Operative Techniques in Thoracic and Cardiovascular Surgery

Left Ventricle Apical–Aortic Conduit for Aortic Stenosis

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Native aortic valve replacement is the procedure of choice for pure aortic valve stenosis. Occasionally, conventional surgery is deemed unacceptably high risk related to calcification of the aortic root, multiple previous median sternotomies, or patent retrosternal grafts. Implantation of a left ventricle apical–aortic conduit (AAC) is an alternative approach in patients with these and other conditions that either preclude a median sternotomy or present a high risk for aortic cross-clamping and aortotomy. There are several imaging and postoperative concerns related to this situation.

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A 64-slice multidetector computed tomography (CT) scan of the chest and abdomen with and without contrast is usually performed to assess the degree of aortic root calcium, calcification of the descending thoracic aorta, and the lay of any retrosternal patent coronary artery bypass grafts. Intraoperative transesophageal echocardiographic assessment of the aortic valve is essential to rule out aortic insufficiency. An apical aortic conduit should be performed in the setting of isolated aortic stenosis. Mild aortic insufficiency can be tolerated but the procedure should be avoided in patients with greater than 1+ aortic insufficiency. Intraoperative echocardiography is also valuable to further assess the degree of calcification of the descending aorta to help direct placement of the conduit-to-aorta anastomosis. We prefer to perform the operation with femoro-femoral cardiopulmonary bypass and mild hypothermia (34°C).

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Operative Technique: Thoracotomy

