, preponderance of elastic fibres (black), and presence of a vasa vasorum (star).

larly to that of the rabbit [23] and dog [18]. According to Tindal and Svendsen [24], the folding may contribute to the resistance of the aorta to dilatation during systole. Secondly, the folds may constitute a reserve of intima, which is stretched during systole to accommodate the increased luminal circumference. Thirdly, it may augment the windkessel mechanism, usually attributed to elastic lamellae of tunica media alone [20]. Finally, the internal elastic lamina is more important in bearing longitudinal forces [10]. Accordingly, the greater prominence and folding in the abdominal aorta suggests that this segment is subjected to forces different from those in the thoracic region, and secondly that alternative mechanisms for sustaining forces exist in other parts of the aorta.

Regional variations in the tunica media

The presence of muscle islands only in the proximal segments of the aorta suggests that they are related to blood pressure profiles. These muscle islands have been ascribed two functions, namely strengthening of the aortic wall and supplementation of the windkessel function [15, 17]. Pertinent to this suggestion is Dobrin's [9] observation that active vascular smooth muscle can markedly resist distension up to 150–250 mm Hg. In addition, studies of incremental stress-strain curves of porcine aortae suggest that high strain behaviour is consistent with an in-series arrangement of collagen and smooth muscle [21]. Conceivably, the in-series arrangement of smooth muscle and collagen observed in the adventitial zone of the tunica media of the goat aorta may constitute part of this mechanism. In the abdominal aorta, where the pressures are comparatively low, the windkessel mechanism of the remaining elastic lamellae is supplemented by a prominent internal elastic lamina. It is also possible that diversion of blood to abdominal viscera [2] and the hind limbs creates a suction effect on the blood in the aorta.

The diminution of elastic lamellae and presumably elastic tissue, similar to literature reports [11, 18, 22], has been related to the blood pressure profile [1]. The volume of blood leaving the heart during systole imparts the greatest tension on the ascending aorta, aortic arch, and proximal thoracic aorta. The pulsatile nature of blood flow probably requires a large amount of elastic tissue to absorb it. Because of elastic recoil in the more proximal aortic segments, blood flow in the abdominal aorta may be less intermittent and impart less tension [1, 18]. An alternative explanation for the craniocaudal decline in elastic lamellae is that some of the lamellae are involved in the formation of small arteries such as intercostals, which arise from the aorta [19]. A similar diminution in elastic lamellae has been reported in the human aorta [25]. This suggests that the goat abdominal aorta is a suitable model for studying human aortic disease. Notably, the findings of the current study suggest that the abdominal aorta is structurally weaker than the thoracic aorta. This may explain its higher predisposition to atherosclerosis and aneurysm formation.

Regional variations in the tunica adventitia

Observations of the current study, that the tunica adventitia is thin in the proximal aorta, are at variance with reports in other animals in which it is thickest in the ascending, arch, and thoracic aorta, and thin in the abdominal aorta [6, 18]. These workers related this craniocaudal decrease in adventitial size to the pattern of turbulent flow during ventricular systole and the influence of systolic pressure. The predominantly collagenous nature of the tunica adventitia in proximal segments described in the present study may, because of the mechanical properties of collagen, provide the structural basis for the function of resisting systolic thrust. The thinness of this layer in proximal segments of goat aorta where pressure is highest suggests that alternative mechanisms for strengthening the aortic wall exist. This mechanism probably resides in the muscle islands present in the adventitial zone of the tunica media in these segments. Indeed, recent studies suggest that smooth muscle plays a significant role in the mechanical properties of the aorta [21]. It is possible, therefore, that in the goat, the strength of the aorta even at high pressure is a function of both the tunica adventitia and media.

Moreover, the tunica adventitia of abdominal aorta, similar to that of dogs [12, 18], guinea pigs, and albino rats [16] is fibroelastic. These latter workers proposed that the adventitial connections between the fibrous elements and their different spatial orientations collectively contribute to the integrity of the vessel wall. Accordingly, it is possible that the composition of the tunica adventitia of the goat abdominal aorta is designed to confer it with both strength and distensibility.

CONCLUSIONS

Regional variations exist in all three layers of the goat aorta. The nature of these differences suggests that they are related to haemodynamic factors. Furthermore, these variations may form the basis for regional differences in aortic physicomechanical strength and disease distribution along the aorta.

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