Operative Techniques in
Thoracic and
Cardiovascular Surgery

Aortic Valve Replacement with Pulmonary Autograft: Subcoronary and Aortic Root Inclusion Techniques

Tirone E. David, MD

In Donald Ross' original description of aortic valve replacement with the pulmonary autograft in humans, the valve was implanted in the aortic root in the subcoronary position.[1] This was the same technique described by Ross to replace the aortic valve with an aortic valve homograft.[2] In his pioneering series of 151 patients operated from 1967 to 1981, 131 had the pulmonary valve implanted in the subcoronary position, whereas 20 were implanted as an aortic root replacement.[3] The technique of aortic root replacement is more reproducible than the technique of subcoronary implantation, and it was favored by most early adopters of the Ross procedure.[4,5] Replacement of the aortic root with the pulmonary root exposes the pulmonary sinuses to systemic pressures, and dilation of the pulmonary autograft is a common late problem.[6] However, this problem can largely be prevented by implanting the pulmonary valve or root inside the patient's aortic root.[6] This article describes how and when we implant the pulmonary autograft inside the aortic root.

Division of Cardiovascular Surgery of Peter Munk Cardiac Centre at Toronto General Hospital and University of Toronto, Toronto, Ontario, Canada.
Dr. David reports receiving lecture fees from Medtronic and St. Jude Medical.
Address reprint requests to Tirone E. David, MD, Division of Cardiovascular Surgery of Peter Munk Cardiac Centre at Toronto General Hospital and University of Toronto, 200 Elizabeth Street 4N457, Toronto, Ontario M5G 2C4, Canada. E-mail: tirone.david@uhn.on.ca

1522-2942/$-see front matter
doi:10.1053/j.optechstcvs.2011.09.002

Operative Technique

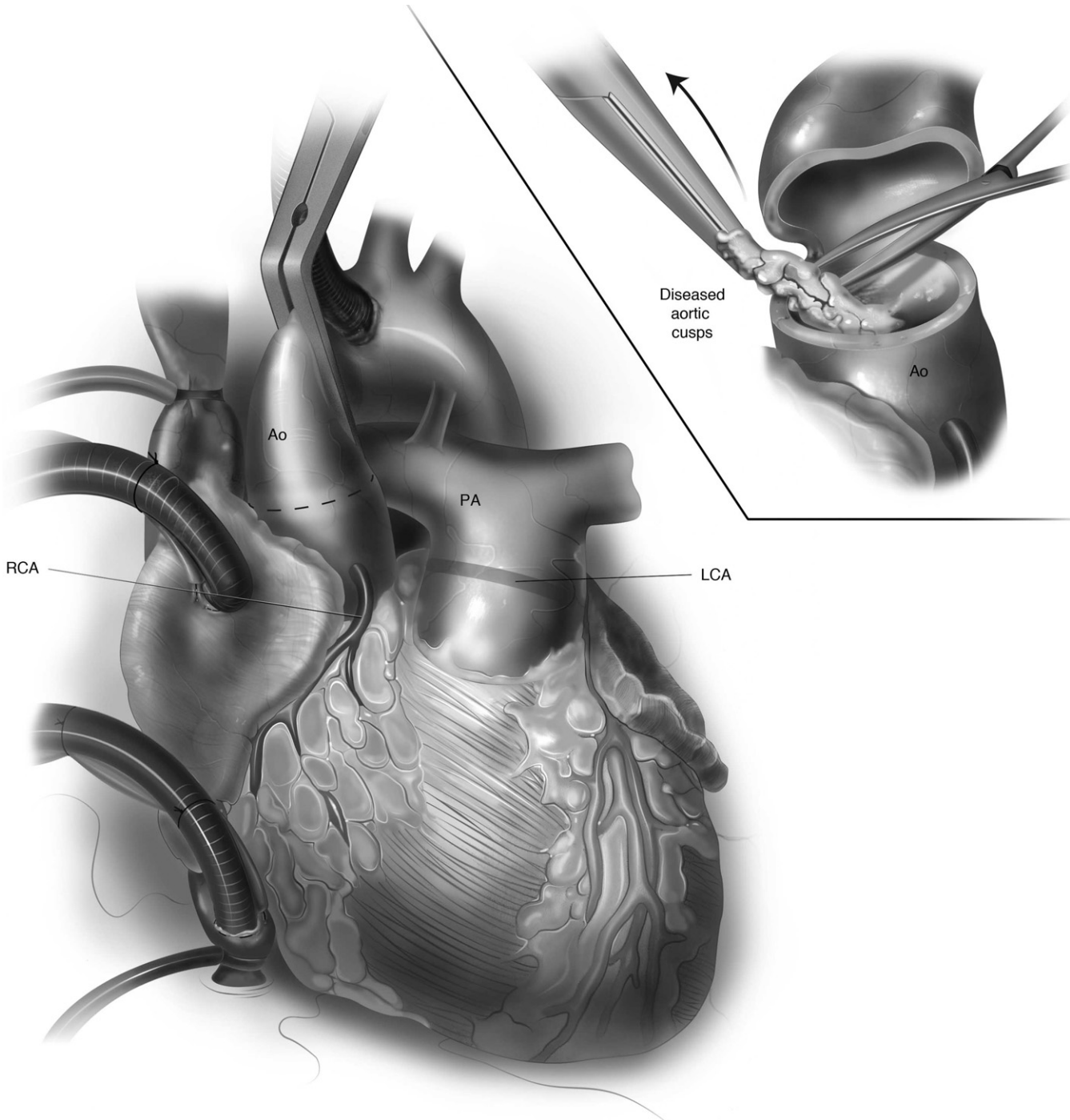
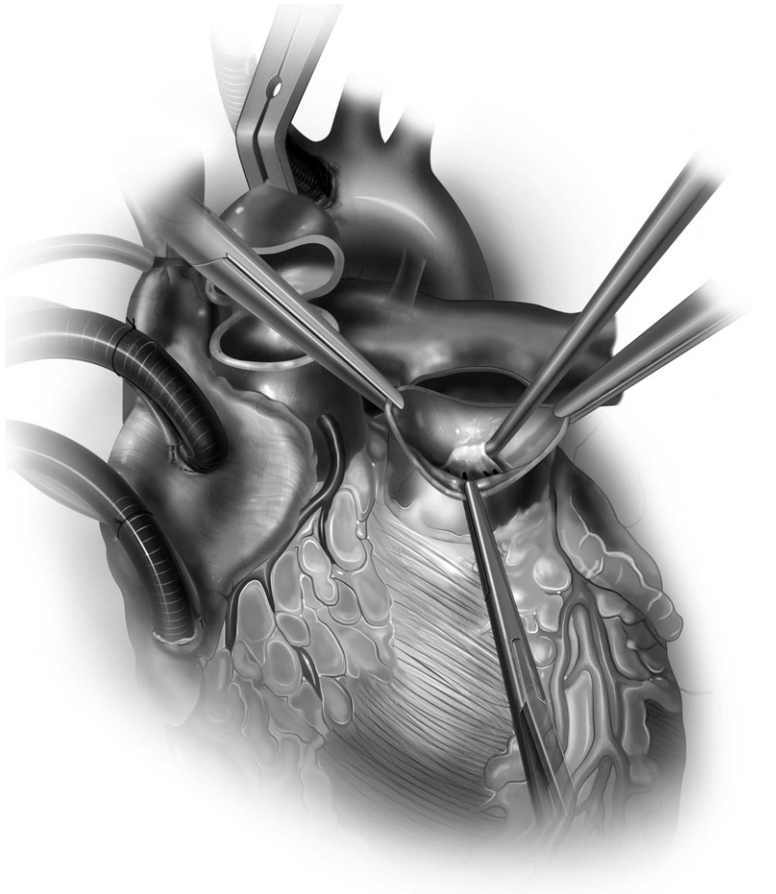
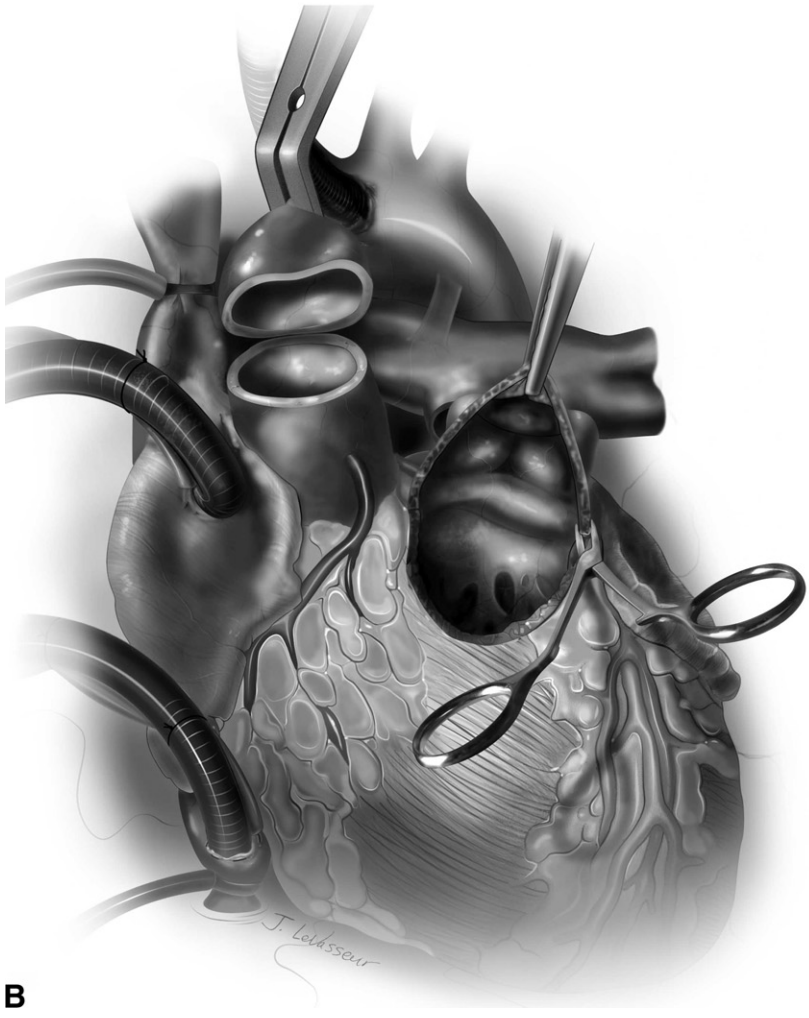


