Operative Techniques in Thoracic and Cardiovascular Surgery

Pulmonary Valve Preservation Strategies for Tetralogy of Fallot Repair

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The optimal repair for tetralogy of Fallot is challenged by the management of the small right ventricular outflow tract (RVOT), which was initially solved by John Kirklin who determined that the absence of the pulmonary valve could be well tolerated owing to low pulmonary artery pressure and preserved right ventricular function.[1] This assumption was affirmed in a significant number of patients who tolerated the persistent effects of right ventricular volume overload for many years. In a significant number of postoperative patients, however, long-term complications of pulmonary regurgitation, residual ventricular septal defects (VSD), distal pulmonary artery stenosis, right ventricular dysfunction, atrial or ventricular arrhythmias, and exercise intolerance[2-5] required further operative intervention to address the residual defects, perform concomitant arrhythmia surgery, and pulmonary valve insertion.

Valve-sparing strategies at the initial reparative operation started to emerge in succeeding decades with efforts to retain the native pulmonary valve with extensive valvotomy techniques and acceptance of high intraoperative right ventricular to left ventricular pressure ratios of 0.7 or less.[6-10] Transannular patches, when necessary, involved a strategy of transatrial RVOT resection, transatrial VSD closure, and limited ventriculotomy, oftentimes not extending the incision more than 1-2 cm. Under these circumstances, transannular patches were intentionally downsized and reconstructed to result in right ventricular gradients of approximately 20 mm Hg.[11,12]

More comprehensive valve-sparing techniques that included a supravalvar pantaloon autologous pericardial patch for supravalvar pulmonary stenosis were highlighted by several authors.[8–10] These techniques permitted an increased incidence of pulmonary valve preservation during initial repair in up to 70% of patients[8] compared with 40% or less in other reports.[13,14] The following drawings highlight the technique of pulmonary valve preservation by supravalvar pantaloon pericardial patch pulmonary artery arterioplasty (Figs. 1-8).

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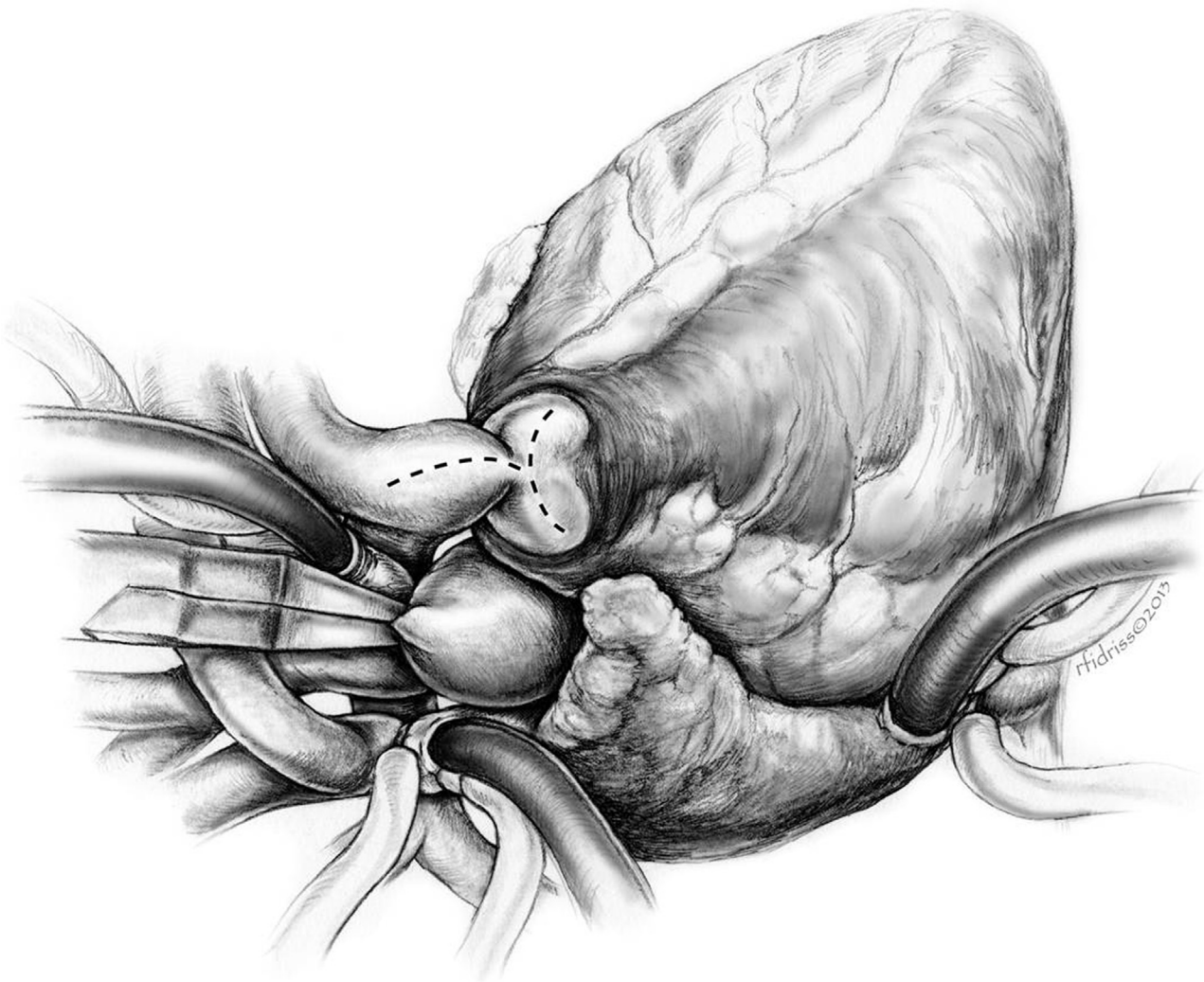

