Valve-Conserving Operation for Aortic Root Aneurysm or Dissection

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A significant number of patients develop potentially life-threatening aortic regurgitation secondary to aortic wall disease in the presence of structurally normal aortic cusps. These patients are commonly treated by replacement of the aortic valve and root. We believe that, whenever possible, the "ideal" operation for these patients is a valve-sparing procedure. This belief stems from the fact that the aortic valve is an extremely sophisticated structure, best suited for its function with reference to hemodynamic performance to maintain optimal coronary flow, left ventricular function, and cardiac output under widely varying physiological and pathological conditions. In addition, all valve substitutes, particularly mechanical valves, have a significant incidence of valve-related complications, such as thrombo embolism in addition to the imperfect hemodynamic performance.

The evolution and execution of effective valve-sparing operations in these patients depends on a thorough understanding of the functional anatomy of the aortic valve as well as the pathophysiology of aortic regurgitation in aortic aneurysms and dissections.

Functional Anatomy of the Aortic Valve and Root

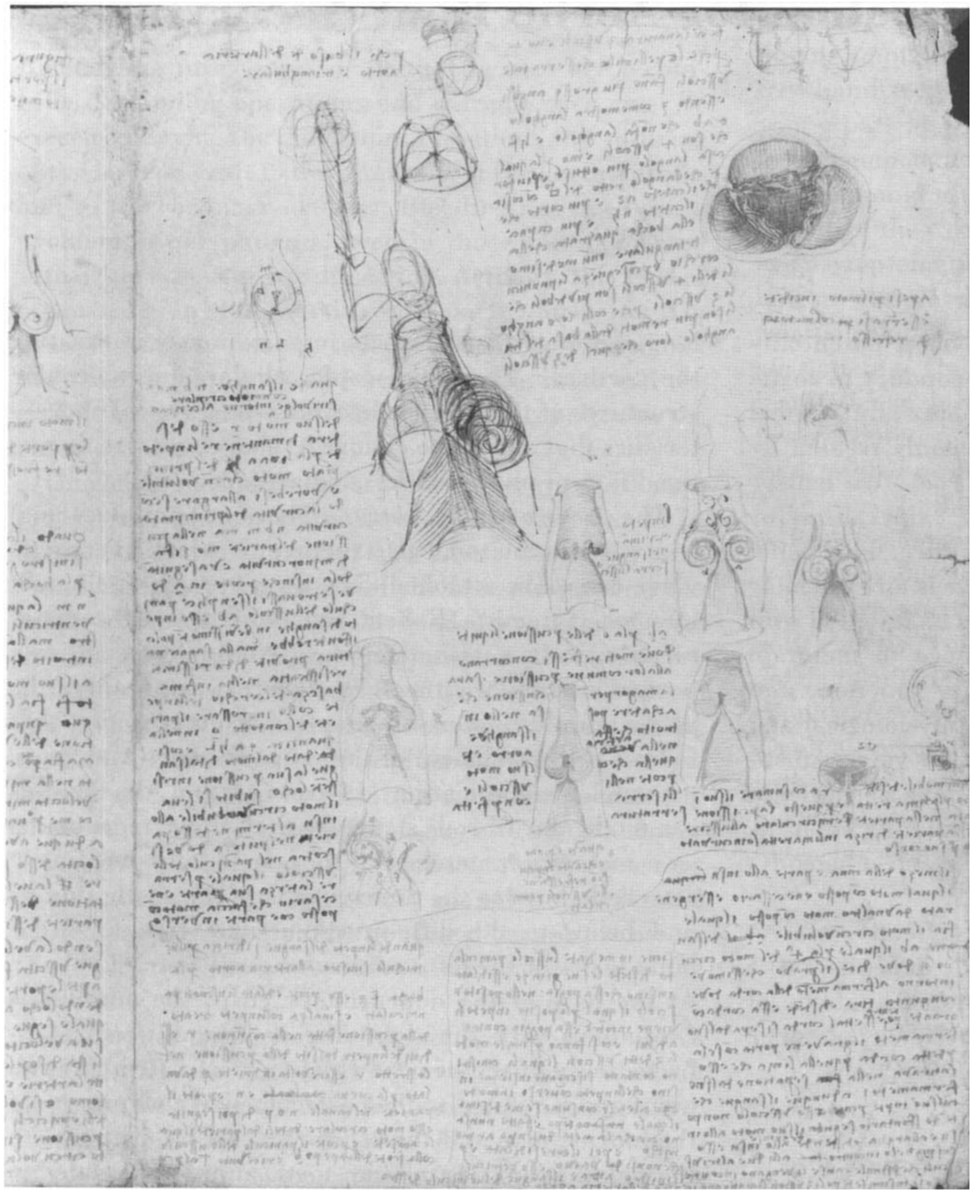
The integrated function of the aortic valve mechanism depends on the coordinated performance of its different anatomical components, which include the following:

