Structural Features of the Sinus of Valsalva and the Proximal Portion of the Coronary Arteries: Their Relevance to Retrograde Aortocoronary Dissection

José R. López-Minguez,* Vicente Climent,* Siew Yen-Ho,* Reyes González-Fernández,* Juan M. Nogales-Asensio,* and Damián Sánchez-Quintana*  
*Sección de Hemodinámica y Cardiología Intervencionista, Servicio de Cardiología, Hospital Universitario Infanta Cristina, Badajoz, Spain.  
*Departamento de Anatomía Humana, Facultad de Medicina, Universidad de Extremadura, Badajoz, Spain.  
*National Heart and Lung Institute, Imperial College and Royal Brompton and Harefield NHS Trust, London, United Kingdom.

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 peristomal 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.
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 distended 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 ostium (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 ostium of origin 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 picrosirius red F3BA (Gurr, United Kingdom) protocols at 1% dilution. Using a polarized light microscope, the collagen fibers stained with picrosirius 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.

The structures of the histological sections were measured using image analysis software (SigmaScanPro 5.0, Jandel Scientific, San Rafael, CA, USA). To aid in visualizing the coronary ostia architecture and the ascending aortic wall, we used a scanning electron microscope (Jeol JSM 5600) to examine the 25-30 µm histological sections that had previously been deparaffinized in xylol for 30 min, then afterwards dried at room temperature for 1 h, and covered with gold (BAL-ECT SDC 005 Sputter coater) for 4 min.

Statistical Analysis

The results are expressed as mean ± standard deviation (SD). Statistical analysis was done using the Student t test for independent samples in the case of quantitative variables. P values <0.05 were considered statistically significant.

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. The diameter of the left coronary artery ostium in 10 specimens (71%) was greater (4.5±0.4 mm) than the right coronary artery ostium (3.7±0.5 mm) (P<0.001). 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 within the wall of the ascending aorta or the aortic sinus. From here, the initial extraaortic part

ABREVIATIONS

PTCA: percutaneous transluminal coronary angioplasty.
López-Minguez et al. Structure of the Sinus of Valsalva: Relevance to Aorto-coronary Dissection

(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.
between the thickness of each sinus of Valsalva wall and the supravalvular ridge in both coronary arteries \((P<.001)\).

The peristomial 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 peristomial 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 peristomial 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 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%. The mechanism by which dissection of the right coronary artery (87% of cases)
those contributed by Cavalcanti et al.,

...those obtained by Muriago et al.,

the sinotubular junction. These results are similar to

85% of the left coronary artery ostia are located below

the 30 ostia, 75% of the right coronary artery ostia and

85% of the left coronary artery ostia are located below the

sinotubular junction. These results are similar to

those described, dissection occurs when injecting

contrast agents. Thus, these variations in angle might

play a facilitating role, together with the structural

factors, given that the sinotubular junction and the

peristomal wall of the left coronary artery are different

from those of the right. Histologically, although the

walls of the right and left 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, but there is also thinning of the

smooth muscle fibers of the aortic tunica media. 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.

REFERENCES


5. Perez-Castellano N, Garcia-Fernandez MA, Garcia EJ, Dekan JL. Dissection of the aortic sinus of Valsalva complicating
López-Minguez et al. Structure of the Sinus of Valsalva: Relevance to Aortocoronary Dissection


702 Rev Esp Cardiol. 2006;59(7):696-702