Figure 1 Cardiopulmonary bypass is established by cannulating the distal ascending aorta or proximal aortic arch (if the ascending aorta is dilated and needs replacement) and the superior and inferior vena cavae through the right atrium. A transverse aortotomy 5 to 10 mm above the sinotubular junction is performed. Myocardial protection is provided by cold blood cardioplegia delivered directly into the coronary arteries through small cannulas with a balloon at the end. We leave these cannulas in the arteries throughout the operation. These coronary cannulas must be smaller than the arteries to avoid intimal damage and possible stenosis. We give initially 1 L of cold blood cardioplegia with a high concentration of potassium chloride and then subsequently 500 mL every 20 minutes with low potassium.

The diseased aortic cusps are excised and all calcified tissues are completely removed. The diameters of the aortic annulus and of the sinotubular junction are measured with commercially available metric sizers, such as those used for stentless porcine valves. The positions of the orifices of the left and right coronary arteries are examined. If the right coronary artery orifice is too close to a commissure and the 3 commissures are symmetrical, subcoronary implantation may not be feasible. Ao = aorta; LCA = left coronary artery; PA = pulmonary artery; RCA = right coronary artery.



A



B

Figure 2 The pulmonary artery is transected 5 mm above the commissures and each cusp of the pulmonary valve is inspected (A). If the pulmonary valve is normal, the pulmonary root is excised along with 3 to 4 mm of right ventricular muscle. The first septal perforator is usually located beneath a muscular band in the upper part of the interventricular septum close to the left anterior descending artery as it crosses the right ventricular outflow tract (B).