The aortic sinuses of Valsalva. The importance of these structures in the smooth function of the aortic valve has long been recognized. Centuries ago, Leonardo Da Vinci (Fig 1) stressed in his masterly drawings the importance of the vortices created by the sinuses in stabilizing the position of the cusps during the different phases of the cardiac cycle as well as ensuring the smooth movement of the cusps with marked reduction in the mechanical stress to which the cusps are subjected. These vortices have been shown to play a critical role in valve closure with minimal regurgitation.[1] In addition, the sinuses have an important function in maintaining normal coronary flow, particularly during ventricular systole.[2] To achieve these functions, the sinuses have a very specific shape, with curvatures in both the horizontal and vertical planes, and join the ascending aorta along a line referred to as the sinotubular junction, which plays an important role in creating the vortices.[2] The microscopic cellular and molecular structures of the sinuses determine its physical characteristics that allow it to change its shape and size during the different phases of the cardiac cycle.

The aortic annulus (ring). The aortic annulus (ring) is a specific anatomical structure to which the aortic valve cusps are attached. The term annulus is thought by some anatomists (Robert Anderson, personal communication) to be a misnomer because it implies a ring or a perfectly circular structure, whereas in reality, the aortic annulus is a crown-shaped fibrous structure that follows the attachment of the cusps (Robert Anderson, personal communication). In cross-section, the annulus is a triangular fibrous structure that, apart from acting as a mooring structure for the aortic cusps, is firmly attached above to the tunica media of the aortic sinuses and below to the different structures that form the boundaries of the left ventricular outflow tract (Fig 2). At the base of the noncoronary cusp, the annulus is continuous with the right fibrous trigone (central fibrous body of the heart), which acts as a firm fixation point and is related to the posteromedial commissure of the mitral valve and the conducting tissue. Anterior to the right fibrous trigone, the aortic annulus is related to the membranous interventricular septum, which is also related to the adjoining part of the right coronary cusp. The annulus of the right coronary cusp and the adjoining part of the left coronary cusp is attached to the muscular interventricular septum and, in terms of strength, is the least developed part of the aortic annulus. The aortic annulus, in the region of the midpoint of the left coronary cusp, is attached to the left fibrous trigone, which is a firm structure but is slightly less developed than the right fibrous trigone. The remaining part of the annulus is attached to the subaortic curtain that, again, is a firm fibrous structure extending from the right to the left fibrous trigone and gives mooring to the anterior leaflet of the mitral valve.

Thus, the aortic annulus is an integral part of the fibrous framework of the heart and conceptually has played an important part in the evolution of the technique to be described in this article.

The cusps. These are thin leaflets (usually three) that consist of three components with different structure and function. The part nearest to the annulus is the



1 Among Da Vinci's many diagrams of the anatomy of the aortic valve in health and in disease, he also explored its physiology. This page of diagrams includes sketches expressing the triangular shape of the aortic aperture, the semilunar configuration of the sinuses, and the formation of the vortex of blood forming in the aortic sinus to assist in closure of the cusp. (Reprinted with permission. The Royal Collection © Her Majesty Queen Elizabeth II.)

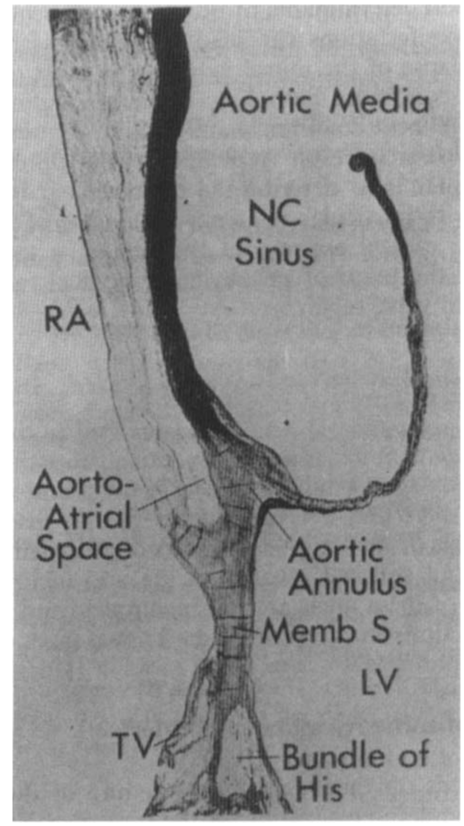
hinge and has the capacity to bend repeatedly without a "bunching" of tissues or a weakening or fracturing as a result of that particular stress. The second part of the cusp is the body, which acts as the main pressure-bearing part of the cusp, with a limited degree of distensibility, through a sliding movement of the different layers that compose that part of the valve. The third part of the cusp is the coapting surface, which, during diastole, touches the opposing part of the other leaflet when the valve is closed and is usually much thinner than the other parts of the valve. The length of the coapting surface plays an important role in guaranteeing competence of the valve under different distending or distorting conditions. It is possible that these nerve fibers may play a role in the normal function of the valve. This could have implications with regard to the choice of the repair procedure.