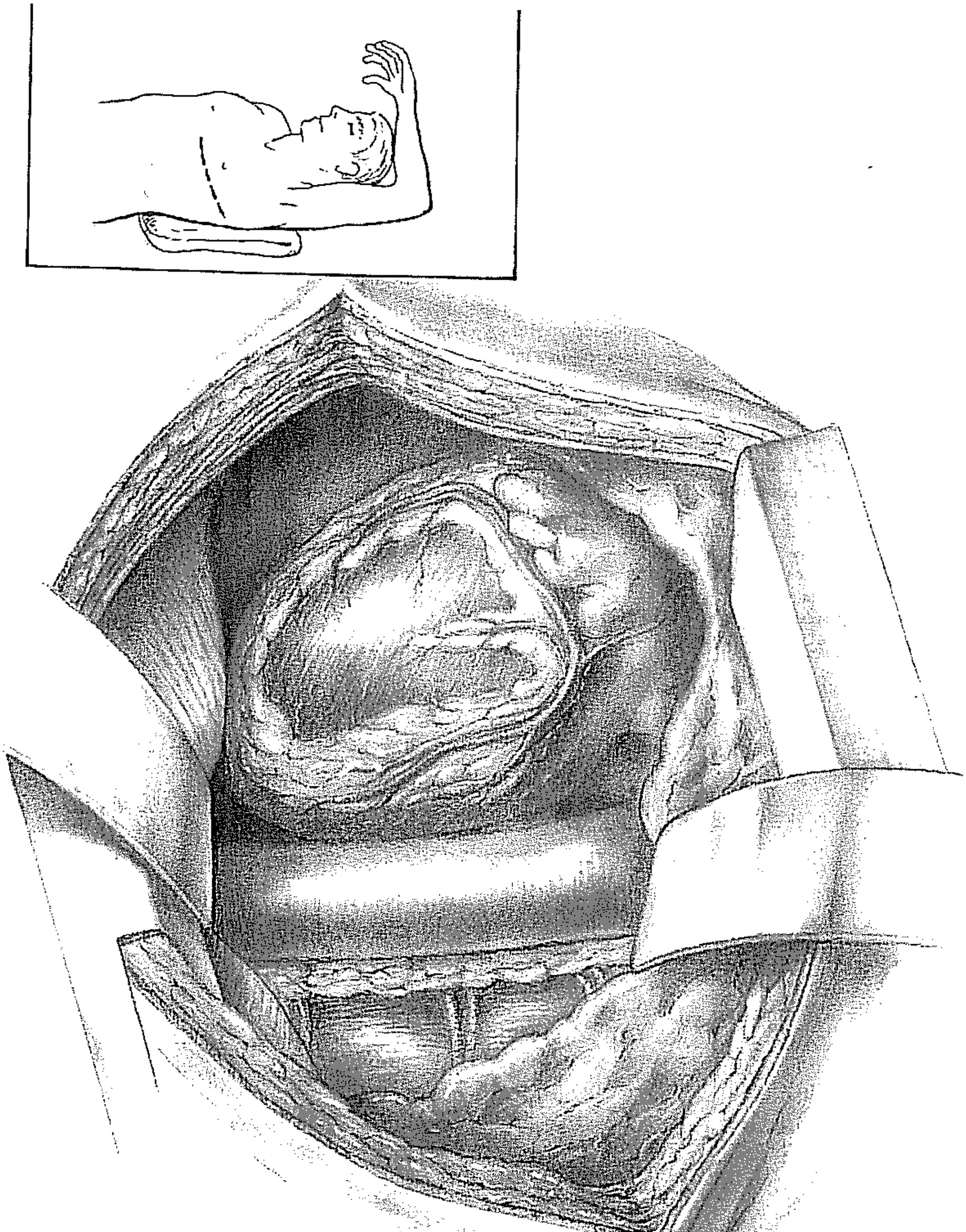

Figure 1 The relevant anatomy as seen through a 5th interspace lateral thoracotomy (inset). The illustration is without pericardium for clarity. When avoiding a risky sternal reentry is the indication for the apical aortic conduit, a left chest approach is used. After femoral cannulation, a left lateral thoracotomy is performed, usually in the 5th intercostal space. The left lung is collapsed; the inferior pulmonary ligament is taken down and the left lower lobe is retracted superiorly. The parietal pleura is opened over the descending thoracic aorta. A malleable retractor can be used to deflect the diaphragm inferiorly to improve exposure. Alternatively, a stay-suture may be anchored to the diaphragm and passed through the chest wall at the costophrenic angle with a large 12-gauge Angiocath (Beckton Dickinson, Franklin Lakes, NJ) to create the tract. The diaphragm can then be retracted caudally. The pericardium is opened anteriorly to the phrenic nerve and the apex of the heart is exposed. (In this illustration the pericardium is omitted.)