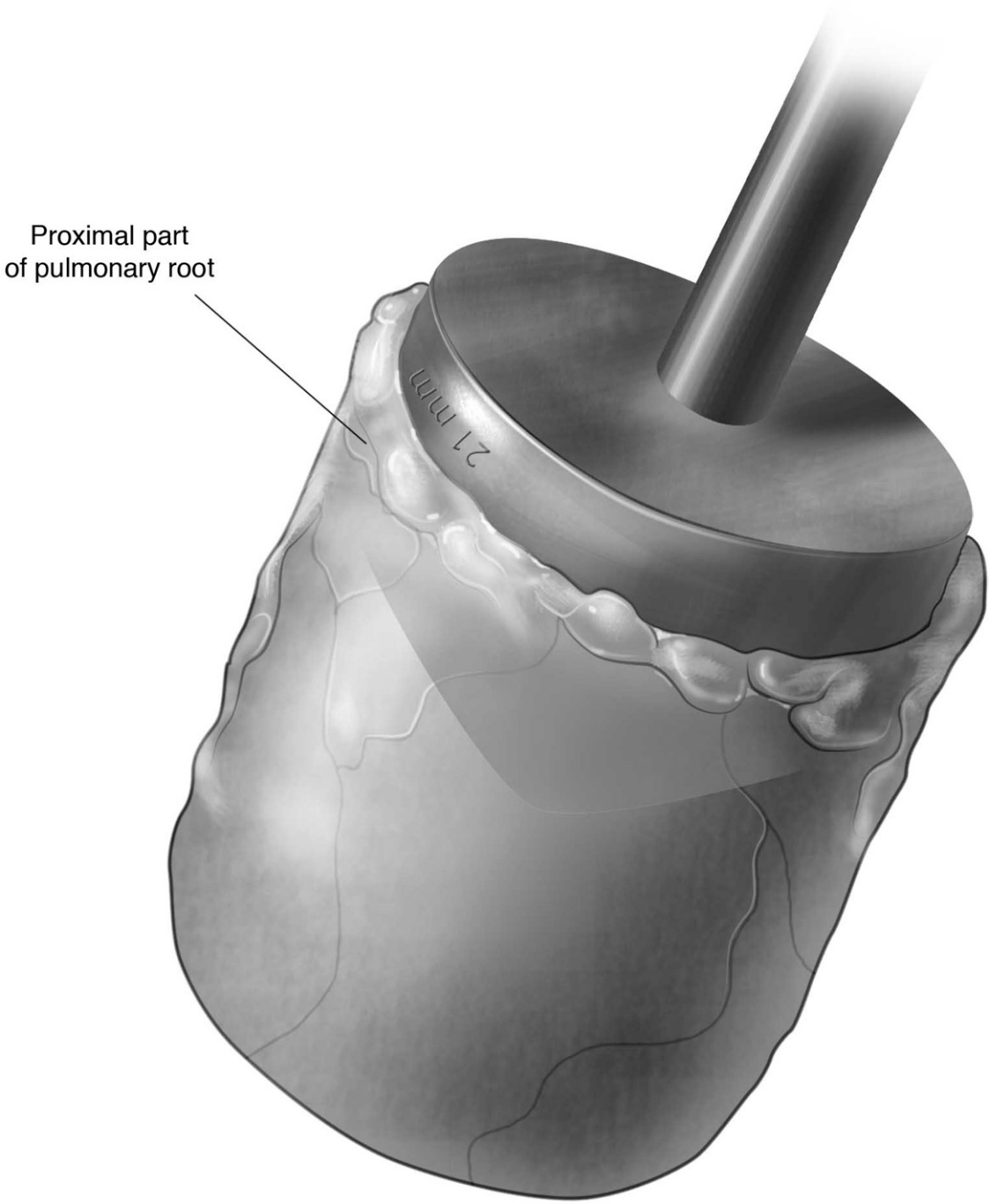


Figure 3 The sinotubular junction of the pulmonary root is gently measured with metric sizers, introduced into the root from its inflow. The pulmonary annulus is assumed to be 10% to 15% larger than the diameter of the sinotubular junction. The diameter of the aortic annulus must be within 10% of the diameter of the pulmonary annulus when the subcoronary technique is to be used. We do not believe the Ross procedure should be performed in patients with annuloaortic ectasia (aortic annulus ≥28 mm) or in patients in whom the pulmonary sinotubular junction is ≥25 mm.

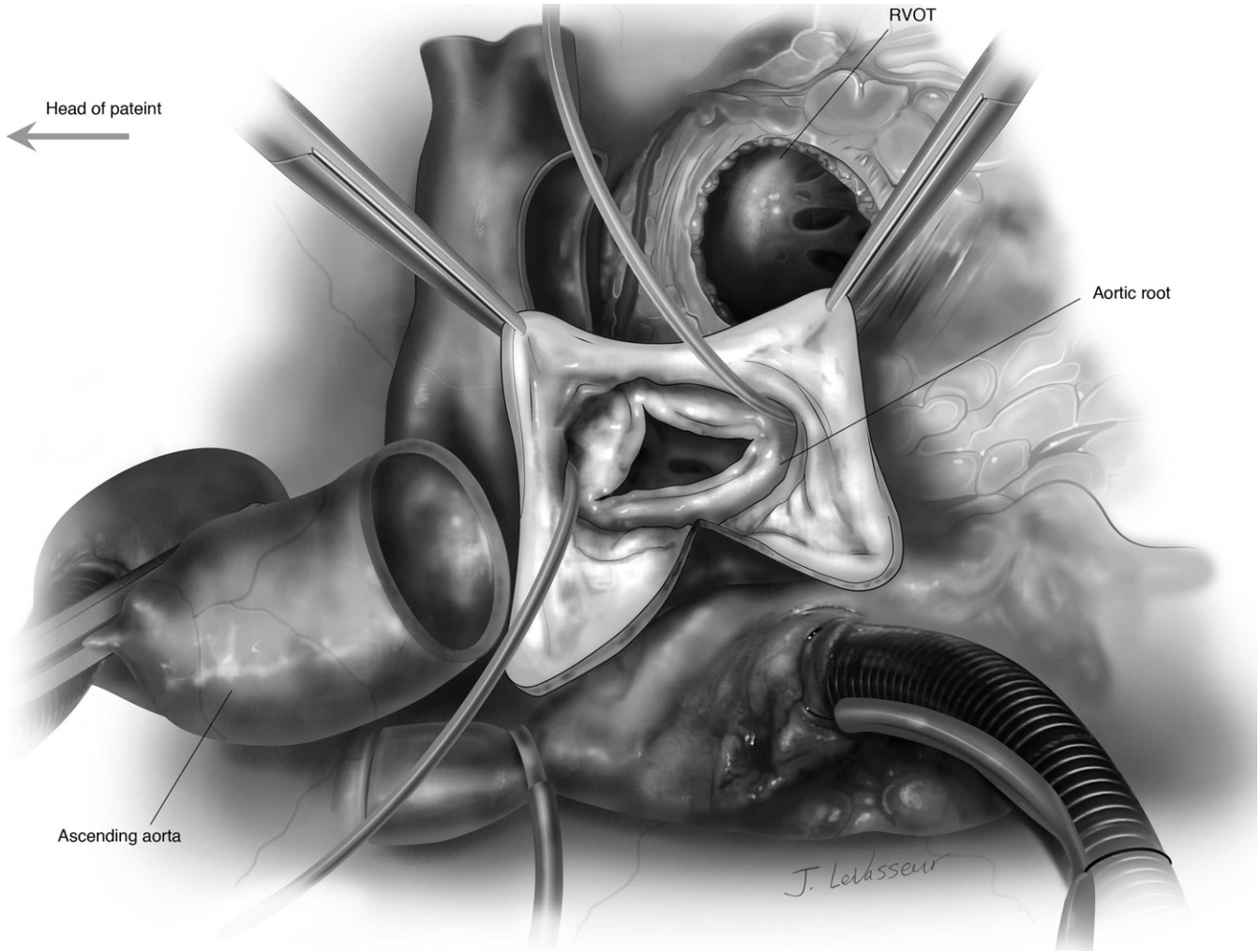


Figure 4 The aortotomy is completed to separate the ascending aorta from the aortic root, and the noncoronary sinus is incised down toward the annulus to expose the aortic root widely. RVOT = right ventricular outflow tract.