The commissures. These are specialized parts of the cusps and annulus that act as suspending pillars for the cusps. The commissures vary slightly in length. Their integrity orientation and tension play a crucial part in maintaining the competence of the valve.

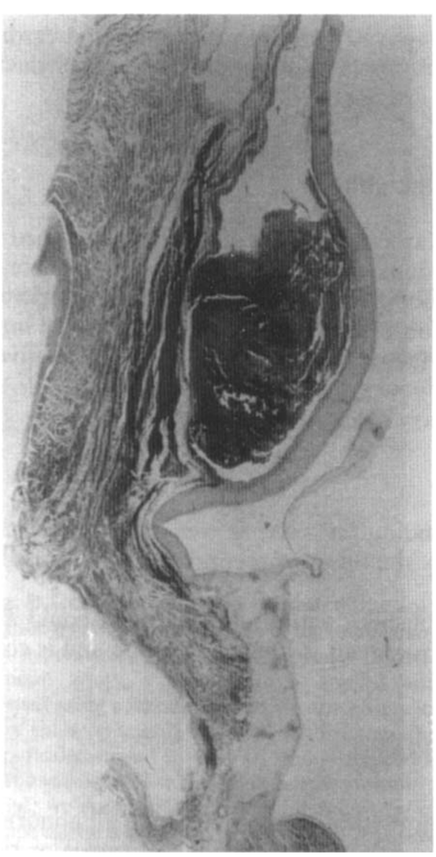
Pathophysiology of Aortic Regurgitation in Aortic Root Aneurysm and/or Dissection

An important feature of aortic regurgitation caused by aortic root aneurysm or dissection is the fact that the primary disease process is localized to the aortic wall of the sinuses and ascending aorta with complete sparing of the annulus, cusps, and commissures, which initially are structurally normal, but could undergo secondary changes if the aortic regurgitation is long-standing (neglected).

In patients with aneurysms of the root, progressive dilatation of the ascending aorta and root result in disappearance of the sinotubular junction and progressive separation of the commissures from each other with resulting failure in coaptation of the cusps.



2 Photomicrograph of a longitudinal section through the region at the anterior half of the noncoronary cusp (elastic stain) shaving the relations of the aorto-atrial space, the aortic media, and the aortic annulus. (Reprinted with permission from Yacoub, et al: Management of aortic valve incompetence in patients with Marfan syndrome. *Cardiovascular Aspects of Marfan Syndrome*, 1995, p. 72.)



3 Photomicrograph of a longitudinal section of the aortic root through the region of the noncoronary cusp from a patient with an acute dissection (hematoxylin and eosin stain). Note that the dissection extends to, but not beyond, the aortic annulus. (Reprinted with permission from Yacoub, et al: Management of aortic valve incompetence in patients with Marfan syndrome. *Cardiovascular Aspects of Marfan Syndrome*, 1995, p. 73.)

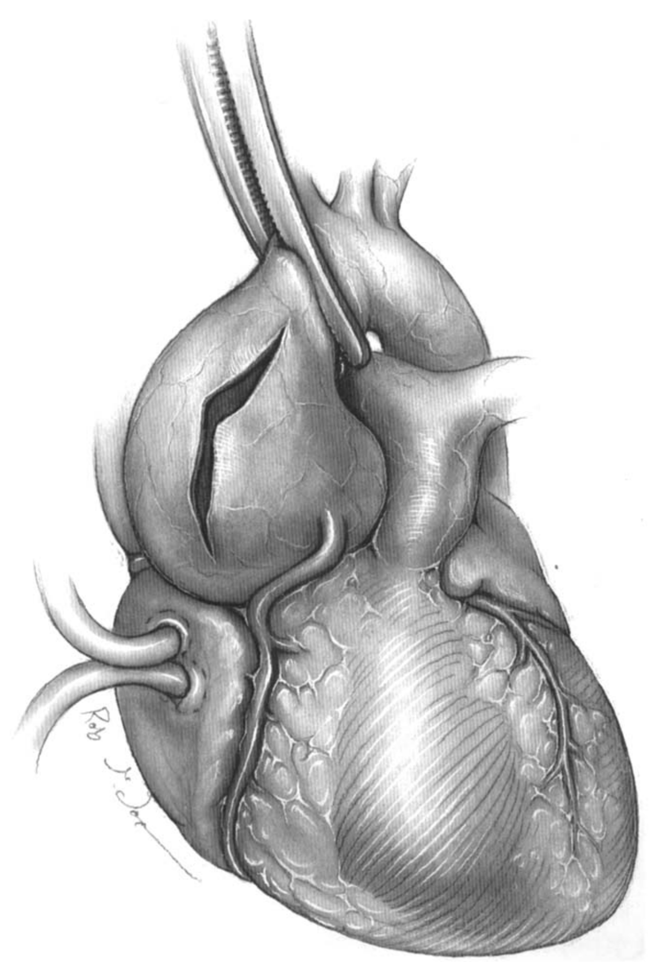
In patients with acute or chronic dissection of the aortic root, an intimal tear is usually present in the proximal ascending aorta with extension of the dissection both distally and proximally. This results in a lifting of one or more commissures, which results in prolapse of two or more cusps. One important feature of dissection of the aortic root is that it never crosses the annulus (Fig 3) into the left ventricular outflow or cusps, even where there is rupture of the dissection into the aorto atrial space, pericardium, or right atrium. All of these features render aortic regurgitation caused by aortic wall disease eminently suitable for the valve-conserving operation described in this article.