Figure 1 Artist's representation of a patient with tetralogy of Fallot and significant RVOT obstruction with supravalvar stenosis undergoing mild hypothermic aortobicaval cardiopulmonary bypass with aortic cross clamping and cardioplegic arrest. The dotted lines show the area where the incisions are to be made in an upside down "Y" configuration into the anterior facing pulmonary valve sinuses of Valsalva.

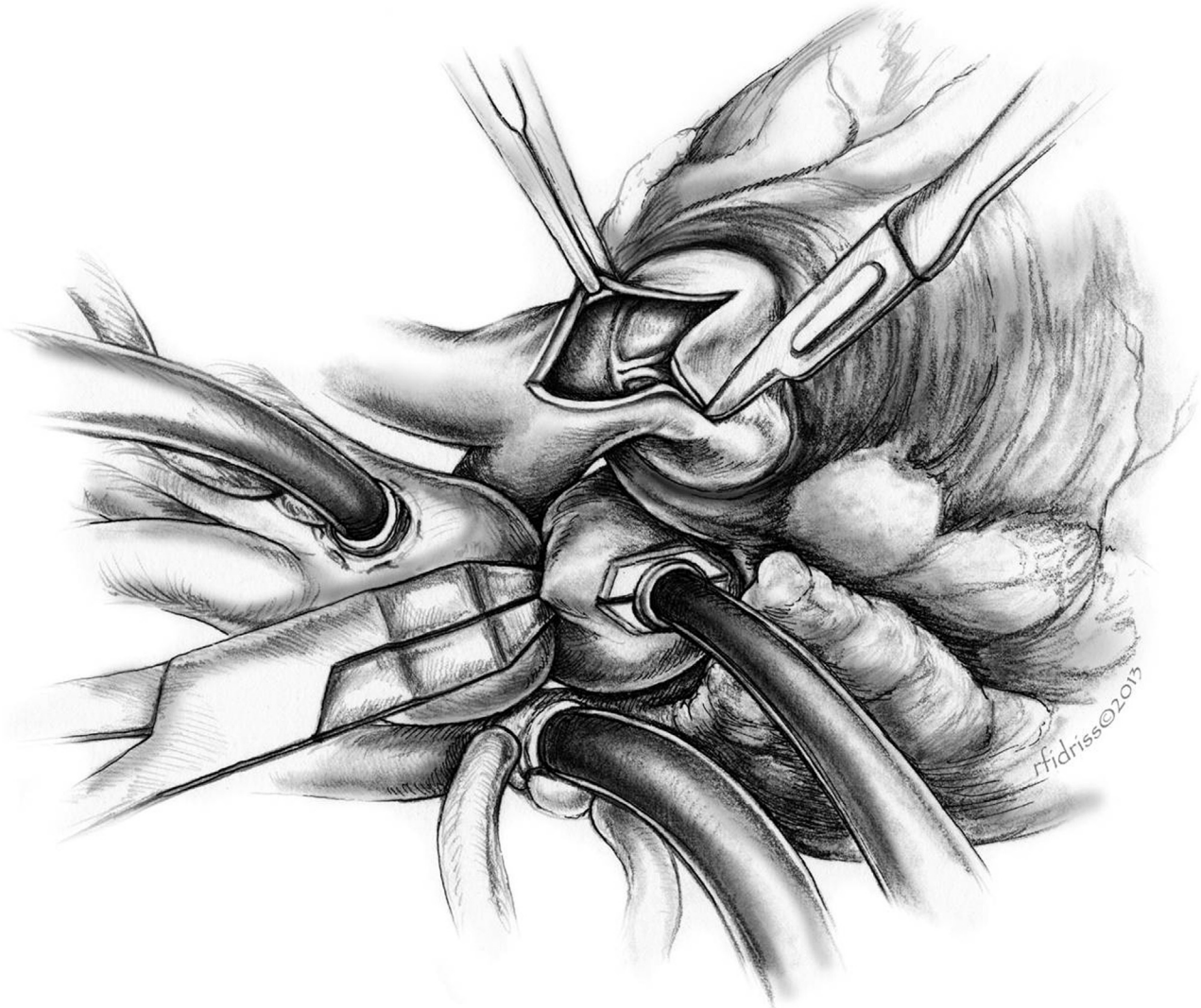

Figure 2 The vertical incision is commenced superior to the pulmonary valve, and the incisions are extended into the sinuses of Valsalva in the event that there is an anterior-posterior orientation of a bicuspid pulmonary valve or into the 2 facing sinuses if there is a tricuspid pulmonary valve. If the pulmonary valve is bicuspid and oriented in a horizontal position, a linear incision into the facing sinus of Valsalva is performed. The incisions are extended to approximately 1-2 mm from the pulmonary valve annulus.