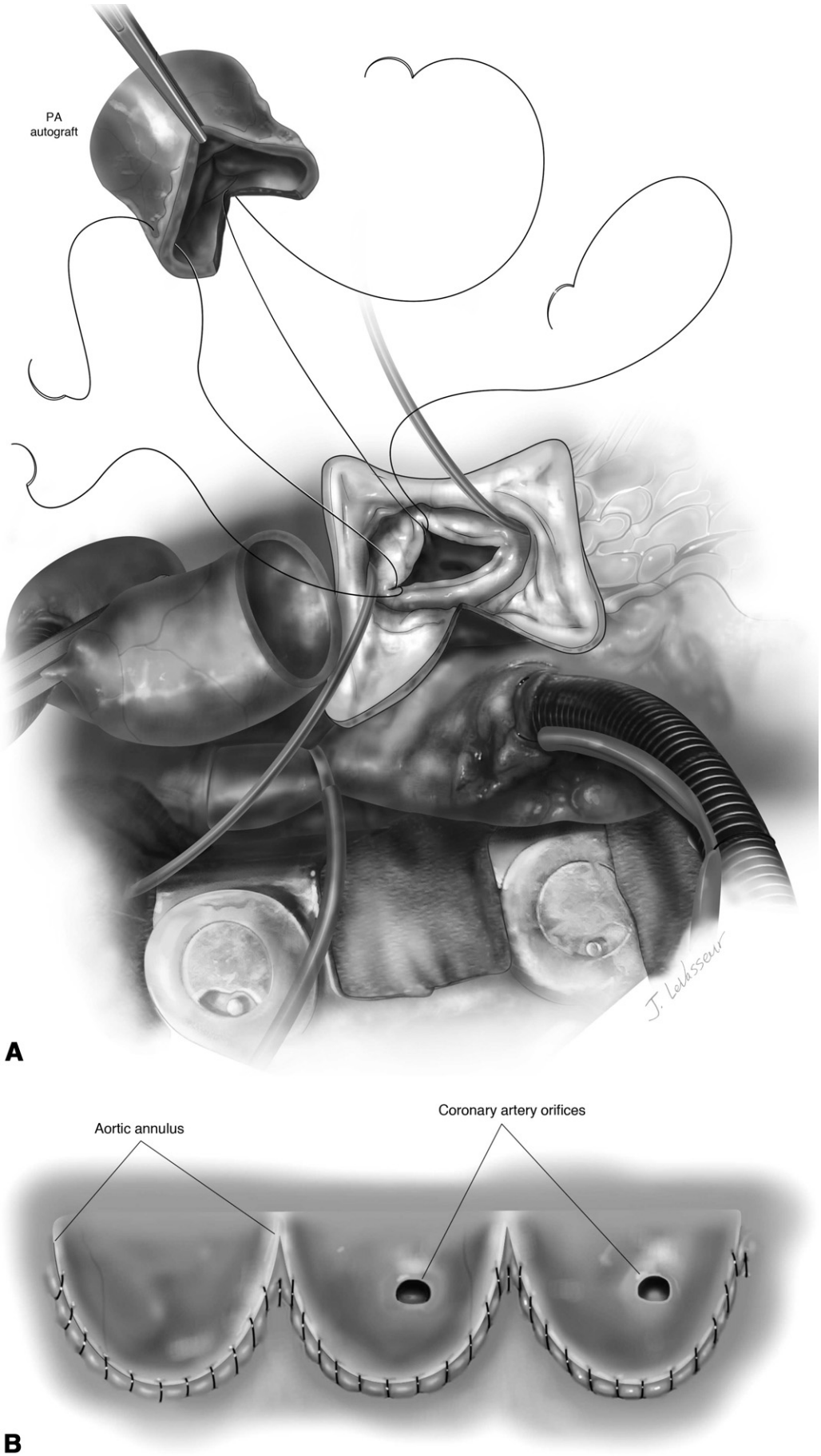


Figure 5 The muscle beneath the commissures of the pulmonary root is trimmed to create a scalloped shape (A). The pulmonary autograft is implanted in its anatomic position (that is, the left pulmonary sinus faces the left aortic sinus, the anterior pulmonary sinus faces the right aortic sinus, and the right pulmonary sinus faces the noncoronary aortic sinus). The pulmonary autograft is secured to the aortic annulus with multiple interrupted sutures of 4-0 polyester. It is important that the scalloped shape of the pulmonary annulus be maintained when the sutures are placed and tied (B). Because the degree of scalloping of the pulmonary annulus is not necessarily identical to that of the aortic annulus, care must be exercised when placing the sutures through the remnants of muscle in the pulmonary and aortic root to maintain the scalloped shape of the pulmonary annulus. Thus, some sutures will be placed entirely in the left ventricular outflow tract, others through the aortic annulus, and some above the aortic annulus. This is often the case in patients with bicuspid aortic valves where the false commissure is lower than the other 2 and the 3 commissures and aortic annulus are not symmetrical. In this setting, the pulmonary autograft annulus may be secured in a supraannular position along the portion of the aortic annulus that is lower than the other 2. Commercially available stentless porcine valve sizers are metric and have 3 equidistant marks at 120°. They are useful to aid the surgeon in dividing the aortic and pulmonary annuluses in 3 equidistant thirds that will serve to guide the distribution of sutures. PA = pulmonary artery.