Surgical Considerations

Based on the anatomical and pathological principles described previously, a technique for preserving the aortic valve in patients with aneurysms and dissection of the aortic root was developed and used clinically in 1978. Since then, we have continued to use this technique with minor modification. The technique consists of radical excision of all diseased sinuses, including the sinuses down to the aortic annulus. The integrity of the aortic root is then reconstituted using a preshaped Dacron tube (Hemashield, Meadox Medical, Inc, Oakland, NJ) of the appropriate size that is used to suspend the aortic valve, restore the normal relation of the aortic sinuses, and to which the coronary ostia are anastomosed.

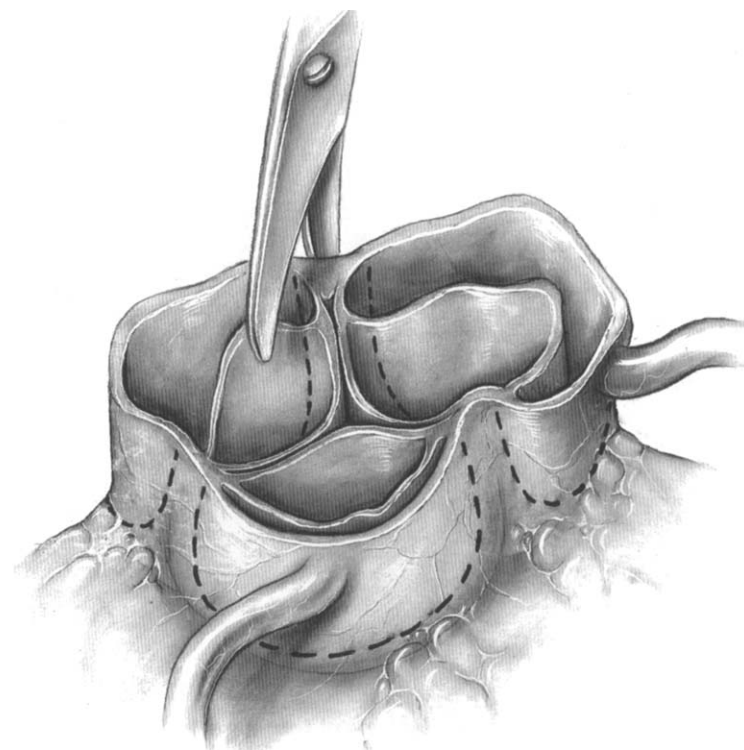
SURGICAL TECHNIQUE

A median sternotomy is used with double cannulation of the superior vena cava (SVC) and inferior vena cava through the right atrium for venous return. Whenever possible in the management of aneurysmal disease, arterial inflow is achieved at the junction of the ascending aorta and arch. In patients with acute dissection or extensive aneurysmal disease involving the arch, the femoral artery is used for arterial return. The patient is cooled to a core temperature of 20°C and myocardial protection is accomplished by intermittent antegrade crystalloid or blood cardioplegia. The circulation is arrested for a short period during the latter part of the operation to excise the site of aortic clamping and to anastomose the graft to the distal arch using an open anastamotic technique. Retrograde perfusion through the SVC cannula is used to clear the head vessels of air and debris.



