Structural Features of the Sinus of Valsalva and the Proximal Portion of the Coronary Arteries: Their Relevance to Retrograde Aortocoronary Dissection
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Introduction and objectives. Retrograde aortocoronary dissection is an unusual complication of coronary angioplasty. Our study provides new structural details of the aortic sinuses and the proximal portions of the coronary arteries, which enable better understanding of several clinical features associated with this complication.

Methods. We studied eight aortic sinus specimens from patients with structural ischemic heart disease using dissection, histologic analysis, and scanning electron microscopy, and compared findings with those in eight control specimens.

Results. We observed the following features: a) in 10 specimens (71%), the left coronary artery diameter was greater than the right; b) the angle that the ascending aorta made with the left coronary artery was acute, whereas that with the right coronary artery was closer to a right angle, thereby possibly providing a better approach for catheterization; c) in contrast to those of the right coronary artery, the pericostial wall and sinotubular junction of the left coronary artery were formed by more smooth muscle cells and by a dense matrix of collagen type-I fibers; and d) the aortic sinuses and coronary arteries in structural ischemic heart disease specimens displayed structural alterations that affected the aortic tunica media and the collagen distribution at the sinotubular junction.

Conclusions. The morphological and structural differences observed between right and left sides suggest that the left aortic sinus is more resistant to traction and is, therefore, less prone to iatrogenic dissection. Structural ischemic heart disease is a risk factor that increases the likelihood of aortocoronary dissection.

Key words: Aortocoronary dissection. Aortic sinuses. Ischemic heart disease. PTCA.

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INTRODUCTION

Aortic dissection is an unusual complication of percutaneous transluminal coronary angioplasty (PTCA). Most cases described in the literature occurred after interventions addressing the right coronary artery and, very rarely, after left coronary artery catheterization. This complication is potentially serious and can lead to acute myocardial infarction or sudden cardiac death.

Using dissection and histological sections, we studied the course and morphological and structural characteristics of the coronary sinuses and the proximal part of the left and right coronary arteries in post-mortem specimens with and without structural ischemic heart disease, with the aim of studying the mechanisms and factors that can make the left coronary artery less prone to retrograde dissection than the right during PTCA.

METHODS

We studied 16 post-mortem hearts that had been previously fixed by immersing them in 10% buffered neutral formalin, while avoiding doing this under pressure via the coronary arteries as this could have distorted them and led to the samples becoming distorted. The causes of death were associated with: road traffic accident (n=6), cirrhosis of the liver (n=2), suicide (n=3), cerebral hemorrhage (n=3), and pulmonary thromboembolism (n=2). In total, 8 of the 16 specimens presented structural ischemic heart disease with stenosis of the right and left coronary arteries due to atherosclerosis. There were 10 male and 6 female patients, 30-78 years old (mean ± standard deviation, 55±9 years). The weight of the hearts ranged between 332 and 450 g (380±22 g); the diameters of the left and right coronary artery ostia presented structural ischemic heart disease with stenosis of the right and left coronary arteries due to atherosclerosis. There were 10 male and 6 female patients, 30-78 years old (mean ± standard deviation, 55±9 years). The weight of the hearts ranged between 332 and 450 g (380±22 g); the diameters of the left and right coronary artery ostia (16 samples in the right coronary artery and 14 in the left) and their proximal course. Using a goniometer, we measured, macroscopically or in the histological sections, the angle between the coronary artery ostium and the proximal part of the right and left coronary artery and the aortic wall. Following this, the histological sections were made via sectioning the ascending aorta horizontally 1.5 cm above the sinotubular junction. Afterwards, the aorta was sectioned again lengthwise through the non-coronary sinus to allow easier examination of the coronary orifices. The sinuses of Valsalva, including the proximal part of the coronary arteries, were resected and processed to create histological sections. Two blocks were made from each heart, approximately 7 mm thick, which were dehydrated in graded alcohol, embedded in paraffin, and sectioned consecutively at 10 μm in the frontal plane. The sections were stained at 60 μm intervals using Masson trichrome and picrosiris red F3BA (Gurr, United Kingdom) protocols at 1% dilution. Using a polarized light microscope, the collagen fibers were stained with picrosiris red present birefringence, indicating the presence of submicroscopic units oriented along the fiber axis. These subunits are made up of type I and II collagen. Type I is strongly birefringent, with colors ranging from yellow to red; on the other hand, type III collagen is less refringent and appears green.