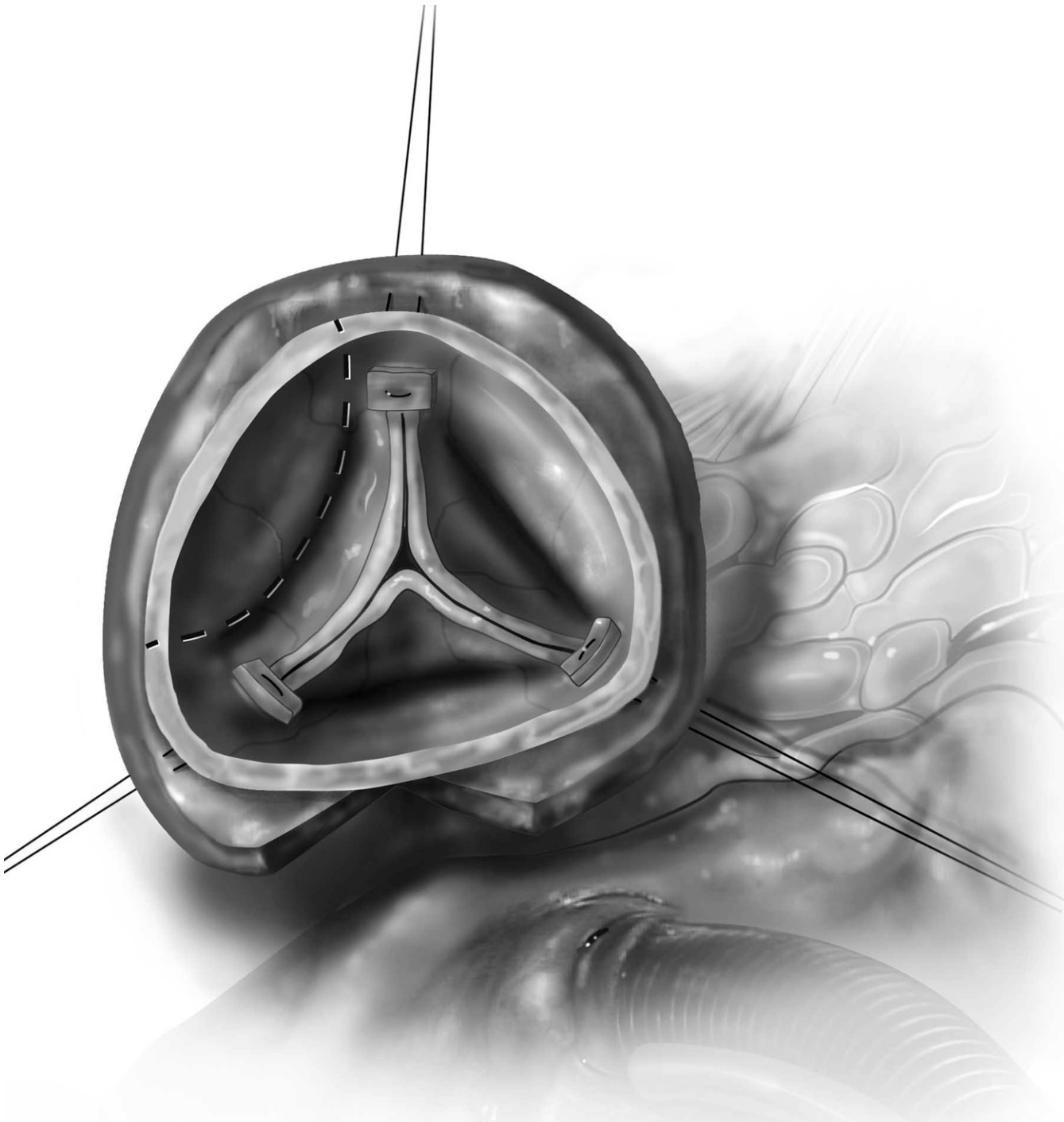


Figure 6 The commissures of the pulmonary autograft are suspended inside the aortic root and secured with transfixing 5-0 polypropylene sutures buttressed on small Teflon felt pledgets. The distances between commissures of the pulmonary autograft must be maintained as they are not necessarily the same as the aortic valve.

Figure 7 The left sinus of the pulmonary root is partially excised, leaving 3 to 4 mm attached to the pulmonary annulus. This remnant of the left pulmonary sinus is sutured to the left aortic sinus with a continuous 5-0 polypropylene suture.

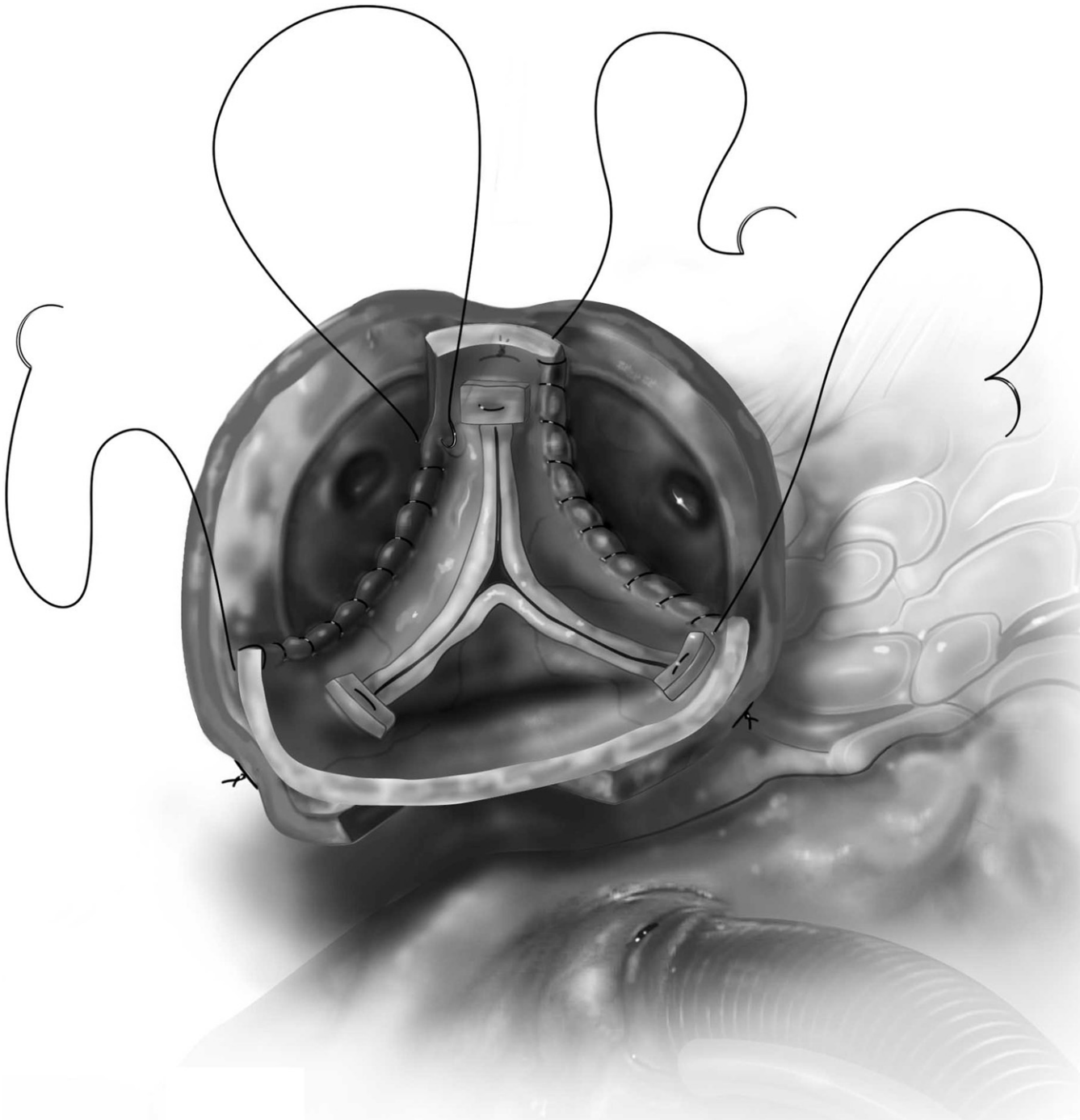


Figure 8 The anterior sinus of the pulmonary autograft facing the right coronary artery is excised and the remnant is sutured to the right aortic sinus. The right coronary artery orifice may be too close to the commissure of the aortic annulus and suturing the pulmonary sinus around it may be difficult. It is important not to change the level and site of fixation of the commissure of the pulmonary autograft to accommodate the coronary artery orifice. After suspending the commissures within the aortic root (as shown in Fig. 6), if there is inadequate space between the orifice of the right coronary artery and the pulmonary annulus for subcoronary implantation, we believe the right coronary artery should be detached from the aortic root and reimplanted into the pulmonary autograft.