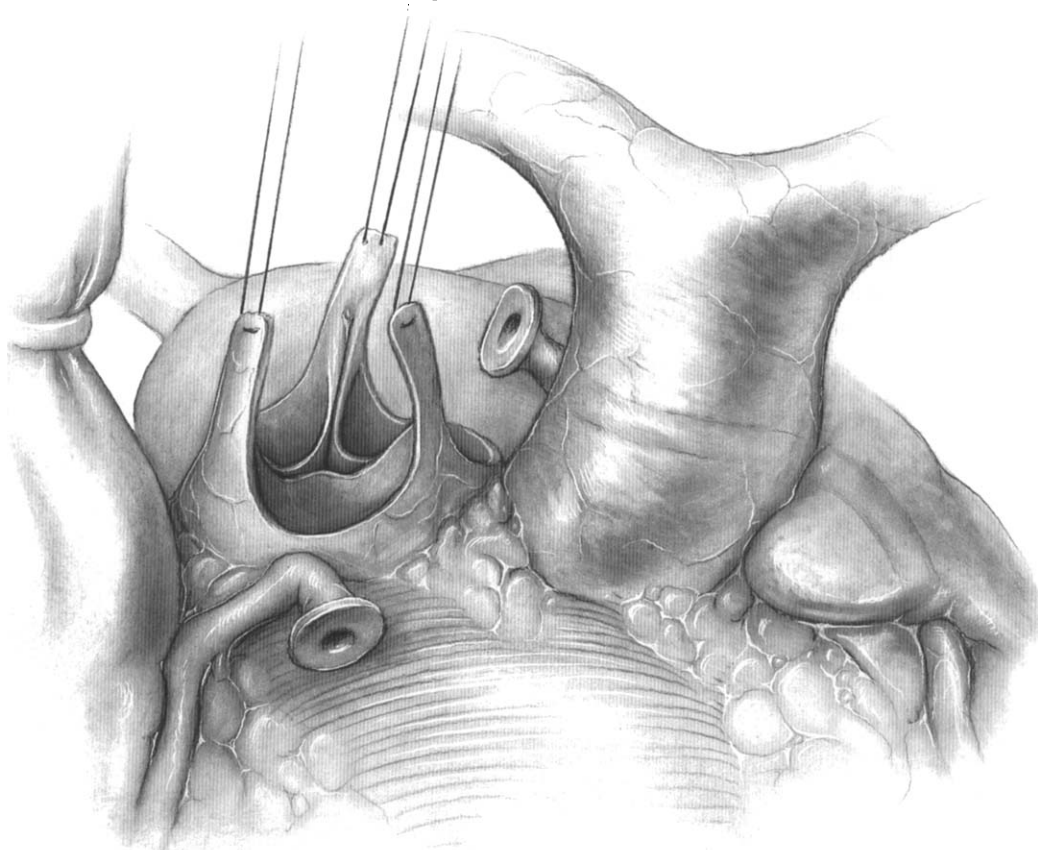
4 After establishing cardiopulmonary bypass and clamping the ascending aorta, the aneurysm is opened using an oblique incision that begins anteriorly and extends towards the root of the noncoronary sinus. Cardioplegia is instilled directly into the coronary ostia.

Excision of the Aneurysmal Ascending Aorta and Root



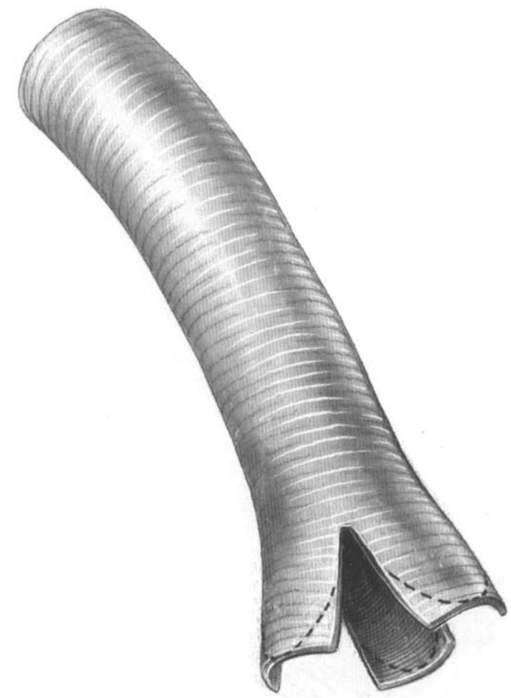
5 The diseased aortic sinuses are excised down to the aortic annulus, which is always healthy and can hold sutures securely even in patients with acute dissection.