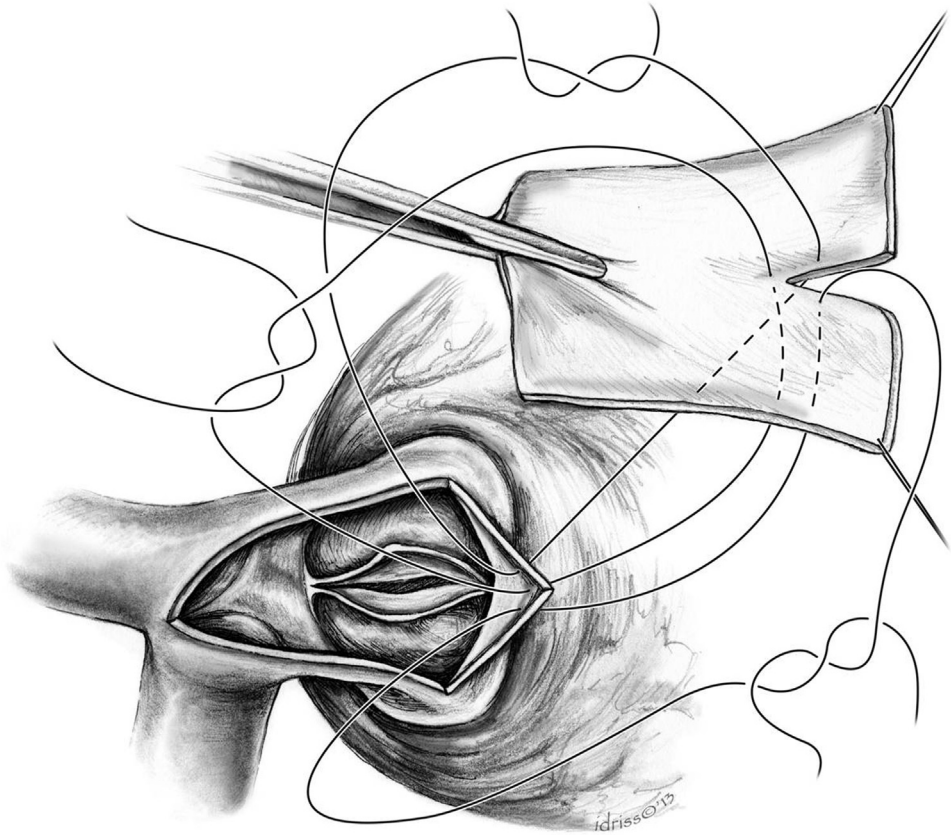

Figure 3 Once the pulmonary valve is exposed, careful anterior and posterior and strategic valvotomies are performed to open the orifice but not cause significant distortion that can result in regurgitation. Local detachment of the commissural attachments is avoided because of the associated and resultant regurgitation that this maneuver can cause as well. A subvalvar, transpulmonary artery muscle resection to compliment the already performed muscle resection through the right atrium and tricuspid valve can be accomplished. The RVOT can now be measured by sized dilators, which should be introduced carefully to avoid valvar injury by excessive dilatation. An autologous pericardial patch is cut to size and in a pantaloon configuration. Three interrupted sutures are placed at the incised portion of the pericardial patch and tied. The purpose of these interrupted sutures is to prepare for a subsequent transannular patch across the reconstruction without suture line disruption in the event that the resultant right ventricular pressure proves excessive.