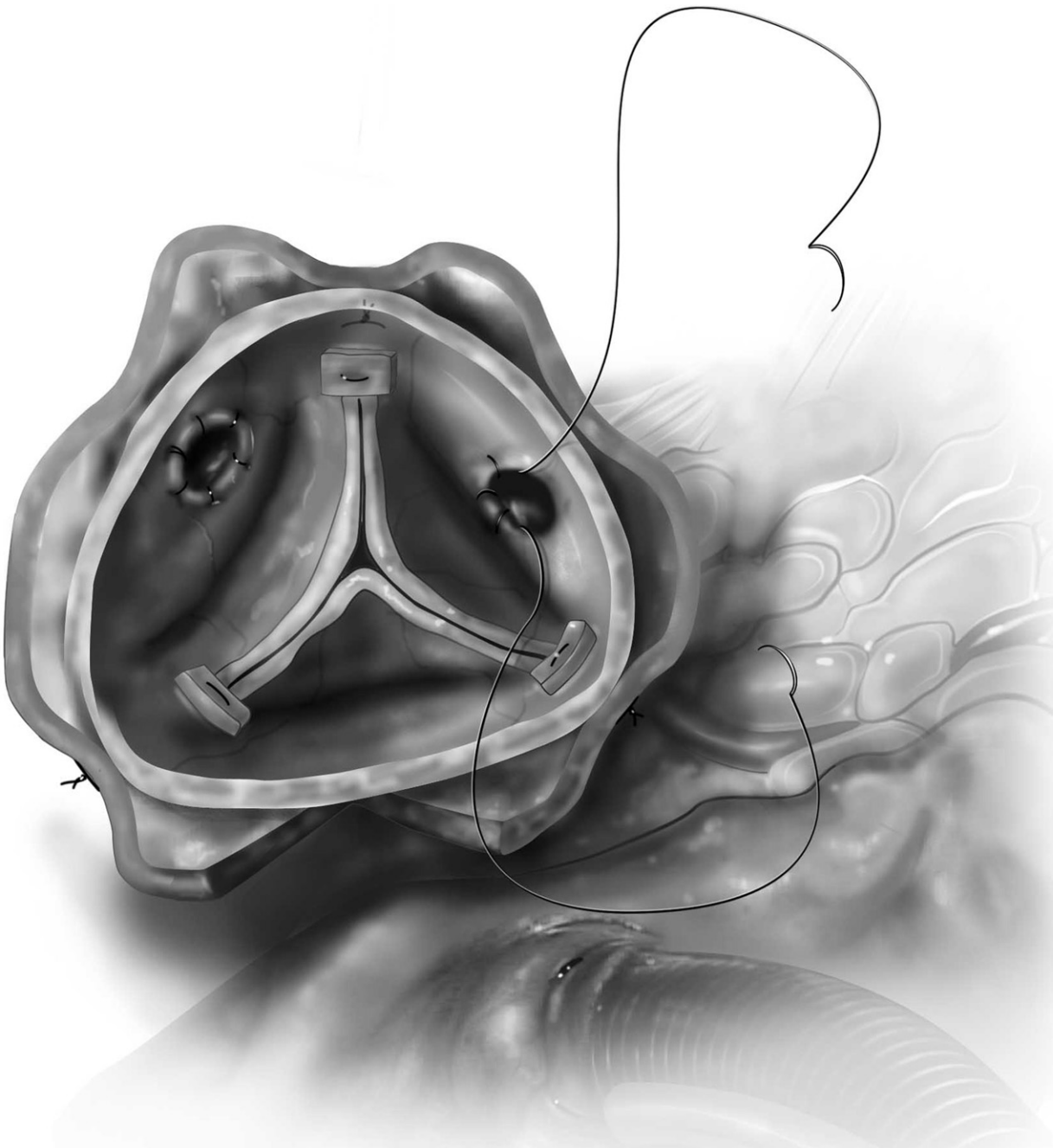


Figure 9 In patients in whom the sinotubular junction of the aortic root is larger than the sinotubular junction of the pulmonary root, the autograft can be implanted entirely inside the aortic root. The commissures are suspended as described in Figure 6 and, instead of excising the pulmonary sinus, an opening of 5 or 6 mm is made and the pulmonary sinus wall is sutured to the aortic sinus wall around the coronary artery orifices with a continuous 6-0 polypropylene suture.

