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STRUCTURE OF THE AORTIC WALL IN THE GUINEA PIG AND RAT

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ABSTRACT

The segmental microscopic architecture of the aortic wall of guinea pigs and albino rats was studied at the thoracic ascending (T2-3), thoracic descending (T6-7) and abdominal infrarenal (L5-6) levels. Variables such as layer thickness, the number of elastic lamellae in the medial layer, and the diameter of the aortic segments were analyzed histomorphometrically. The aortic wall of both species showed the usual elastic pattern, although variable amounts of elastic lamellae, collagen fibers and smooth muscle cells were observed in the segmental analyses. A marked reduction in the number of elastic lamellae in the medial layer and in vascular diameter was observed in the abdominal aortic segment of both species. Intimal folds, a gradual decrease in elastic lamellae from the ascending to the aorta abdominal aorta and a meshwork of adventitial collagen fibers and elastic lamellae were observed. These data indicate that there are small but significant segmental variations in the aortic wall of these two species.

Key words: Aortic wall, collagen, elastic lamellae, guinea pig, morphology, rat

INTRODUCTION

The structure of the aortic wall has typically been defined as elastic in man [3,5,13], rat [2], and guinea pig [4], based on analyses of the thoracic (ascending and descending portions) and abdominal segments [2,13]. In contrast, the abdominal segment of the aorta in miniature pigs has a transitional organisation in which the medial layer contains a relatively low number of elastic fibers compared to other parts [17]. The origin, course and vascular ramifications of the pig aorta have been described [4], but there has been no report on aortic wall structure in this species.

In several species, the variation in aortic diameter and thickness and in the structure of different segments of the aortic wall have been correlated with the pattern of systolic arterial pressure [2,6,10,11,19], the mechanical, elastic and viscoelastic properties of the vessel wall [3,5,7,14,16,20], the myoelastic architecture and the relative elastin density in the aortic layers [2,3,5,7,10,13,14,17,19,20].

In this report, we compare the structural features of the aortic wall in guinea pigs and rats based on morphological and morphometrical analyses using light microscopy and scanning electron microscopy (SEM). The diameters of different aortic regions were measured in order to compare the thoracic and abdominal vascular segments in both species.

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MATERIAL AND METHODS

Aortas were collected from 12 young adult guinea pigs (*Cavia porcellus* ~ 450 g) and 12 adult Wistar rats (*Rattus norvegicus albinus*, 300 g) of both sexes. Eight animals of each species were anesthetized and perfused via the left cardiac ventricle with 0.1 M phosphate buffered formalin, pH 7.2.

Sections of the ascending (T2-T3) and descending (T6-7) thoracic aorta and of the infrarenal (L5-6) abdominal aorta were cut transversally and longitudinally and processed for conventional histological analysis. The samples were embedded in paraplast mainly in a transversal orientation, followed by sectioning (5 - 7 µm thick), and stained with Masson's trichrome and Calleja's stain [9]. Morphometric analyses of the intimal, medial and adventitial layers of the aortic walls, measurement of the vessel diameters and counting of the elastic lamellae of the medial layer were done using a Zeiss KS-300 (Carl Zeiss, Germany) image analysis system and Optimas 4.1 software (IBM, USA). The data were analyzed statistically by analysis of variance [12]. In all tests, statistic significance was defined when the $p<0.05$.

The relative layer thickness and the number of elastic lamellae of the medial layer of the three aortic segments (ascending thoracic, descending thoracic and abdominal) were obtained from five slides containing four transverse sections of each aortic segment from each species. Twelve random measurements were obtained from 10 transverse sections (7 µm thick) of each aortic segment of both species. The largest and smallest aortic diameters and the number of medial layer elastic lamellae were determined for each aortic segment in both species.

Transverse and longitudinal sections of the descending thoracic and abdominal aorta from four guinea pigs and four rats were fixed [8] and processed for SEM. The tissues were dehydrated, brought to the critical point, sputtered with gold, and analyzed and photographed in a Philips SEM 515 scanning electron microscope.

RESULTS

The intimal layer of the aortic wall of guinea pigs and rats consisted of a thin endothelium, subendothelial connective tissue and an elastic core containing the inner elastic lamina (Fig. 1 A,B,C). The medial layer, which lay immediately adjacent to the intimal layer was the thickest of the aortic layers (Table 1) and was formed by interrelated elastic lamellae, collagen fibers and smooth muscle cells (Fig. 1A,B).

