Rupture of vasa vasorum and intramural hematoma of the aorta: a changing paradigm

Ruptura dos *vasa vasorum* e hematoma intramural da aorta: um paradigma em mudança

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Abstract

Rupture of *vasa varorum* has been recognized as one cause of intramural hematoma of the aorta for 90 years. This brief revision presents systematically, the physiology of these vessels and its role in the physiopathology of the alterations in the aortic wall secondary to hypertension, arteriosclerosis and in Acute Aortic Syndrome. The hypothesis is that rupture of *vasa vasorum* is a secondary phenomenon and not one causal factor in the physiopathology of intramural hematoma.

Keywords: Aortic intramural hematoma, vasa vasorum, aortic dissection.

Resumo

A ruptura dos *vasa vasorum* tem sido reconhecida como uma das causas do hematoma intramural da aorta há 90 anos. Esta breve revisão apresenta sistematicamente a fisiologia desses vasos e o seu papel na fisiopatologia das alterações parietais da aorta que ocorrem na hipertensão arterial, na arteriosclerose e na síndrome aórtica aguda. A hipótese defendida aqui é a de que a ruptura dos *vasa vasorum* ocorre como um fenômeno secundário e não como um dos fatores causais na fisiopatologia do hematoma intramural.

Palavras-chave: Hematoma intramural da aorta, *vasa vasorum*, dissecção da aorta.

Introduction

Vasa vasorum (VV) are small arteries which penetrate the arterial wall both through the luminal surface (vasa vasorum internae) and the adventitia (vasa vasorum externae). Adventitial VV ramify into smaller vessels supplying the outer media layers. Venous VV are more numerous and also supply mainly the outer media. In humans, arteries containing less than 29 cellular layers or less than 0.5 mm diameter do not present VV.[1,2]

Thanks to microcomputerized tomography, tridimensional study of these vessels became possible,[3,4] as well as microarteriography have enabled a more thorough understanding of their anatomy and distribution[5] through the injection of a silicone polymer (Microfil®, Flow Tech, U.S.).

VV seem to play a fundamental role in the physiopathology of the three acute aortic syndrome entities: aortic dissection, intramural hematoma (IMH), and penetrating ulcer.

VV reactivity

Anatomically VV are characterized by the presence of endothelial cells, smooth muscle cells and by being externally covered with connective tissue. These features are similar to those encountered in small coronary arteries, indicating that VV can regulate their own tone and consequently arterial wall perfusion.[6-8] Isolated porcine aortic VV responded to endothelium-dependent vasodilator substance P and to bradykinin similarly to the native artery, confirming the afore mentioned autoregulating aspect.[9,10]

VV hemodynamics

VV's anatomic localization and ramification characteristics prevent the blood flow from reaching the inner media due to the compressive stress inside the arterial wall, as described by the Lamé's formula (Figure 1). This formula indicates that the compression stress in the arterial wall's

interior equals the luminal pressure in subendothelial region, but decreases toward the adventitia.

Consequently, no wall perfusion may occur near the artery's lumen in the wall's site where tissue pressure exceeds vasa vasorum's pressure (determined mainly by pressure drop throughout the vasa vasorum, as described in Poiseulle's law).[11]

Flow resistance in the VV is high because its radius is considerably smaller than arterial lumen, especially in large arteries as the aorta. In the inner media the compression stresses are higher than VV's luminal pressure. However, these comments are related to a static condition, without considering the dynamics of systole and diastole. Systolic impulsion in the VV progresses throughout its rami and reaches the terminal rami with some delay if compared to the systolic pressure inside the native artery. Therefore, perfusion may be slightly higher than expected in a static state.[11]

Adventitial VV are connected through a plexus, but behave as terminal arteries; VV's microembolization reduces the density of these vessels in that point and increases the number of ramifications in areas of low blood suppliance.[11] This characteristic may impact on spatial distribution of perfusion and arterial wall drainage. The fact that the highest concentration of atheroma plaques in the several arterial segments coincides anatomically with lower perfusion by the VV may be a direct evidence of the role these vessels play in atherosclerotic disease.[1,2,11]

The reason for pulmonary arteries and veins not developing atherosclerosis may be related to the decreased flow of solutes toward the wall's interior due to the lower intraluminal pressure. In these vessels, the VV are not compressed during the whole cardiac cycle, keeping the media's perfusion stable. On the other hand, VV plexus in large veins is more numerous than in arteries because, contrarily to what happens in the latter, transendothelial diffusion from the lumen does not supply the inner media with oxygen and nutrients.[11]
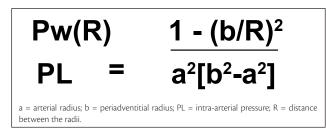
$$\frac{Pw(R)}{PL} = \frac{1 - (b/R)^2}{a^2[b^2-a^2]}$$

a = arterial radius; b = periadventitial radius; PL = intra-arterial pressure; R = distance between the radii.