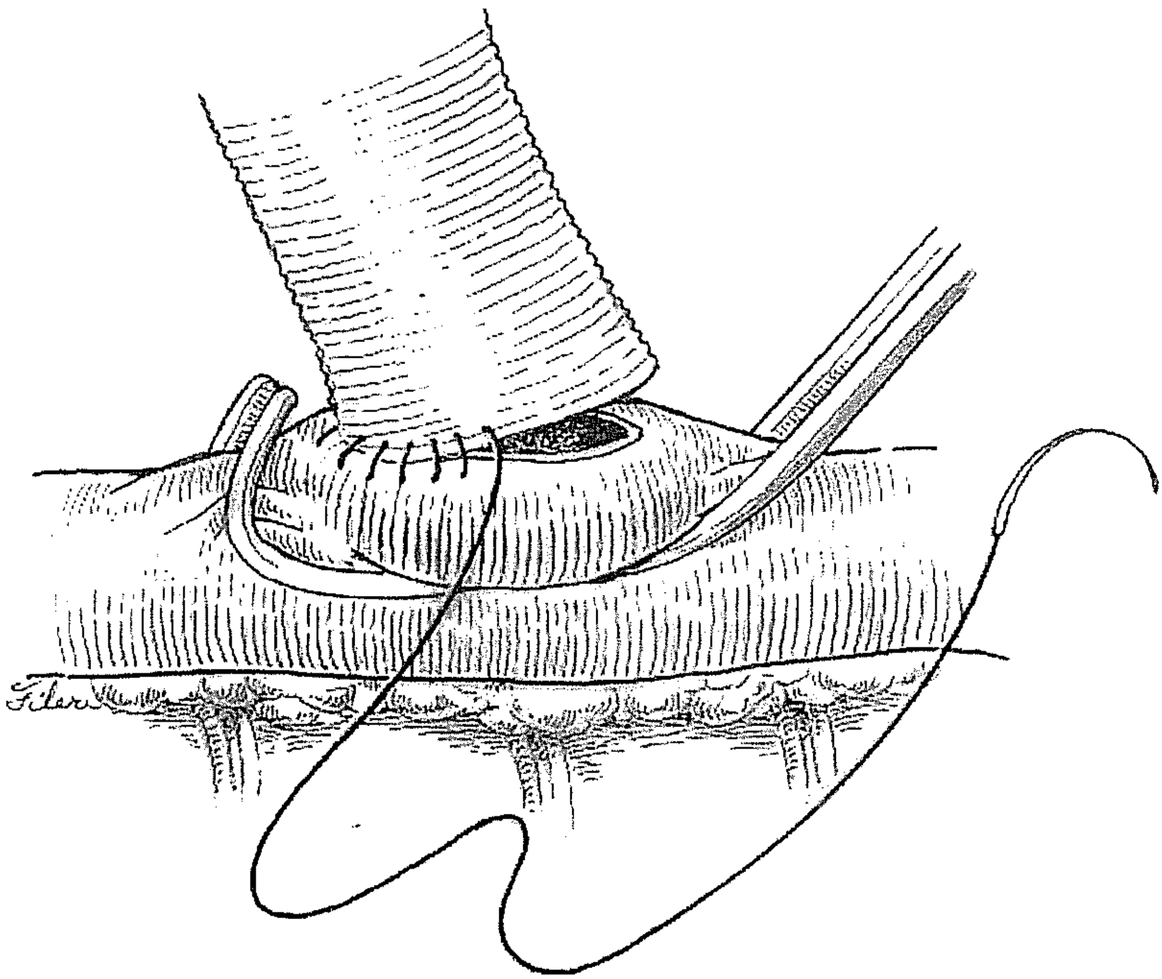

Figure 2 There are 3 components required for the operation: an outflow graft to the descending aorta, a valved conduit, and an elbow apical connector. The first of these is accomplished by application of a partial occlusion clamp to the distal descending thoracic aorta. The graft is beveled to direct the flow slightly cranially. A partial occlusion clamp is applied to the aorta, paying attention not to completely occlude its lumen. Occasionally, calcification precludes the use of a partial occlusion clamp. In these cases, complete isolation of a portion of the aorta may be required and a local endarterectomy is performed. Perfusion is then required above and below the isolated segment to prevent spinal and visceral ischemia. This can be accomplished with partial femoro-femoral cardiopulmonary bypass. Arterial pressure monitoring in both a femoral and a radial artery is helpful to assure good perfusion in either setting. An aortotomy is performed and an appropriate sized woven Dacron (Hemashield, Boston Scientific, Natick, MA) valve conduit (22 to 26 mm) is sutured to the aortotomy with a continuous 4-0 Prolene anastomosis. The partial occlusion clamp is then moved from the aorta to the conduit to check the anastomosis for hemostasis.

Figure 3 An intraoperative photograph showing the radially placed sutures before insertion of the right-angled apical conduit. A stab incision is made in the apex of the left ventricle (LV) using an 11-blade knife. It is started at the apex and extended 1.5 cm anterolaterally toward the base of the heart. The stab incision is then crutiated. A Foley catheter (Murray Hill, NJ) is inserted inside the left ventricle and inflated with saline. This helps to control bleeding from the LV apex. The heart may be left beating or may be fibrillated. The LV apex coring device is spun around the Foley cannula coring out a cylindrical segment of LV apex. A series of large pledgetted 3-0 Prolene sutures is placed around the apex in a circular fashion. Alternatively, a continuous circular "collar" of Teflon felt may be used.

A special LV-roving device is available from Medtronics Inc. (Minneapolis, MN) manufacturers of the apical elbow connector. The device is inserted into the apex via the cruciate incision and a plug of myocardium is removed. The circular knife is sized for the specific elbow desired.

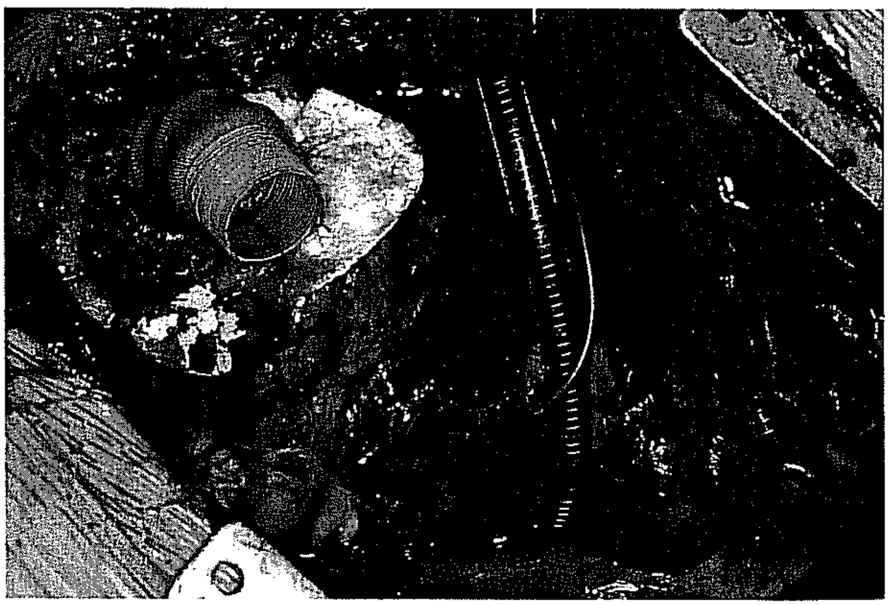

Figure 4 An intraoperative photograph after insertion of the right-angled conduit after suture fixation. The stitches are then radially brought up through the valved conduit sewing ring, and the right-angled conduit (Hancock, Medtronics Inc., Minneapolis, MN) is snugly inserted in the LV apex. The sutures are tied. A layer of bovine serum albumin–glutaraldehyde glue (Bioglue, Cryolife, Inc., Kennesaw, GA) is used to infiltrate the sewing cuff and Teflon felt collar for additional hemostatic control.