Table 1. Mean thickness (μm) of the intimal, medial and adventitial layers of different aortic segments in guinea pigs and rats.

Wall layer	Aortic segment	Guinea pig	Rat
Intimal	Ascending thoracic	4.03	2.68
	Descending thoracic	3.37	2.65
	Abdominal	4.12	2.79
Medial	Ascending thoracic	218.1	87.3
	Descending thoracic	152.8	71.6
	Abdominal	91.3	66.0
Adventitial	Ascending thoracic	202.5	57.9
	Descending thoracic	95.4	30.0
	Abdominal	70.2	53.3

The elastic lamellae and fibers were arranged concentrically with circular and oblique orientations in the different aortic regions. These lamellae were more developed in the ascending thoracic aortic (Fig. 1B). The elastic lamellae were interconnected by bridges of intertwined elastic fibers and were intercalated with collagen bundles and smooth muscle cells (Fig. 1B,D). The quantity of elastic lamellae and fibers in the medial layer varied in the different aortic regions (Table 2). In both species, the interstitium among the elastic lamellae of the aortic medial layer thus contained fusiform smooth muscle cells and collagen bundles (Fig. 1 A,C).

The number of elastic lamellae in the medial layer of the abdominal segment was lower than in thoracic segments and showed mainly a circular (transverse) orientation (Fig. 1C). In both species, the adventitial aortic layer showed a random pattern of collagen fibers and elastic lamellae (Fig. 1C) that formed a meshwork as confirmed by SEM (Fig. 2A,B).

SEM examination showed that the intimal layer of the guinea pig aorta had a longitudinal enfolded pattern in the endothelium of the three segments, especially in the ascending thoracic aorta (Fig. 2C). Intimal folds were also present in rat aorta. In both species, the folds were least prominent in the abdominal segment (Fig. 3D). The medial aortic layer of both species appeared homogeneous in SEM (Fig. 2A,B), with a thicker and more organized structure of the intermingled components when compared to the light microscopy observations (compare Fig. 1A-D). The diameters of the three aortic segments varied in each species, being widest in the ascending thoracic aorta with a progressive decrease towards the abdominal segment (Table 2).

DISCUSSION

The greater relative thickness of the medial and adventitial layers of the ascending portion of the thoracic aorta in guinea pigs and rats was related to the influence of systolic pressure [19] and the pattern of turbulent blood flow during ventricular systole [11]. The presence of a large amount of elastic lamellae with a circular and concentric arrangement in the medial aortic layer of both species also reflected the need for constant mechanical adjustments of the arterial wall to variations in ventricular systolic and diastolic pressures [14,20]. The greater number of elastic lamellae seen at the thoracic level compared to the abdominal level (see Fig. 2) has also been observed in human aorta [10], and may be related to a slight decrease in the arterial aortic pressure in the abdominal segment [6].

This conclusion is supported by similar morphological findings in the medial aortic layer structure of the rat [2], dwarf pig [17] and rabbit [19].

Table 2. Mean values of elastic lamellae and fibers number and diameters of the aortic medial layer in the guinea pig and rat.

Aorta Segment	Guinea pig		Rat	
	nº elastic lamellae	diameter	nº elastic lamellae	diameter
ascending	29.31 ± 0.96	2.0 ± 0.22	11.84 ± 0.74	1.6 ± 0.32
thoracic	15.53 ± 0.84	1.5 ± 0.09	8.78 ± 0.6	1.4 ± 0.15
abdominal	7.87 ± 0.93	1.1 ± 0.05	7.0 ± 0.93	1.2 ± 0.12

