The Vasa Vasorum in the Abdominal Aorta of the Dog

Normal Aorta and
Aorta with Surgically Created Artificial Stenosis

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ABSTRACT

The authors studied the distribution of the vasa vasorum in the abdominal aorta of the normal dog and following surgically created aortic stenosis. Twelve dogs with normal aorta and 6 dogs with surgically created stenosis in the abdominal aorta were used. The dogs with aortic stenosis were sacrificed at two, four, and six weeks after creation of the stenoses. The vasa vasorum network was evaluated by the Spalteholz technique, microangiography, histology and scanning electronic microscopy (SEM).

In the normal aorta there is in the adventitia a network of vessels from which arise arterioles that extend up to the outer third of the media. At the stenotic zone there is interruption of the vasa vasorum and proliferation on each side of the stenosis up to 5 mm.

The authors conclude that the effect of revascularization techniques on vasa vasorum of surgically created stenosis should be analyzed at least 5 mm away from the stenosis.
Introduction

Vasa vasorum are the small vessels that supply the walls of large arteries and veins with blood. In different species as the intimal thickness of the aorta exceeds 0.5 mm, "critical depth," nourishment of the outer layers is supplemented by vasa vasorum. The intima and inner two thirds of the media are avascular and thus nourished from the lumen of the vessels by diffusion of nutrients.2

The first observation of the vasa vasorum is attributed to Willis in 1757.3 The distribution and origin of the vasa vasorum has been studied by several authors using different methods.4-8 The vasa vasorum of the aorta of the dog have been investigated previously; however, the arterial network in the media has not been described in detail.7-10

Damage to the vasa vasorum can occur following percutaneous transluminal angioplasty (PTA).11 The increased use of PTA and of arterial stents stimulated us to reexamine the distribution of the vasa vasorum of the normal aorta of the dog and the changes after an artificially created stenosis by use of chromic catgut suture. Our purpose was to obtain anatomic baseline information to be used for further studies regarding changes that might happen after PTA and stent placement. The animals were sacrificed at various times in order to determine at which time the chromic catgut suture becomes reabsorbed and therefore the best time for attempting endoluminal techniques on these experimental stenoses.

The experimental dog model has been chosen because of its anatomic similarities with the human abdominal aorta. Microangiography, histology, scanning electronic microscopy (SEM), and the clearing technique of Spalteholz were used to study these changes as completely as possible and to determine whether any of these single techniques could provide adequate information by itself.12

Materials and Methods

The vascularity of the abdominal aorta wall of the dog was studied in 18 dogs of both sexes, weighing 13–21 kg, 12 of them with normal aorta and 6 dogs with experimental stenoses. Under general anesthesia with sodium pentobarbital (30 mg/kg) a midline laparotomy was performed to create a stenosis in the abdominal aorta, above the bifurcation. The stenoses were created by placing a 3/0 resorbable chromic catgut suture that was passed twice around the aorta. To achieve uniform tension in the suture, a piece of 10F Teflon tubing was placed alongside the aorta, inside the suture before, the suture was tied, and then it was removed after the suture was tied.

Dogs with stenotic aorta were sacrificed in groups of 2 at different times at weeks 2, 4 and 6 following creation of the stenosis. Before sacrifice an abdominal angiogram was obtained in order to evaluate diameter at the level of the stenosis, which was usually 3.5 mm (Figure 1).

After heparinization and complete exanguination, the aorta was flushed with normal saline solution at 37°C under 100 mmHg controlled pressure until clear saline was obtained.

Figure 1. Abdominal angiography of aorta of a dog with experimentally created stenosis.
At that time, the aorta was opacified with a mixture of Micropaque and pink-colored gelatin at 100 mmHg pressure, at 37°C.

Transverse sections were taken for histology, microangiography, and SEM. For microangiography we performed sections of 250 to 300 microns that were mounted between two films of Styrofoam and placed between two glass slides held together by an elastic band for twenty-four hours. After removal of the glass slides in the dark room, the specimen in its mount was laid on a photographic plate and the whole put into a box and x-rayed.

For Spalteholz technique the remainder of the specimen was dehydrated with increasing concentration of ethanol at 60°, 80° and 100°C for each concentration for twenty-four hours. Then the specimens were placed in acetone for forty-eight hours and afterward in a mixture of benzyl benzoate and methyl salicylate in equal parts and cleared according to Spalteholz technique in order to obtain good transparency including air evacuation. The tissue preparations were mounted between glass slides, again evacuated, and observed three dimensionally in reflected light.