The distal anastomosis is usually performed first so that the back side of the anastomosis can be sewn easily and checked for hemostasis. The angled apical conduit is then placed. We prefer full cardiopulmonary bypass and fibrillatory arrest of the heart. This allows for careful, deliberate placement of the conduit within the LV apex. The LV apex of many of the patients having indications for this procedure is fragile and the sutures must be placed and tied carefully to avoid linear ventricular muscle tears. The felt collar aids nicely as a buttress to prevent these tears.

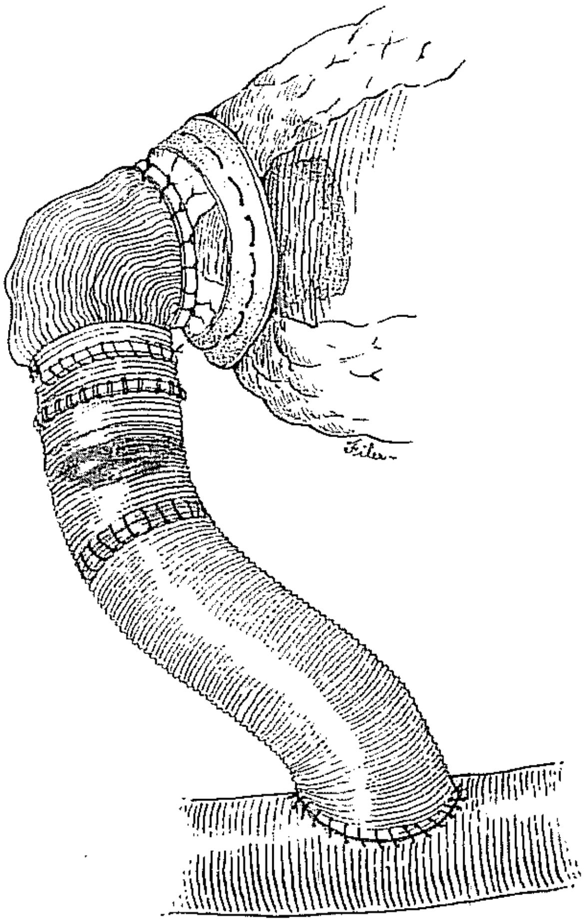

Figure 5 The valved conduit (Hancock, Medtronics Inc., Minneapolis, MN) is then trimmed as close as possible to the valve and sewn to the elbow again trimming the excess graft as short as possible to minimize the "dead space" between the LV and the actual valve. Finally, the valved conduit is connected to the aortic graft, again making it as short as possible to avoid kinking. Before removing the clamps, the conduits must be adequately de-aired.

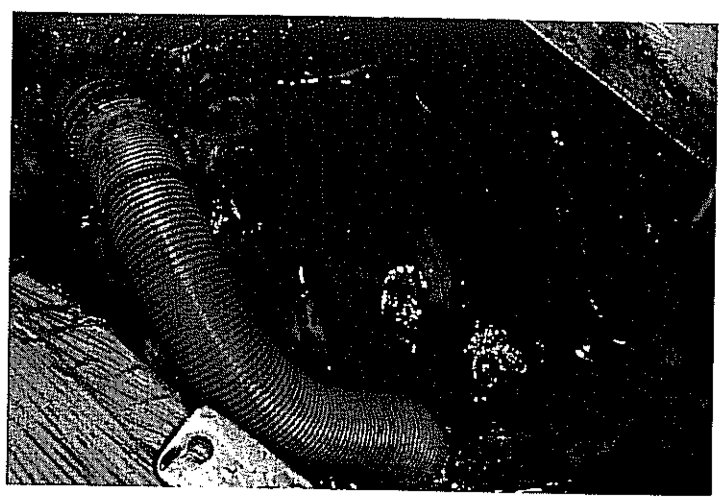

Figure 6 An intraoperative photograph after completion of the apical aortic conduit.