Sizing the Aortic Root



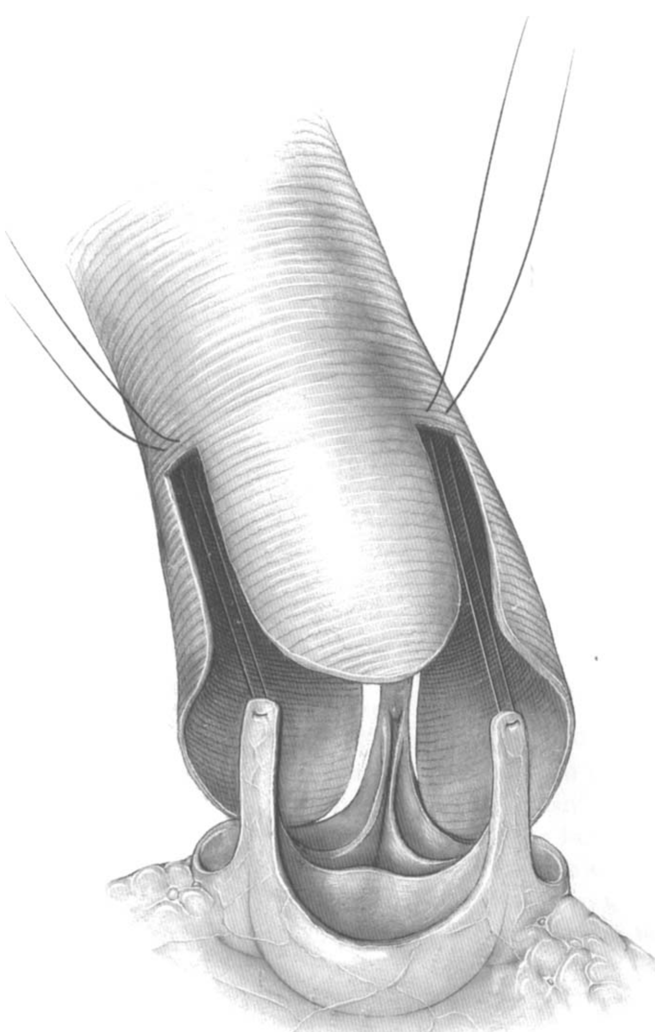
6 An essential part of this operation is choosing an appropriately sized Dacron tube, which is necessary for restoring competence of the valve. This is estimated by passing horizontal mattress sutures just above the top of each commissure and stretching the three commissures in a vertical direction while observing the position of the cusps. The distance between the commissures, observed to produce optimum coaptation of the cusps, is measured. As this represents approximately one third of the circumference of the desired tube, it also provides a guide to the diameter of the tube needed. In general, a 30-mm tube is required in large adults and a 20-mm tube in adolescents and small individuals.

Preshaping the Dacron Tube



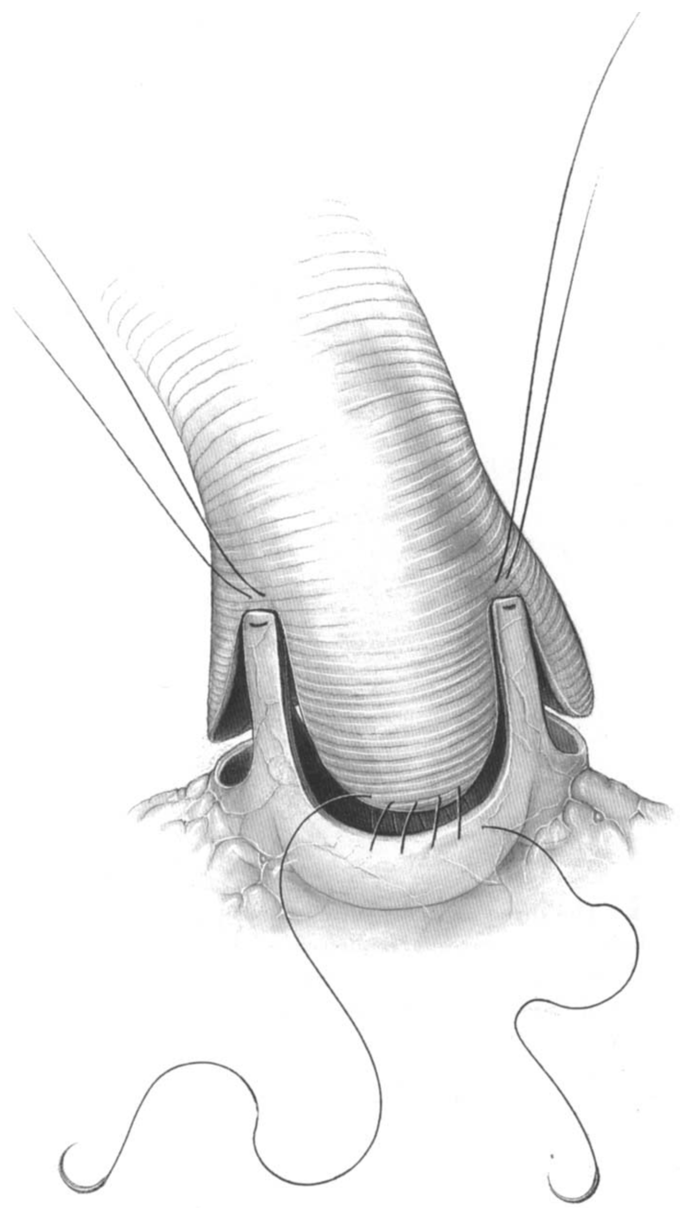
7 One end of the Dacron tube is trimmed to produce three separate extensions designed to replace the three sinuses. The width of each extension is approximately one third of the circumference of the tube, and therefore, is measured to be equal to the diameter of the tube. The height of the grooves is made at least one-half times the height of the commissures in the patient (as measured from the bottom of the sinus to the top of the commissures) to allow for trimming the excess Dacron to precisely fit each sinus when it is being sutured.