**Results**

The caliber of the normal abdominal aorta was between 8 and 12 mm, average 10.2, and at the level of the stenosis was 3.5 mm.

Vasa vasorum were better shown with Spalteholz technique because they could be observed three dimensionally in reflected light, although they were also well seen with microangiography.

We considered separately the normal aorta and the stenotic aorta.

**Normal Aorta**

The vasa vasorum arise just distal to the origin of the lumbar arteries. By SEM and Spalteholz technique we demonstrated that at its origin the main branch has a caliber of 0.35 mm and a length of 4 mm and is situated in the connective tissue of the peripheral adventitia of the aorta. It courses laterally to the flanks of the aorta. The trunk divides in dichotomous fashion in two secondary branches that course superiorly and inferiorly parallel to the axis of the aorta. These secondary vessels measure approximately 0.15 mm and they establish anastomoses with the opposite side, as well as upper and lower ones. Thus, a polygonal network whose branches measure 0.2 to 0.1 mm is formed in the adventitia (Figure 2). In cross-section, we found that from the inner surface of that plexus, arterioles with a caliber between 0.1 and 0.03 mm arise. These arterioles reach the outer third of the media of the aorta and form an incomplete circle we call the “arterioles in arch” (Figures 3, 4). From the inner surface of these arterioles originate precapillary arterioles whose caliber is 0.03 to 0.01 mm and that are situated in the junction of the external and middle third of
the media. This pattern was present in all the specimens from normal aorta.

Stenotic Aorta

By the sixth week the chromic catgut suture had been reabsorbed in each case. At the site of the stenosis were intimal hyperplasia, hypertrophy of the media, and rupture of the elastic lamellae fibers, and these were better shown with histology and SEM. The intimal hyperplasia and hypertrophy of the media increased up to four weeks and they remained the same at six weeks.

At the stenotic zone there was complete interruption of the adventitia of vasa vasorum (Figure 5). The vasa vasorum in the outer media "arterioles in arch" and precapillary arterioles did not show any change in comparison with normal nonstenotic aorta. Just above and below the stenosis there was proliferation of the vasa vasorum and a large number of vessels forming a network on each side of the stenosis. The degree of proliferation of vasa vasorum increased from two to four weeks, and at six weeks the proliferation remained the same in every specimen. Anastomoses could be shown between the networks on each side of the stenosis, some of them forming bridges over the stenoses (Figure 5). Five millimeters from the stenotic zone the vascular pattern of the wall was completely normal.
At the site of the stenosis were intimal hyperplasia, medial thickening, elastic lamellae fibers, and muscle cells’ rupture.

**Discussion**

Since the dog is an experimental model often used in revascularization procedures it is useful to know the distribution of the vasa vasorum in the normal abdominal aorta and the changes caused by the creation of stenoses.

Nylander et al observed that vasa vasorum lie in line with the long axis of the aorta and branch at oblique angles, forming rhomboid forms with their long axis parallel with the axis of the aorta. They found this pattern down to the middle third of the media.\(^9,10\) We had similar findings in the distribution of the vasa vasorum in the normal aorta.

The animals were sacrificed at different times in order to know at which time the chromic catgut suture has been reabsorbed and lost its strength and therefore the best time for revascularization techniques on experimental stenosis.

The changes in the vasa vasorum following experimentally created stenoses with chromic suture have not been previously reported. The interruption of the vasa vasorum at the level of the stenosis was due to suture ligation. The blood
flow decrease in the vasa vasorum and the resulting hypoxia may have stimulated neovasorum formation on each side of the stenosis and may explain the proliferation we observed. Although the distribution of the vasa vasorum in abdominal aorta of the dog has been previously described, certain characteristics have not yet been described. In particular the arterial network in the media has not been discussed in detail. In transverse sections we observed arterioles that form an incomplete arch in the junction of the outer and middle third of the media from which arise precapillary arterioles with a caliber of 0.03 to 0.01 mm situated in the junction of the external and middle third of the media. It is reasonable to presume that it is in these small vessels that the main vascular changes following interventional procedures occur.

**Conclusion**

There are incomplete arches of arterioles in the outer third of the media from which arise precapillary arterioles. The chromic catgut suture becomes reabsorbed at six weeks, and therefore, the experimental endoluminal revascularization procedures should be performed only after that time. At the level of the stenoses there is interruption of the normal vasa vasorum network and proliferation on each side of the stenoses. The proliferation increased up to four weeks and remained thereafter. Since the vascular pattern of the wall of the artery is normal 5 mm from the stenosis, the effect of PTA or stenting should be analyzed at least 5 mm away from the stenosis.

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**References**