Operative Technique: Sternotomy

This setting usually occurs when a previously undiagnosed porcelain aorta root is encountered after a median sternotomy has already been performed. After the pericardium is opened and suspended on the left side, a site for aortic cannulation is chosen. If the ascending aorta, the arch, or an axillary artery is chosen for cannulation, then it is preferable to insert an additional arterial line in a femoral artery, to ensure adequate monitoring of perfusion pressure to the lower body when the partial occlusion clamp is placed on the descending thoracic aorta. Likewise, if the femoral artery is cannulated, a radial artery monitoring line is used.

A two-stage right atrial cannula is used for venous return to the pump, and, whenever possible, an aortic needle tack vent is inserted in the ascending aorta for adequate de-airing.

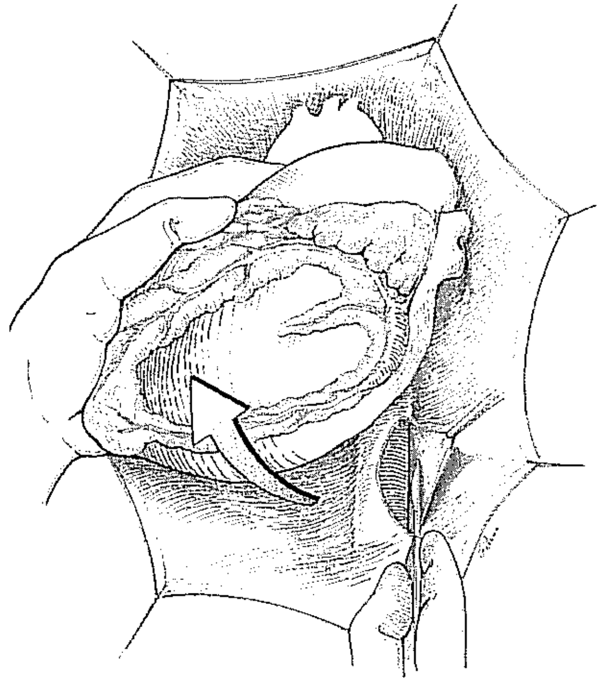

Figure 7 The relevant anatomy and exposure of the distal descending thoracic aorta via the posterior pericardium through a median sternotomy. After institution of normothermic cardiopulmonary bypass (CPB), the right pleural space is opened widely to improve mobilization and retraction of the heart in the right chest.

As the apex of the heart is lifted and retracted toward the right chest, the posterior pericardium is opened with a longitudinal incision starting 1 cm caudal to the left inferior pulmonary vein and extending 6 cm toward the diaphragm.

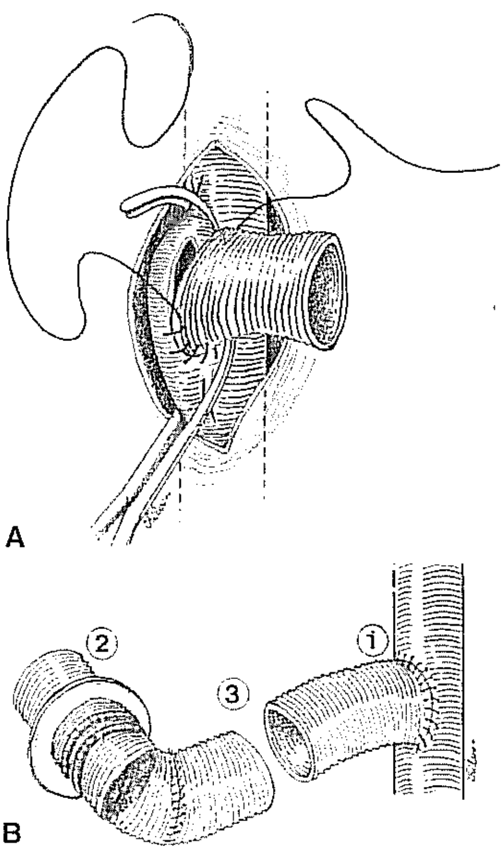

Figure 8 (A) Clamp position for the distal valve conduit to distal descending thoracic aorta anastomosis. The descending thoracic aorta is dissected free laterally to the esophagus, and a long partial occlusion clamp is applied to the aorta. The anastomosis is deep and difficult. Obtaining adequate hemostasis of the valve conduit to descending thoracic aortic anastomosis is critical as it is nearly impossible to place repair sutures after the return of the heart to its normal position. (B) The sequence of anastomoses for the anterior median sternotomy approaches.