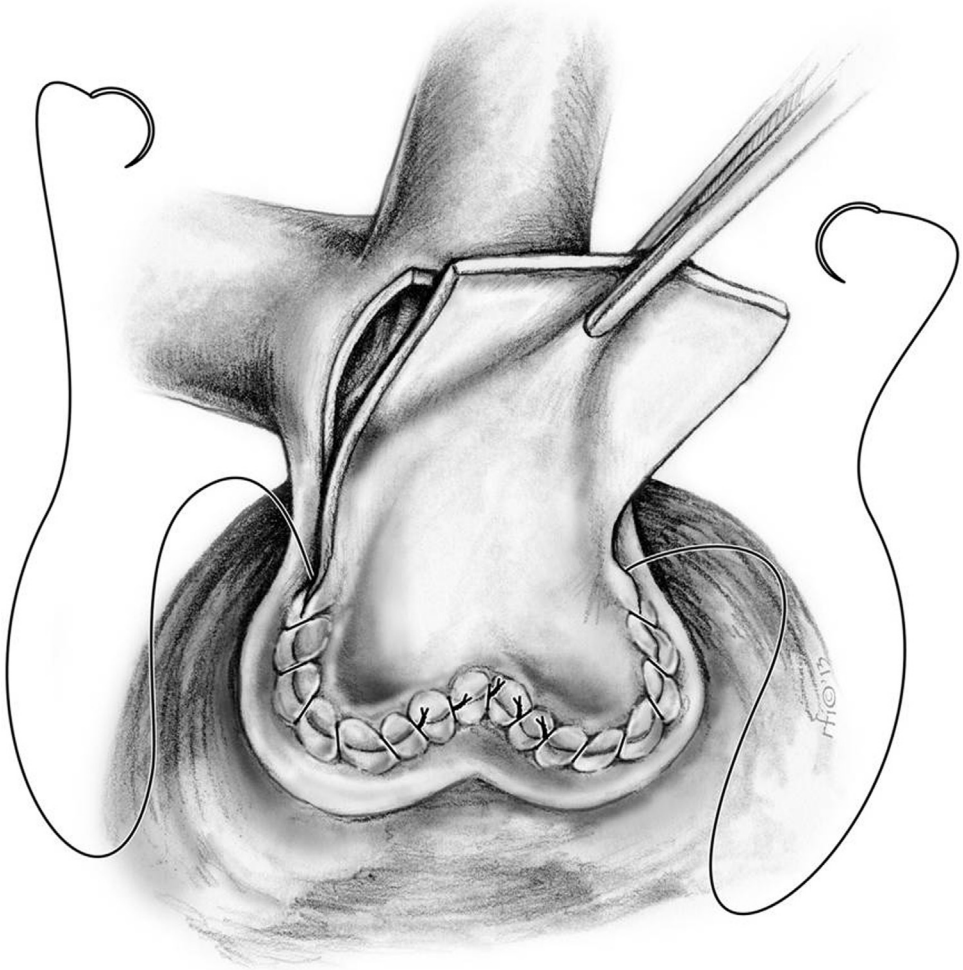

Figure 4 Once the interrupted sutures are placed in the incised portion of the pericardium, a running suture technique is commenced to augment the respective and incised sinuses of Valsalva. At this point of the operation and after the VSD and atrial septal defect are closed, the cross clamp can be removed and the patient can be rewarmed. The left ventricular vent is allowed to drain and the vena cava catheters are allowed to capture the right atrial return without caval tapes.