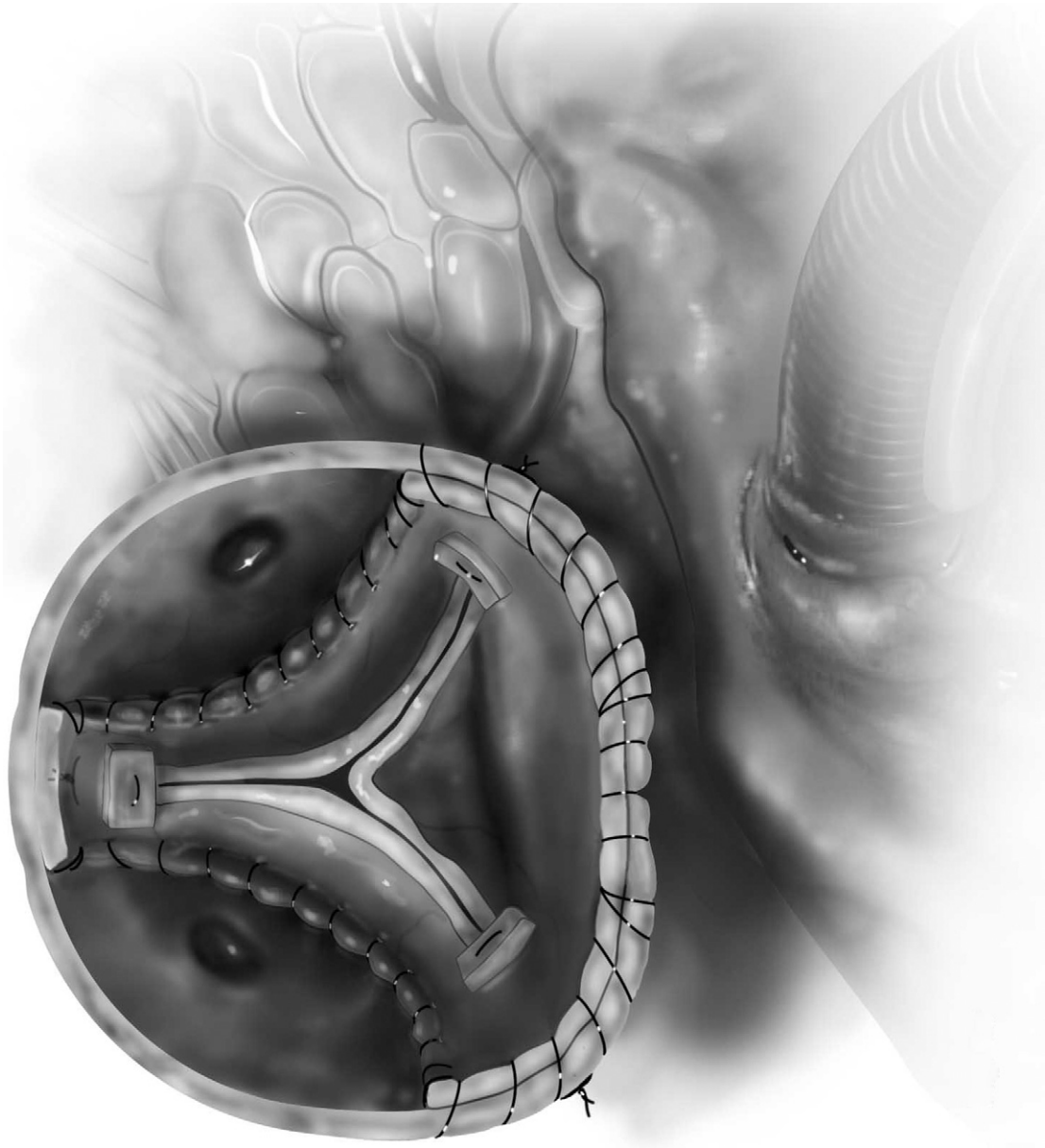


Figure 10 The aortic and pulmonary roots are trimmed 5 mm above the sinotubular junction of the pulmonary autograft. The aorta above the sinotubular junction along the noncoronary aortic sinus may be sutured to the pulmonary autograft with continuous 5-0 polypropylene sutures. The vertical opening in the noncoronary aortic sinus is left open at this stage of the operation.

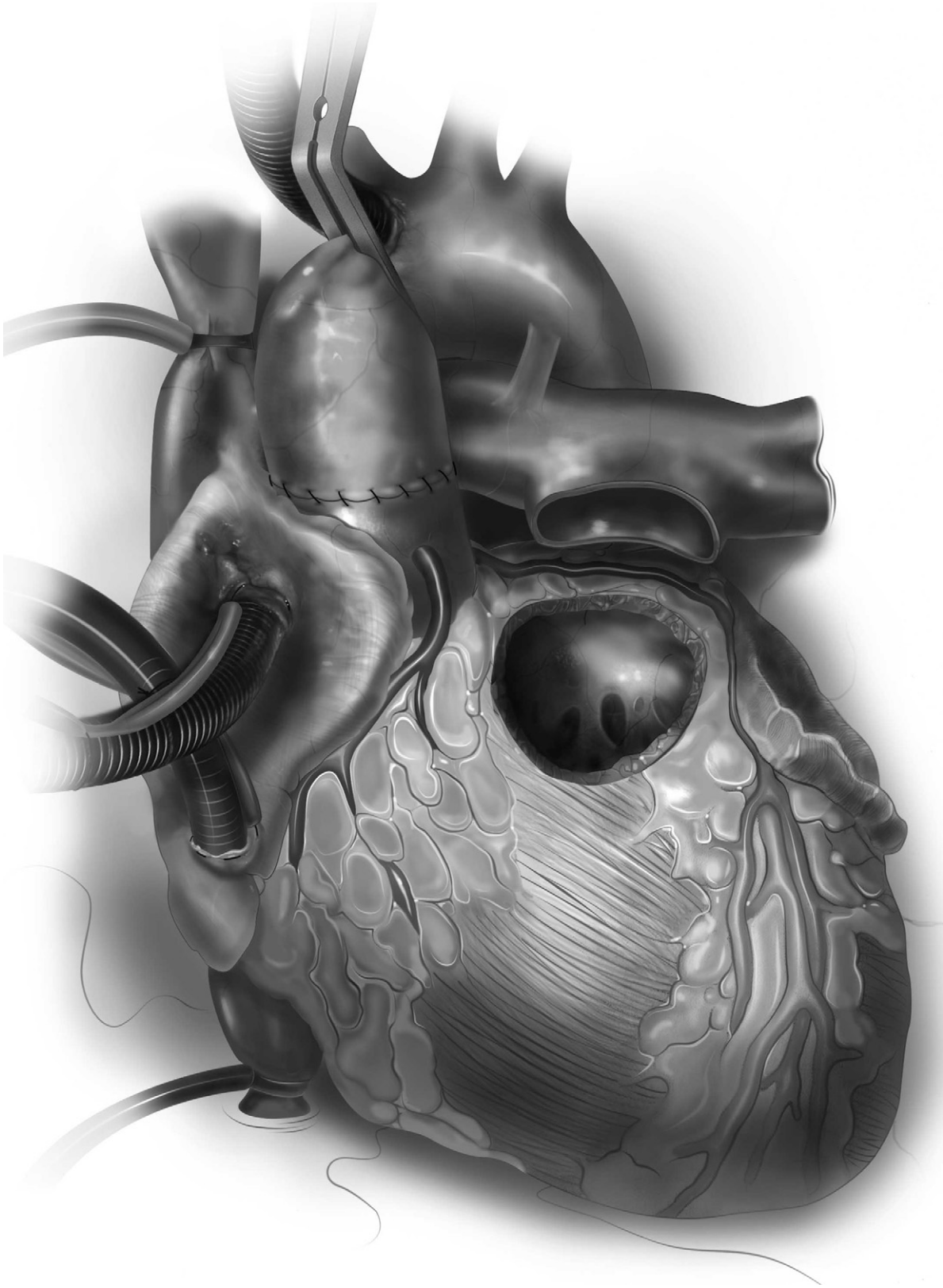


Figure 11 The reconstructed aortic root containing the pulmonary autograft is sutured to the ascending aorta in an end-to-end fashion with continuous 5-0 polypropylene sutures. This suture line should be buttressed on a strip of Teflon felt to prevent late dilation. If the ascending aorta is dilated, it should be replaced with a tubular Dacron graft. The diameter of the Dacron graft at the site of the anastomosis with the pulmonary autograft should be the same as the diameter of the sinotubular junction.

The vertical opening in the noncoronary aortic sinus is closed primarily or with a patch of autologous pericardium, if necessary, only after unclamping the aorta and making sure that there is no bleeding in between the aortic wall and pulmonary autograft.