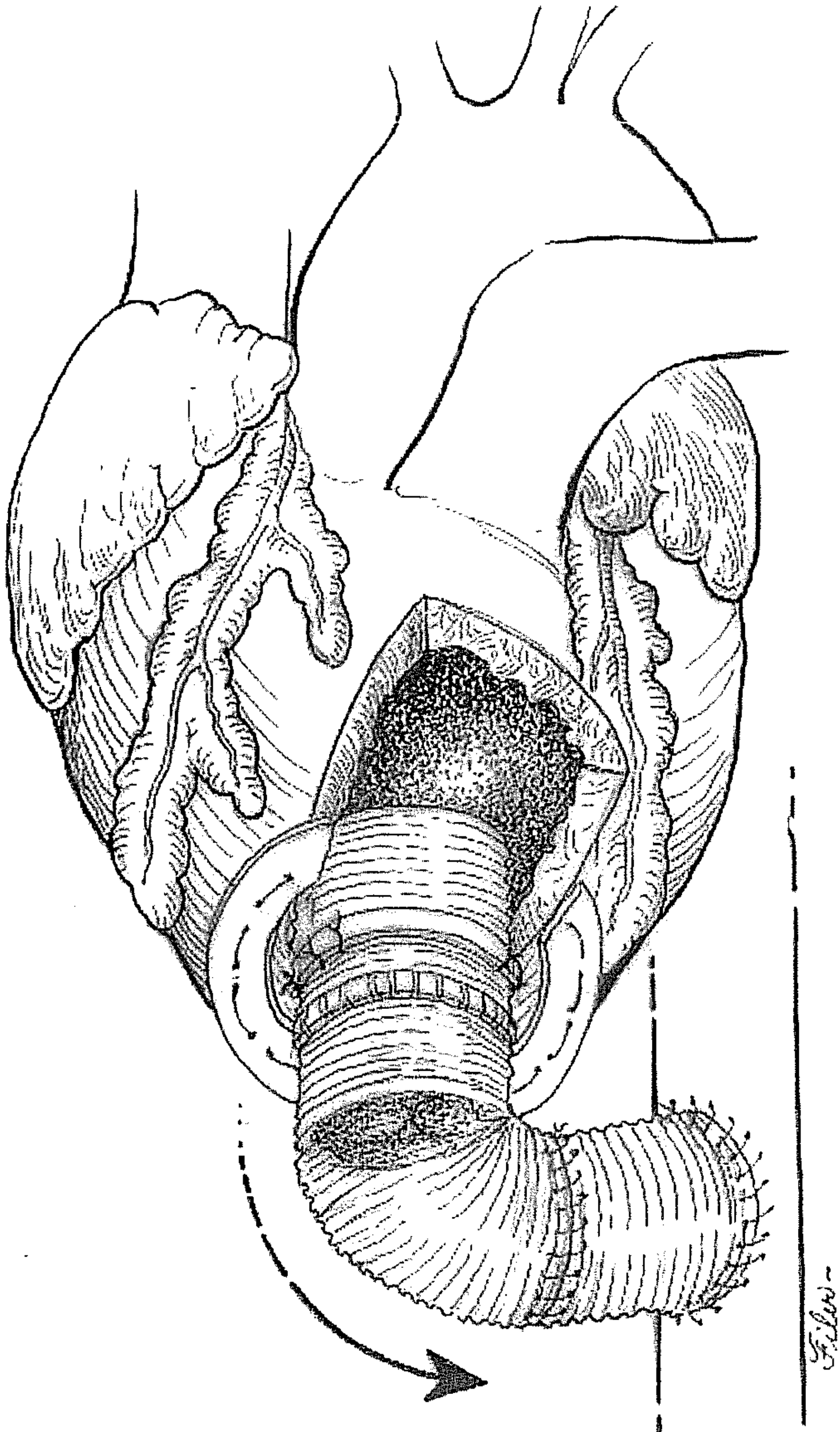

Figure 9 The final position of the apical aortic conduit for the anterior median sternotomy approach. This is a schematic view of the completed operation.

Special Circumstances

Several situations prevent safely performing a standard aortic valve replacement, the most common being a porcelain aortic root. Extensive calcification can involve the entire aortic root as well as the ascending aorta and arch, which not only makes it nearly impossible to seat the valve prosthesis but also precludes cross-clamping and cannulation.