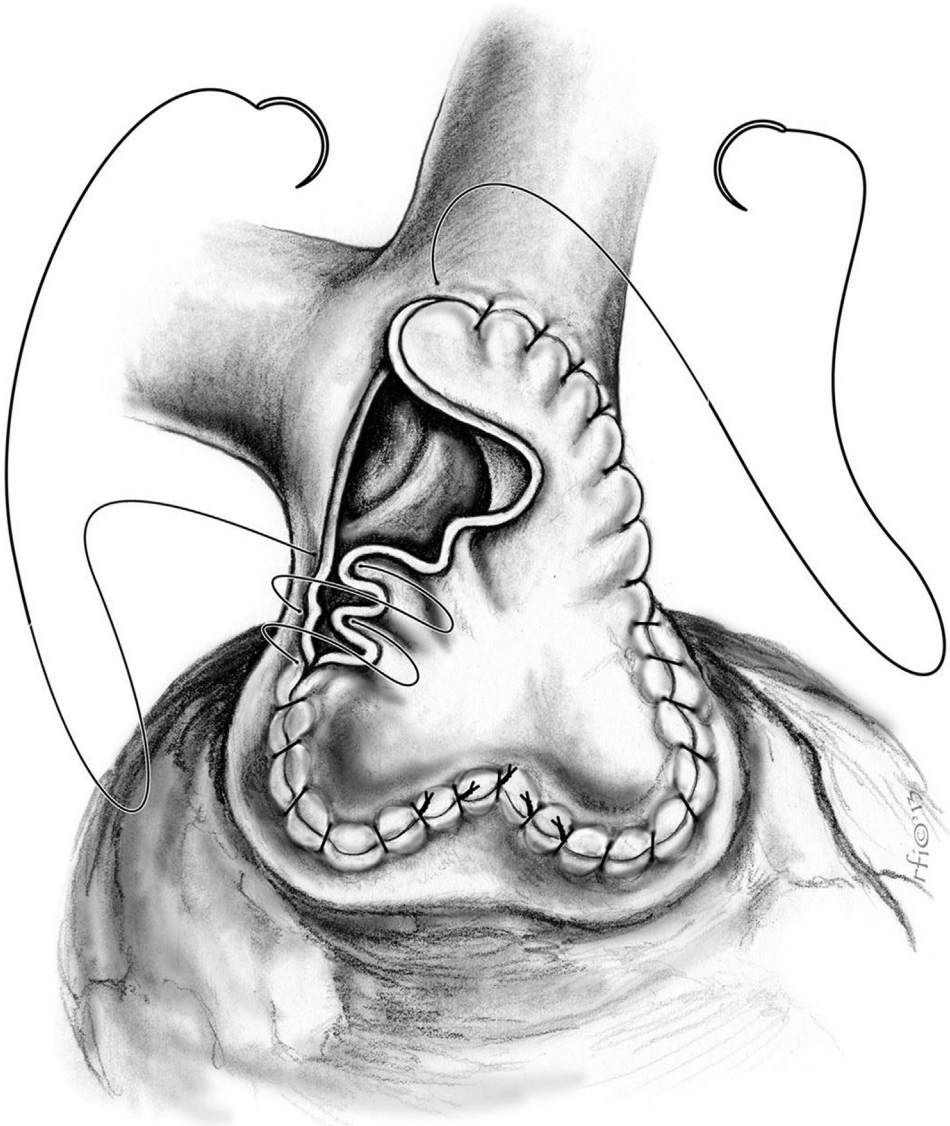

Figure 5 Rather than tapering the superior portion of the pericardial patch to the estimated exact size and risk resultant supravalvar stenosis, the pericardial patch is left in a redundant