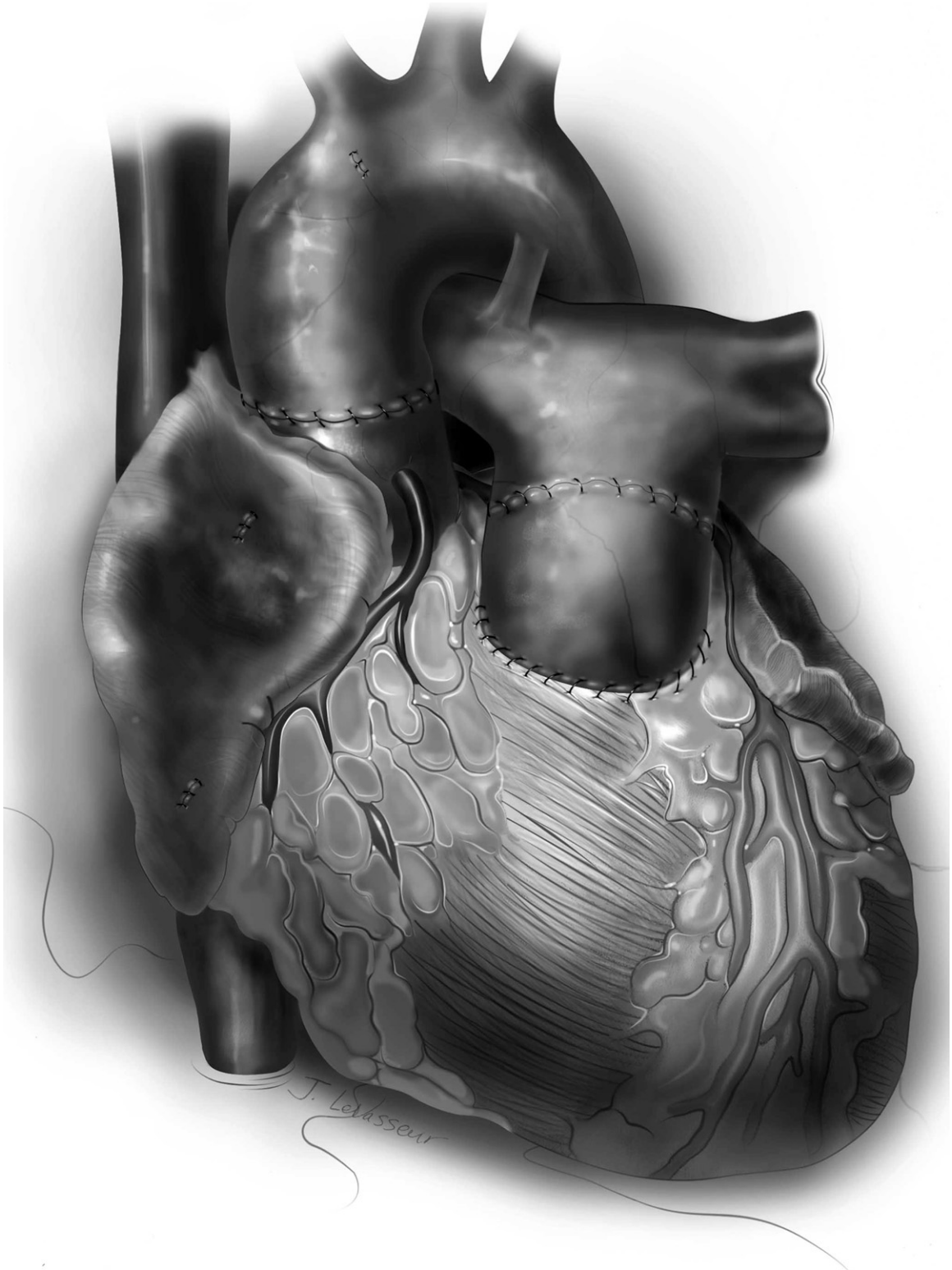


Figure 12 We do not unclamp the aorta until the right side of the heart is reconstructed with a pulmonary homograft. We use a larger pulmonary homograft than the size of the pulmonary autograft and seldom smaller than 25 mm in adults. The pulmonary homograft is sutured to the remnant of pulmonary artery with a continuous 5-0 polypropylene suture and then to the right ventricular outflow tract with a continuous 4-0 polypropylene suture. During this proximal anastomosis, care must be exercised to avoid damage to the first septal perforator and to the left anterior descending artery.

Conclusions

The ideal patient for the technique of subcoronary implantation is one with aortic and pulmonary roots of similar sizes and coronary arteries in the center of the aortic sinuses. Incising the noncoronary aortic sinus toward the aortic annulus increases exposure and facilitates the implantation of the pulmonary root inside the aortic root with either technique, that is, subcoronary implantation or aortic root inclusion technique. We do not believe it is necessary to buttress the annular suture line when the pulmonary autograft is implanted inside of the aortic root as described in this article. However, the anastomosis between the aortic root and ascending aorta probably should be buttressed with a strip of Teflon felt because the ascending aorta tends to dilate, particularly in patients with a bicuspid aortic valve.

In our experience, most patients who have the Ross procedure have bicuspid aortic valve disease. As mentioned above, careful inspection of the anatomy of the aortoventricular junction is necessary to plan the implantation of the pulmonary valve inside an abnormal aortic root. Attention must be given to the lack of symmetry among the 3 scalloped parts of the aortic annulus, the level of the nadirs of these 3 scalloped parts, and the intercommissural distances. The pulmonary valve must be secured inside the aortic root without distortion of the annulus, commissures, and sinotubular junction of the pulmonary autograft.

The results of the Ross procedure in carefully selected patients have been excellent.[7] In our experience, the long-term survival is identical to the population matched for age and gender and the number of adverse valve-related events is very low.

References

1. Ross DN: Replacement of the aortic and mitral valves with a pulmonary autograft. Lancet 2:956-958, 1967
2. Ross DN: Homograft replacement of the aortic valve. Lancet 2:487, 1962
3. Chambers JC, Somerville J, Stone S, et al: Pulmonary autograft procedure for valve disease: long-term results of the pioneer series. Circulation 96:2206-2214, 1997
4. Kouchoukos NT, Davila-Roman VG, Spray TL, et al: Replacement of aortic root with a pulmonary autograft in children and young adults with aortic valve disease. N Engl J Med 330:1-6, 1994
5. Stelzer P, Jones DJ, Elkins RC: Aortic root replacement with pulmonary autograft. Circulation 80(Suppl):III209-213, 1989
6. David TE, Omran A, Ivanov J, et al: Dilation of the pulmonary autograft after the Ross procedure. J Thorac Cardiovasc Surg 119:210-220, 2000
7. David TE, Woo A, Armstrong S, et al: When is the Ross operation a good option to treat aortic valve disease? J Thorac Cardiovasc Surg 139:68-73, 2010