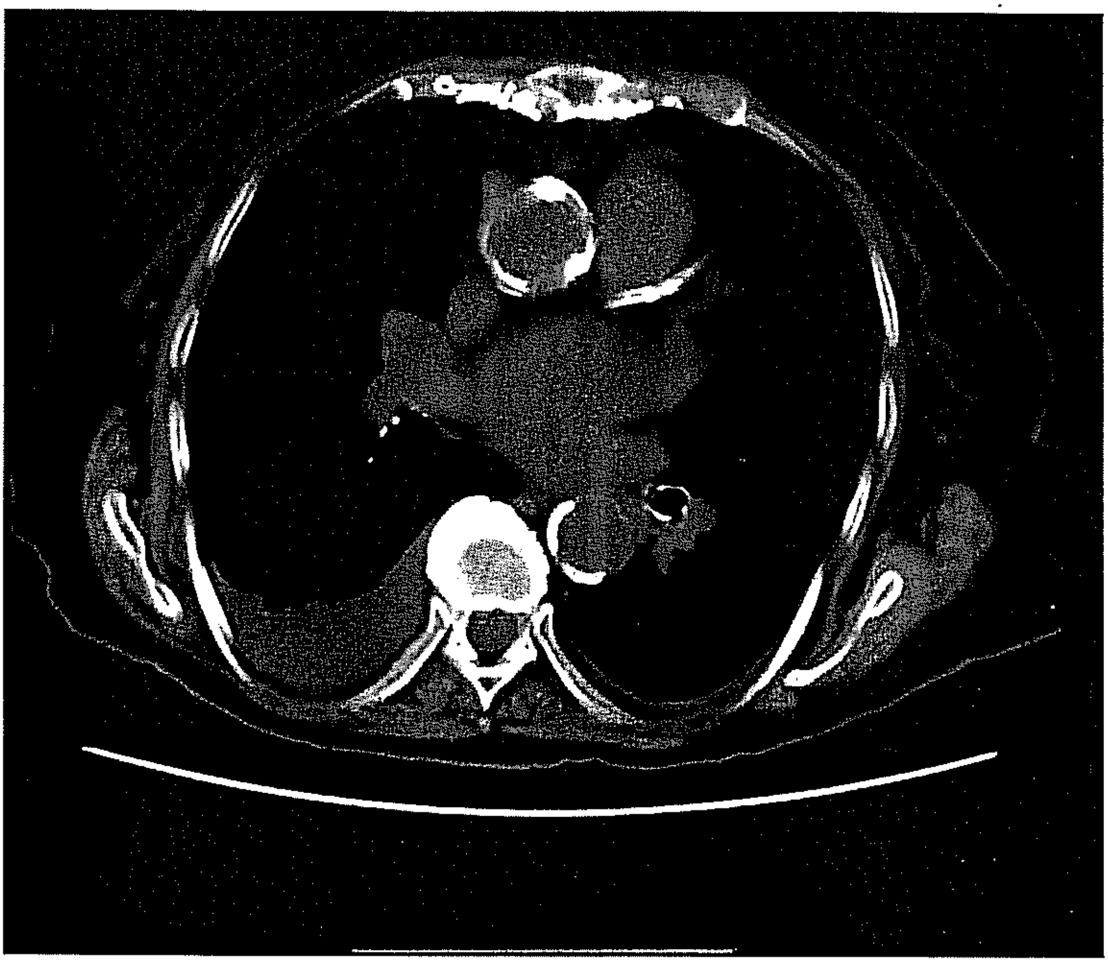

Figure 10 A preoperative CT scan of an 85-year-old patient depicting a porcelain aortic root. Note the nearly completely calcified left coronary system. The patient had a patent retrosternal right internal thoracic artery graft to the left anterior descending coronary artery bypass graft and patent left internal thoracic artery to obtuse marginal coronary artery bypass graft. These cases have been performed with alternative axillary or femoral artery cannulation with a period of hypothermic circulatory arrest to replace or endarterectomize the aortic root and ascending aorta. Morbidity and mortality have been high with this approach because of the risk of complications related to dissection, embolization, and bleeding.[1-4] A 30-day mortality of 9% and mid-term survival of 40% have been reported in a series using this technique.[3] Other patients for whom one would consider the apical approach are those presenting with an extremely risky redo sternotomy. Potential situations include previously placed patent arterial grafts tightly adherent to the posterior sternum in the midline, multiple previous sternotomies, or previous mediastinal radiation, or a situation in which a patient has a retrosternal colonic interposition.[5]