size and the suture line technique is performed by gathering the pericardium to match up with the extant pulmonary artery wall.

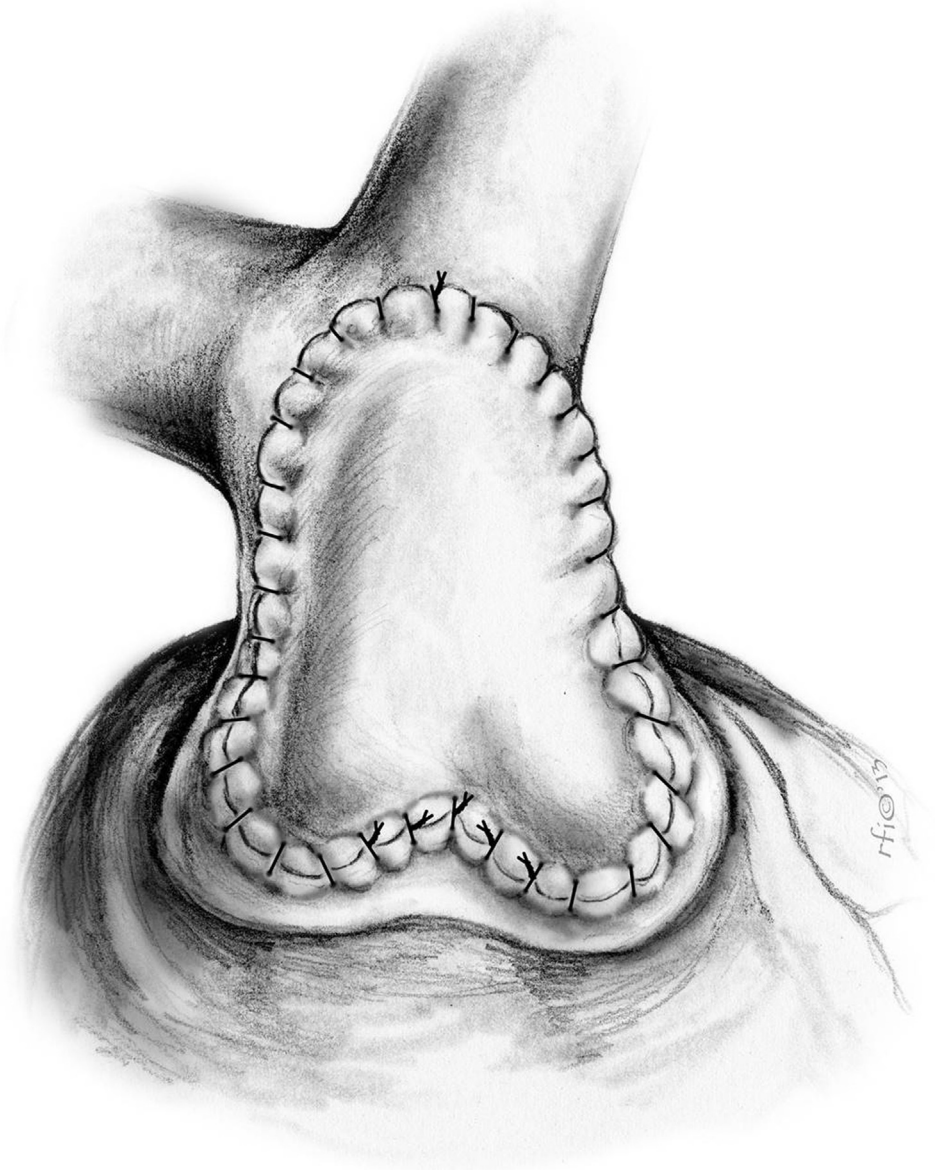

Figure 6 Artist's representation of the complete repair.