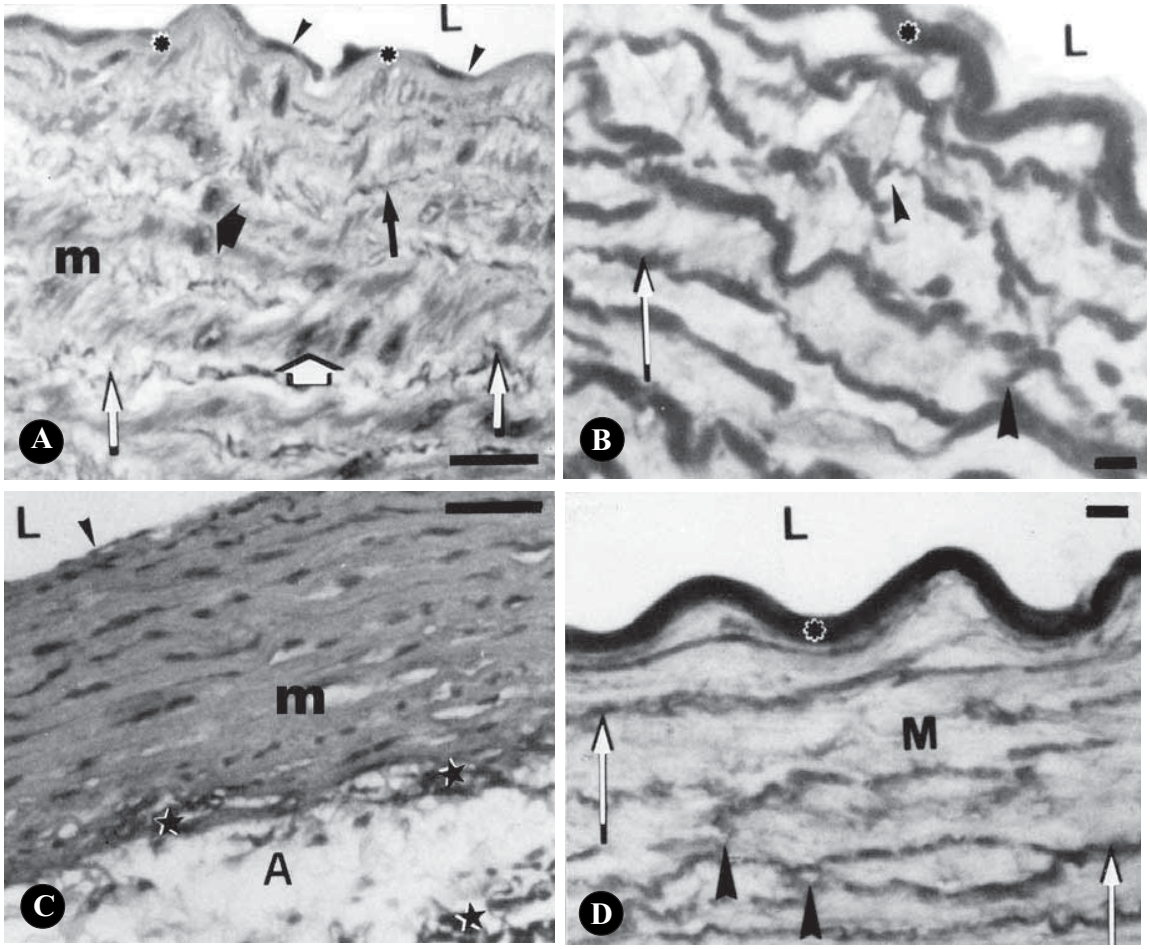

Figure 1. Architecture of the aortic wall in guinea-pig (panels A,B and C) and rat (panel D). **A.** Ascending thoracic aorta guinea-pig; Masson's trichrome. Bar = 12 µm. **B.** Ascending thoracic aorta guinea-pig: Calleja's stain. Bar = 5'µm. **C.** Ascending thoracic aorta, rat; Masson's trichrome. Bar = 12 µm. **D.** Abdominal aorta, guinea-pig; Calleja's stain. Bar = 5'µm. The structures seen in these sections include the vascular lumen (**L**), endothelium (**small arrowhead**), internal elastic lamina (*), medial layer (**M**), elastic fiber trabeculae (**large arrowheads**), elastic lamellae (**long arrows**), smooth muscle cells (**M**), adventitial layer (**A**).

In dwarf pigs, the abdominal aortic segment contains a transitional structure consisting of a mixed myostromal pattern [17].

The decrease in the number of elastic lamellae in the abdominal aortic segment, and the relative decrease in the aortic diameter at this level, further support a reduction in mural elastic resistance. In human aorta, these changes contribute to the relatively higher incidence of abdominal aortic aneurysms [10].