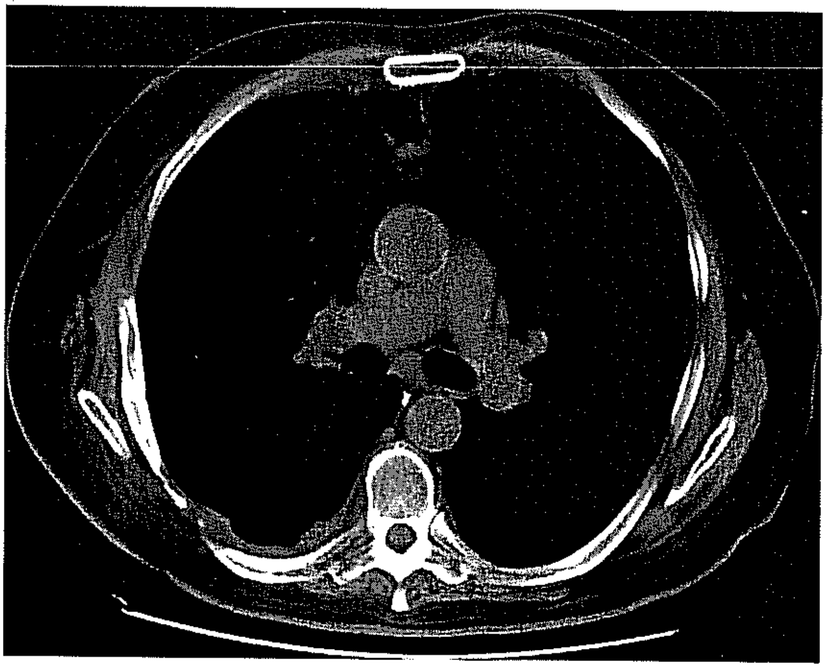

Figure 11 A preoperative CT scan on a patient with a previous replacement of his esophagus with a retrosternal colonic interposition graft. Note the additional extensive calcium in the ascending thoracic aortic wall. Apical aortic conduits have been used in pediatric or young adults with annular hypoplasia and subvalvular left ventricular outflow tract tunnel stenosis.[6-8]

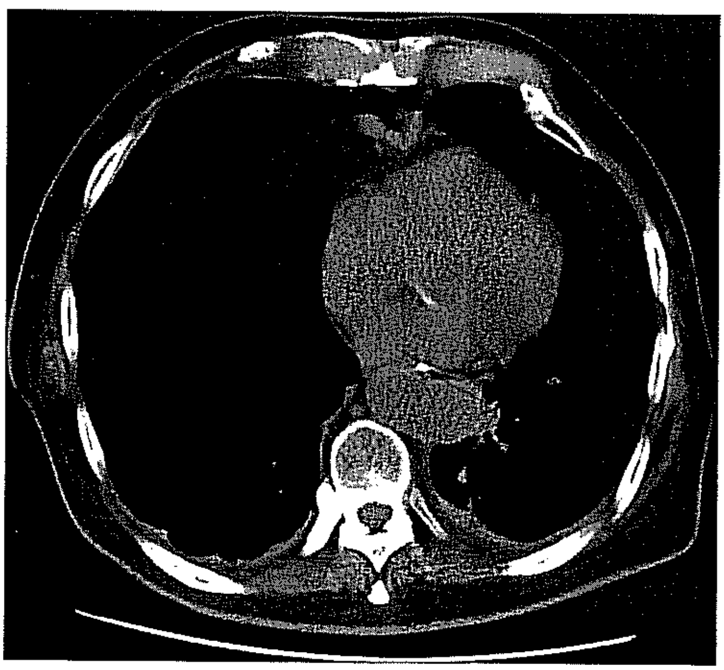

Figure 12 A postoperative CT scan detailing the apical aortic conduit to descending thoracic aortic anastomosis. Because of concerns of sluggish flow within the aortic root after placement of the conduits, we recommend that the patients be maintained on warfarin and low-dose antiplatelet therapy. This is a theoretical concern but is based on echocardiographic observations from patients having received a left ventricular assist device from the left ventricular apex to the descending thoracic aorta with similarly altered hemodynamics.

Discussion

Early and late mortality in patients undergoing an apical–aortic conduit has been reported to be similar to patients undergoing conventional surgery with similar comorbidities.[1,3,5] However, the left thoracotomy approach alternative is often technically much easier particularly in the setting of multiple previous median sternotomies. The procedure can be done with no cross-clamp, no hypothermic circulatory arrest, and markedly less time on cardiopulmonary bypass. Most importantly, the risk of perioperative stroke is markedly decreased.

Because there are no annular constraints to conduit insertion, the appropriate valve conduit size should be chosen according to body surface area to avoid patient prosthesis mismatch.[9] Because the native aortic valve remains, however, a large prosthesis is not generally required. Furthermore, in order to minimize prosthetic obstruction, a larger valve conduit may be placed with a smaller elbow connector, beveling the anastomosis. Postoperative echocardiographic assessment requires a transesophageal approach as the function of the valved conduit cannot be adequately assessed by surface echocardiography. A CT scan is useful to delineate the path of the conduit within the left chest and to assess anastomotic integrity during follow-up.

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