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RESULTS

Morphology of the Aortocoronary Junction and Its Proximal Tract

All the hearts studied had 3 aortic leaflets and the coronary arteries originated in the corresponding sinuses of Valsalva (Figure 1). Aortic sinus diameters were 3.7±0.3 cm (range, 2.6-4.2 cm). The right coronary artery ostium (12 hearts, 75%) and the left (12 hearts, 85%) were located below the sinotubular junction. There were significant differences between the diameters of the left and right coronary artery ostia (1% dilution). Using dissection and optical microscopy techniques, all the specimens showed that the ostium and the first 2-3 mm of the coronary arteries were located in the wall of the ascending aorta or the aortic sinus. From here, the initial extraaortic part

ABREVIATIONS

PTCA: percutaneous transluminal coronary angioplasty.

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López-Minguez et al. Structure of the Sinus of Valsalva: Relevance to Aortocoronary Dissection

697
(approximately 2 cm) of the left coronary artery descends parallel to the ascending aorta and forms, with the aortic sinus wall, an angle of 35.5°±11.5° (range, 20°-55°), to course between the pulmonary trunk and the left atrial appendage (Figure 1). In contrast, the initial part of the right coronary artery originates almost perpendicular to the aortic sinus wall forming an angle of 71.5°±8.5° (range, 60°-88°), and passes in front of and slightly to the right of the right atrium, lying between this and the trunk of the pulmonary artery (Figure 1). As it approaches the atrioventricular groove, the right coronary artery descends almost vertically.

Histological and Structural Study of the Coronary Artery Ostia and the Aortic Wall

Using conventional, polarized light and scanning electron microscopy, histological examination showed that the walls of the sinuses of Valsalva are basically made up of type I collagen in their lower part proximal to where the aortic leaflets attach, where muscle fibers insert into the left ventricle (Figure 2); however, the number of type I collagen fibers decrease as the elastic fibers in the ascending part of the aortic sinuses increase (Figure 2). The aortic wall thickness was 1.8±0.3 mm (range, 1.1-2.4 mm) in the medial portion of each sinus, both in the normal hearts and in those presenting structural ischemic cardiopathy. However, the sinuses where structural ischemic cardiopathy was found presented non-uniform variations in thickness of the elastic lamina of the medial layer and atherosclerotic plaque, at times with hemorrhagic clotting, at the base of the leaflet attachment below its arterial wall (Figure 2).

The upper limit of each sinus at the peak of the line of the semicircular edge of each leaflet is known anatomically as the supravalvular ridge, marking the junction between the sinuses and the tubular part of the aorta. The ridge at the sinotubular junction is mainly made up of elastic and collagenous fibers mixed with smooth muscle cells and fibroblasts. The ridge in the left coronary sinus contains a greater number of smooth muscle cells within a dense extracellular matrix of type I collagenous fibers (Figure 3). In contrast, the right coronary artery has a smaller amount of smooth muscle fibers, which are basically set within type III collagen (Figure 3). The aortic wall thickness at the ridge is 4.3±0.5 mm (range, 3.6-5.1 mm), with significant differences
The periostial aortic wall in the sinotubular ridge is characterized by having a prominent tunica media between the internal elastic lamina and the adventitia. This media is predominantly made up of layers of elastic material that alternate with bundles of smooth muscle cells with differing spatial orientation and type I and III collagen fibers (Figure 3). The periostial aortic wall of the right coronary artery has less interstitial type I collagen positivity than the left among the smooth muscle fibers (Figure 3). The thickness of the aortic tunica media in this location was 2.8±0.4 mm (range, 2.1-3.5 mm). The spatial orientation of the smooth muscle cells within the tunica media that surrounds the ostium in both coronary arteries is very irregular, the longitudinal fibers being mixed with oblique ones. The presence of atherosclerotic plaque and intramural hematoma in the sinotubular ridge produces a thinning of the aortic tunica media (Figure 3), less than 1 mm thick, and its visualization via polarized light shows a non-homogeneous distribution of type I collagen within the sinotubular ridge, like layers of an onion, which decreases on the periostial aortic wall (Figure 3). In one case of progressive atherosclerosis, as found in the 72 year old specimen (Figure 4), the aortic tunica media was characterized by an absence of smooth muscle fibers, immediately above the sinotubular ridge, such that the media was made up of elastic fibers only in this region (Figure 4).