Figure 1 - Lamé's formula. Compression stress in inner arterial wall equals the luminal pressure in the subendothelial region[5]

Interestingly, VV in humans are less numerous in abdominal aorta and is probably one reason for a greater chance in developing aneurysms. In other species, like dogs, VV are numerous in the abdominal aorta; characteristically, they do not develop aneurysms.[12]

Vasa vasorum and aortic dissection

For more than 4 decades it has been known that adventitia excision and, consequently, that of VV, leads to ischemia of the outer media.[13] In 2000, Angouras et al.[14] published a neat study in swine submitted to adventitia excision associated to intercostal ligature. After adventitia excision, the aorta was wrapped in non-porous material (polyvinyl chloride) to prevent periaortic fibrosis and neovascularization. After 15 days the pigs were sacrificed, and the material was sent to microscopy and in vitro mechanical analysis. VV flow interruption resulted in ischemic necrosis of the outer media, with complete loss of smooth muscle cells and elastin and collagen fibers' architecture. In several sections, features of wall dissection were present. In vitro mechanical analysis evidenced arterial wall stiffening, which was, in some specimens, four times higher than in control animals.

Hypertension, the chief condition associated with dissection, is accompanied by hypertrophy and hyperplasia of smooth muscle cells and increase in oxygen consumption. Chronic hypertension is associated with VV occlusion and neovascularization, increased arterial thickness and accelerated atherosclerosis. In hypertensive crisis, ischemia of the media may be aggravated by VV constriction. The inner media remains nourished by diffusion from the arterial lumen.[15-22] These factors result in two regions with distinct characteristics in the media: a more elastic inner region and a stiffer outer region. Due to the differences in the two regions' elastic moduli, an increased shear stress occurs in this interface.

Vasa vasorum and intramural hematoma

IMH is the cause of 5-20% cases of acute aortic syndrome.[23-25] The relation between VV rupture and intramural hematoma was first established in 1920 by Krukenberg et al.;[26] since then, IMH has been accepted as a possible cause. IMH is by definition distinguished from acute dissection and hematoma secondary to penetrating ulcer due to the absence of an intimal rupture site. IMH without penetrating ulcer is usually more extensive, sometimes impairing the ascending aorta,

arch and descending aorta. Most publications accept this cause-effect relationship between VV rupture and HI, but evidence is scarce, as observed by Sundt[27] in a recent literature review. It seems difficult to explain how these small vessels with low intraluminal pressure may dissect big portions of the aorta and often lead to arterial wall rupture. This mechanism also does not explain why in penetrating ulcer the hematoma tends to be more restricted even when there is a direct communication between the lumen and the media. On the other hand, Park et al.[28] have observed a 73% frequency of intimal rupture in patients with type A IMH (ascending aorta) who had been submitted to surgery with no preoperative defect detected by tomography. In other words, more than 70% of type A IMH patients were erroneously diagnosed, once intimal rupture was present.

In 2008, Grimm et al.[29] suggested that small atheroma plaques was another mechanism for IMH development, affecting the whole thoracic aorta in eight of their treated patients; the authors related the plaques position with the greater or lesser extension of the lesion.

Despite the huge advances in imaging technology, as 128-multidetector computed tomography, IMH diagnosis is still controversial, since it is necessary to demonstrate the absence of intimal rupture to perform this diagnosis. In this context, the quality of the images is crucial. Distinguishing acute dissection with thrombosis of the false lumen from IMH is difficult, some authors prefer to define the lesion as dissection without reentry orifice.[30-32]

Discussion on pathophysiological causes of IMH may seem more philosophical than actually helpful for clinical practice, as stated by Reuthebuch,[33] since most cases of type A IMH would be treated by open surgery, and type B IMH, observed with clinical treatment. Knowledge about pathophysiological mechanisms involved in the IMH genesis is notwithstanding desirable and may imply a change in some paradigms in prognosis and treatment in an age of rapid advances of methods and images.

Conclusions

As already established, IMH occurs in older patients, generally hypertensive. Complex structural and metabolic alterations of the aortic wall related with ischemia of the media are a substratum for the division of layers of this tunica, as observed above. VV rupture is probably a secondary phenomenon and occurs in other arterial territories, not accompanied by arterial wall lamination. Lower blood supply by the VV is probably involved in the pathophysiology of the three entities of acute aortic syndrome, but its importance in each of them is yet to be defined.

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