Intimal folds in the aortic wall endothelium were seen in guinea pigs and rats by SEM [15,18,19]. Such folds in large vessels may serve as a functional reserve to allow the intimal layer to accommodate increases in the luminal circumference of the vascular wall [15,18,20]. Indeed such folding has been considered to be a consequence of "a slight contraction of smooth muscle cells" [1] which form the vascular wall [13]. These intimal folds may also be technical artefacts formed during tissue fixation [14].

The "myostromal system" or myofibrous pattern involving smooth muscle cells, elastic lamellae and collagen fibers intermingled in the medial layer of the aortic structure, seen here, has also been observed in other mammals [2,3,5,13,17,19,20]. The interrelations of the myostromal elements may guarantee the modulation of smooth muscle tonus and contractility [3,5]. The vascular myofibrous system may contribute to the viscoelasticity of the arterial wall, which also depends on hemodynamic factors involved in vascular blood flow [16].

A typical network of interconnected collagen and elastic fibers, was noted in the adventitial aortic layer of guinea pigs and rats, as also described for rabbit [19], and dog [7]. The adventitial connections between the fibrous elements and their different spatial orientations contribute to the health of the vascular wall [7].

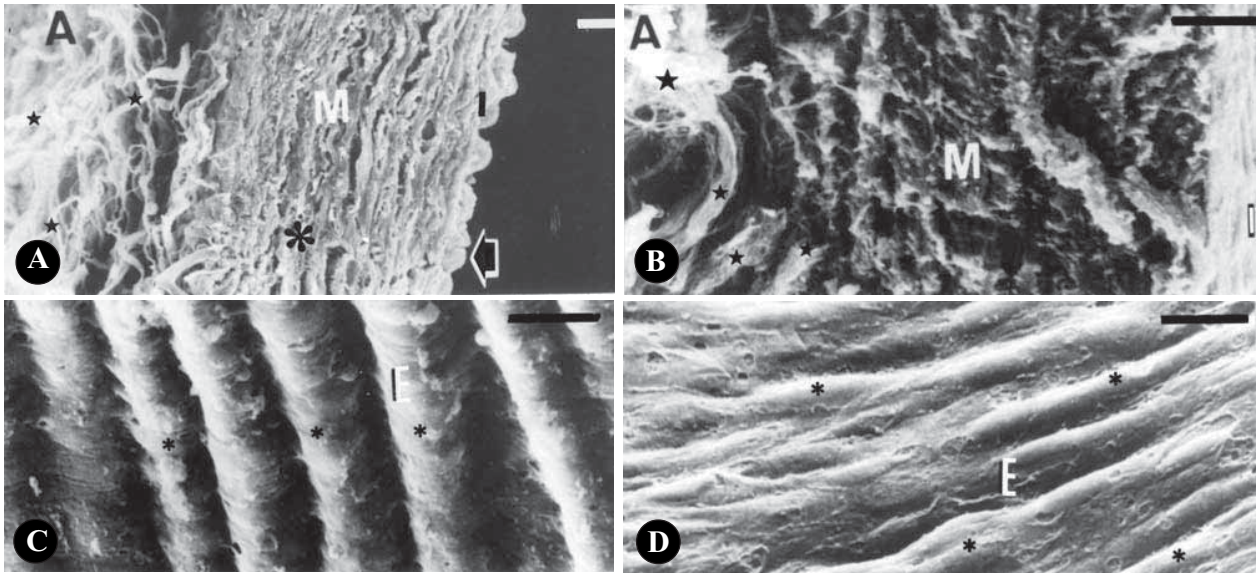

Figure 2. SEM of the aortic wall in rat (panel A) and guinea pig (panels B,C and D). **A.** Descending thoracic aorta, rat. Bar = 7 µm. **B.** Abdominal aorta, guinea pig. Bar = 14 µm. **C.** Intimal layer of the ascending thoracic aorta seen from the endothelical surface, guinea pig. Bar 15 µm. **D.** Intimal layer of the abdominal aorta, guinea pig. Bar = 14 µm. In A and B, note the intimal layer (**I**) with longitudinal folds (**arrows** in panel A), the medial layer (**M**) with the homogenous appearance of its myostromal components, and the adventitial layer (**A**) in panels A and B) with its intermingled fibrous components (**stars**). In panels C and D, longitudinal folds (**asterisks**) are seen on the surface of the endothelium (**E**), particularly in the thoracic region (panel C).

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