Suturing the Commissures to the Tube



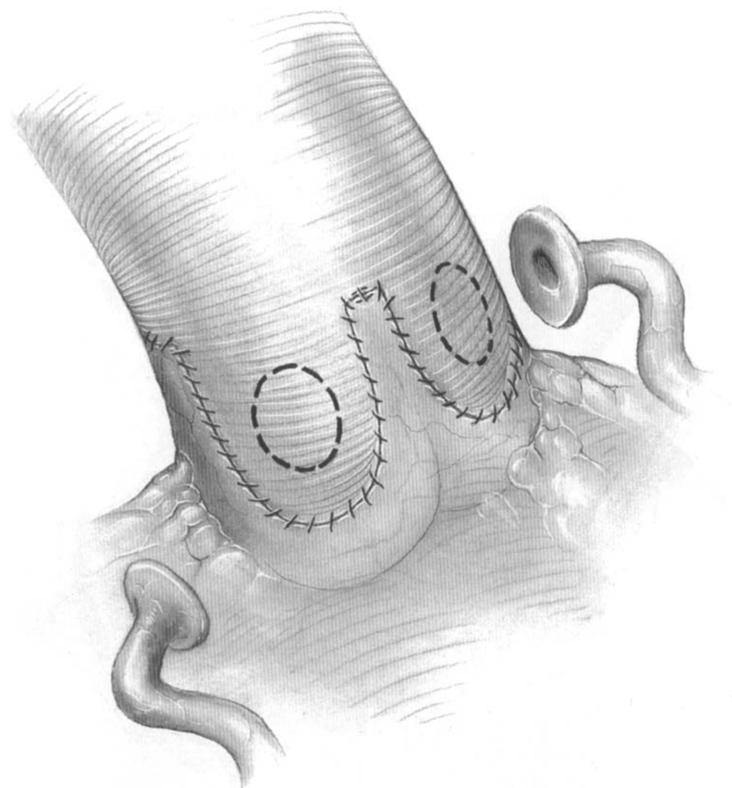
8 The three mattress sutures inserted at the top of the three commissures are then fixed to the apex of each groove in the Dacron tube, making sure that the orientation of the top of each commissures is exactly in the long axis of the Dacron tube with no tilting to either side. For each sinus, the excess Dacron is trimmed from the tongue-like extensions after putting both the Dacron and the sinus under tension to match both their length and width.