In addition to aortic disease, atherosclerotic plaque affects the most proximal segment of the coronary arteries and is accompanied by marked atrophy of the tunica media with a reduction in elastic and smooth muscle fibers, and at times ulceration, i.e., rupture of the plaque coating due to an increase in pressure promoting thrombosis and coronary obstruction. Such obstruction shows positive staining under polarized light, basically for interstitial type I collagen in the adventitia and media (Figure 4). Finally, it is worth considering the possibility that the plaque is sclerosed and calcified (Figure 4), and the percentage reduction of the lumen is relevant regarding its functional impact.
The most external layer of the aortic coronary wall is the so-called tunica adventitia, which consists of a network of fibers, basically type I collagen, elastic fibers, adipocytes and macrophages (Figures 1 and 2). No visible alterations in this layer were found in the atherosclerotic arteries studied. The vasa vasorum is normally located in the adventitia, where nerve bundles are also found. The thickness of the tunica adventitia in the aortic wall is 1.2±0.4 mm (range, 0.5-1.8 mm). The aortic tunica adventitia is continuous with the adventitia of both coronary arteries.

**DISCUSSION**

Although the risk of retrogressive dissection in the ascending aorta during PTCA is rare, and that this technique is currently very common and the number of cases has increased, the number of times this serious complication occurs continues to be low. The incidence (0.029%) in our hospital is similar to that in other hospitals, ranging from 0.02 to 0.15%, with an average of 0.059%.1,5,8,9 The mechanism by which dissection of the right coronary artery (87% of cases)
those obtained by Muriago et al., the sinotubular junction. These results are similar to 85% of the left coronary artery ostia are located below histological and structural study done shows that, of tensile strength, type I collagen, in contrast to type III, has greater collagen, and its periostial wall also has greater smooth muscle cells set in large amounts of type I sinuses increase; however, higher up, in the elastic fibers in the ascending part of the aortic walls of the right and left sinuses of Valsalva have periostial wall of the left coronary artery are different as the elastic fibers in the ascending part of the coronary arteries, mainly type I collagen fibers proximal to where the sinuses of Valsalva have mainly type I collagen fibers proximal to where the aortic leaflets attach, these fibers decrease in number as the elastic fibers in the ascending part of the aortic sinuses increase; however, higher up, in the sinotubular ridge, the left has a greater number of smooth muscle cells set in large amounts of type I collagen, and its periostial wall also has greater expression of type I collagen. It is well-known that type I collagen, in contrast to type III, has greater tensile strength, which could mean that the right coronary artery ostium is less resistant to traction and, as a result, could more easily give rise to retrogressive aortic dissection as a complication of coronary intervention. We have also found structural differences between the normal coronary sinuses and sinotubular junction regarding the specimens with structural heart disease due to myocardial ischemia, which could be a risk factor for increased predisposition to aortocoronary dissection; however, these differences were not found when comparing the atherosclerotic right coronary artery with the left, which indicates that the pathogenesis of the atherosclerotic plaque should be thought of as a set of noxious conditions able to cause endothelial damage, regardless of whether the aortocoronary junction is the right or left although, as stated by Zamir and Sinclair, it is the aortocoronary junction which is compromised more often. Although one specimen varies from another, the atherosclerotic lesion penetrates the internal elastic lamina and not only affects the distribution of the sinotubular union type I collagen, but there is also thinning of the smooth muscle fibers of the aortic tunica media. In more severe cases, the weakness of the wall occurs in a 1 or 2 mm longitudinal section in the tunica media, where the smooth muscle fibers are replaced by elastic fibers. Aortic weakness in atherosclerotic disease could be a preexisting factor that may play a role in iatrogenic dissection in the face of aggressive interventions such as mechanical traction or contrast-agent injection, as done during PTCA. Another potential risk factor is the presence of total or partial coroinal occlusion in its proximal part, as found in some of the specimens, which possibly plays a role radically different to that of degeneration of the aortic tunica media, since percutaneous recanalization is much more complex and requires more aggressive maneuvers than other types of stenosis.

CONCLUSIONS

Our study demonstrates structural differences between the aortic sinuses and the proximal part of the right and left coronary arteries. These differences indicate that the left aortic sinus is more resistant to traction and mechanical pressure than the right and, thus, is less prone to iatrogenic dissection. Atherosclerotic lesions that compromise the aortocoronary junction are a risk factor that increases predisposition to dissection and should be taken into account during PTCA.

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