Fixation of the Dacron Sinuses



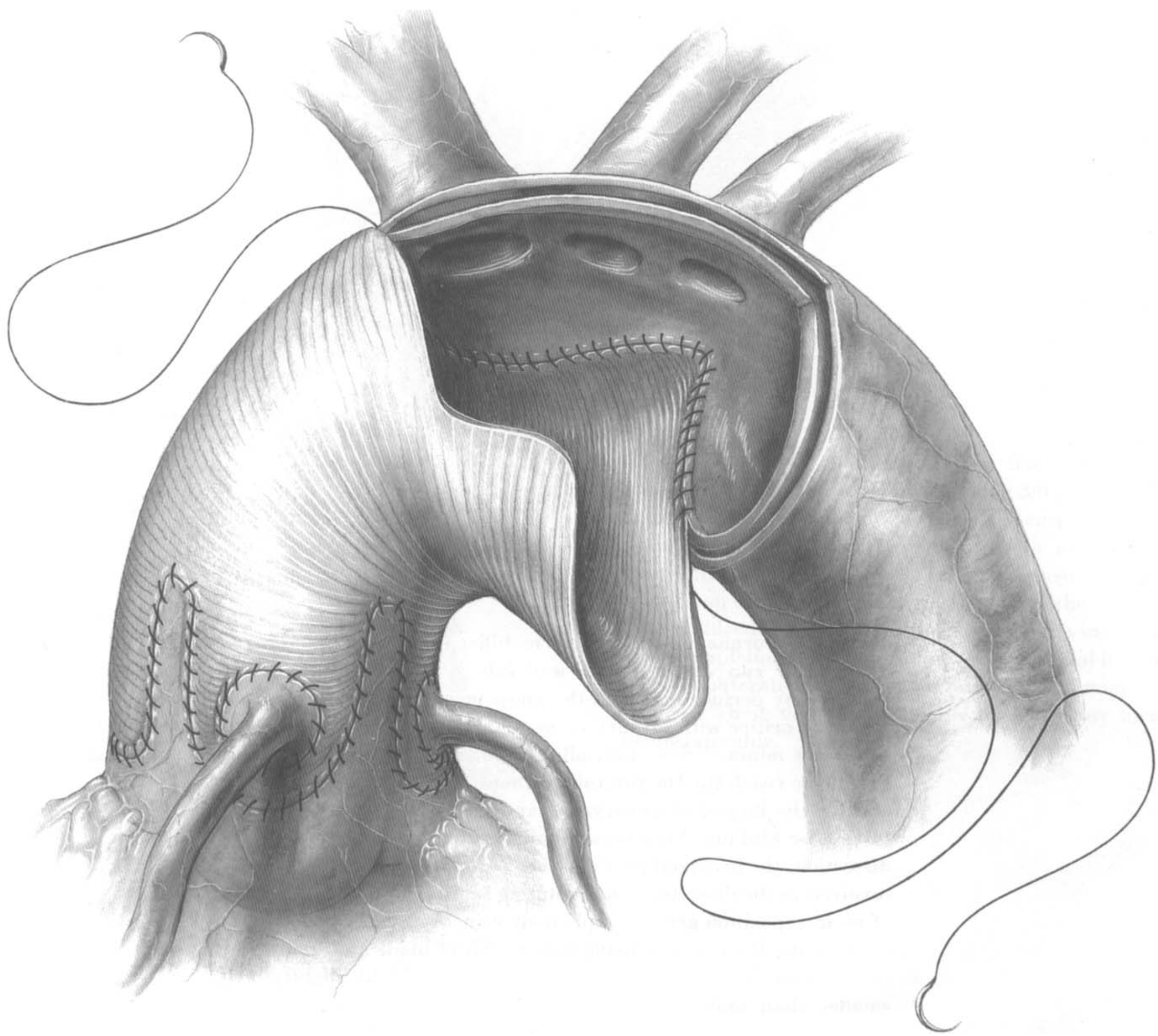
9 Each Dacron extension is then fixed to the aortic annulus surrounding each sinus, using 3/0 polypropylene sutures and starting at the bottom of the cusp and working toward the top of each commissure. In executing this suture line, special care is taken to ensure complete apposition of the relatively rigid Dacron to the annulus to prevent bleeding from the suture line, which is inaccessible after completion of the operation. Any potential irregularity is obliterated by using additional interrupted 4/0 sutures. These details obviate the need for any form of hemostatic glue.

Mobilization of the Coronary Ostia and Anastomosis of Coronary Buttons



10 The coronary ostia are then mobilized with a surrounding narrow run of the aortic wall (about 2 mm). This is achieved by performing a full-thickness incision around each coronary orifice with no further mobilization. In our experience, this minimal dissection allows enough mobility for the buttons to reach the Dacron tube without interposition grafts, even in the largest of aneurysms, and minimizes the risk of torsion or kinking. Very occasionally, in patients with acute dissection, the proximal part of either coronary artery may be involved in the dissection, necessitating excision and insertion of an interposition graft of saphenous vein. A circular hole is made in the Dacron tube using a sharp No 11 blade and small sawing movements. The size of the hole should be slightly smaller than that of the button to allow for inserting the sutures, and to prevent undue tension on the button that could lead to tears around the coronary orifice. Equally, the button should not be too large because this could lead to a bunching of tissues and obstruction of the coronary ostium. In addition, the aortic wall of the sinuses is usually diseased, and therefore, only minimal amount of the abnormal tissue is retained. The location of the anastomosis in the Dacron tube is dictated by the position of the button. However, in the vast majority of patients, it is made in or near the center of the corresponding sinus. The anastomosis is performed using a 4/0 monofilament suture, ensuring that no tension, torsion, or kinking of the proximal coronary artery occurs.

The Distal Aortic Anastomosis



11 This anastomosis is performed "open" to allow excision of the site of aortic clamping, which could cause future problems. The circulation is interrupted for a period of up to 15 minutes at a core temperature of 25°C. The aorta and Dacron tube are trimmed and anastomosed using a 3/0 Prolene suture. The aortic arch is replaced if it is diseased or prophylactically in patients with connective tissue disease.

COMMENTS

A valve-conserving operation based on understanding the functional anatomy of the aortic root and the pathophysiology of aortic regurgitation in patients with aneurysms and/or dissection of the aortic root has been presented. We have developed and regularly used this technique since 1978. The technique is applicable to virtually all patients with acute dissection and the majority of patients with aneurysms of the root of the aorta, including those with Marfan Syndrome. The technique is relatively simple, reproducible, and, if applied at the appropriate time (early) in the natural history of the disease, can provide durable good results with an improvement in quality of life, which compares favorably with composite root and valve replacement.

REFERENCES

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