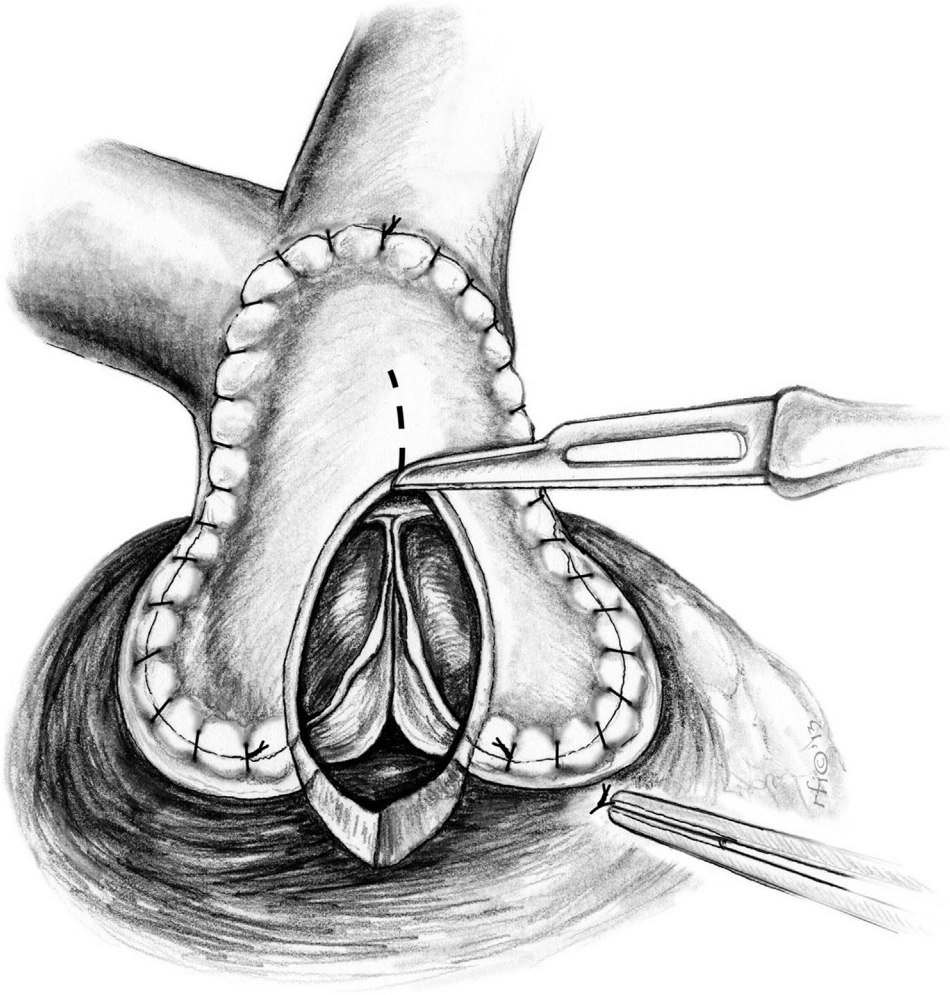

Figure 7 In the event that right ventricular hypertension attends the completed repair after separation from cardiopulmonary bypass, resumption of cardiopulmonary bypass can be instituted and a transannular patch can be performed. One or 2 interrupted sutures can be removed without disrupting the entire extant pulmonary reconstruction. The incision across the anterior commissure is performed carefully to allow the valvar attachments to remain in place and maintain competency. Recent reports have extolled the virtue of this maneuver in the event that future operations for pulmonary insufficiency might be necessary.[15,16,18] Growth of these leaflets might allow restoration of the pulmonary valve by bicuspidization thereby avoiding the placement of a homograft, heterograft, or polytetrafluoroethylene pulmonary valve at the subsequent operation. A limited right ventriculotomy with extension in the pericardial patch can then be performed as noted to prepare for the RVOT reconstruction.

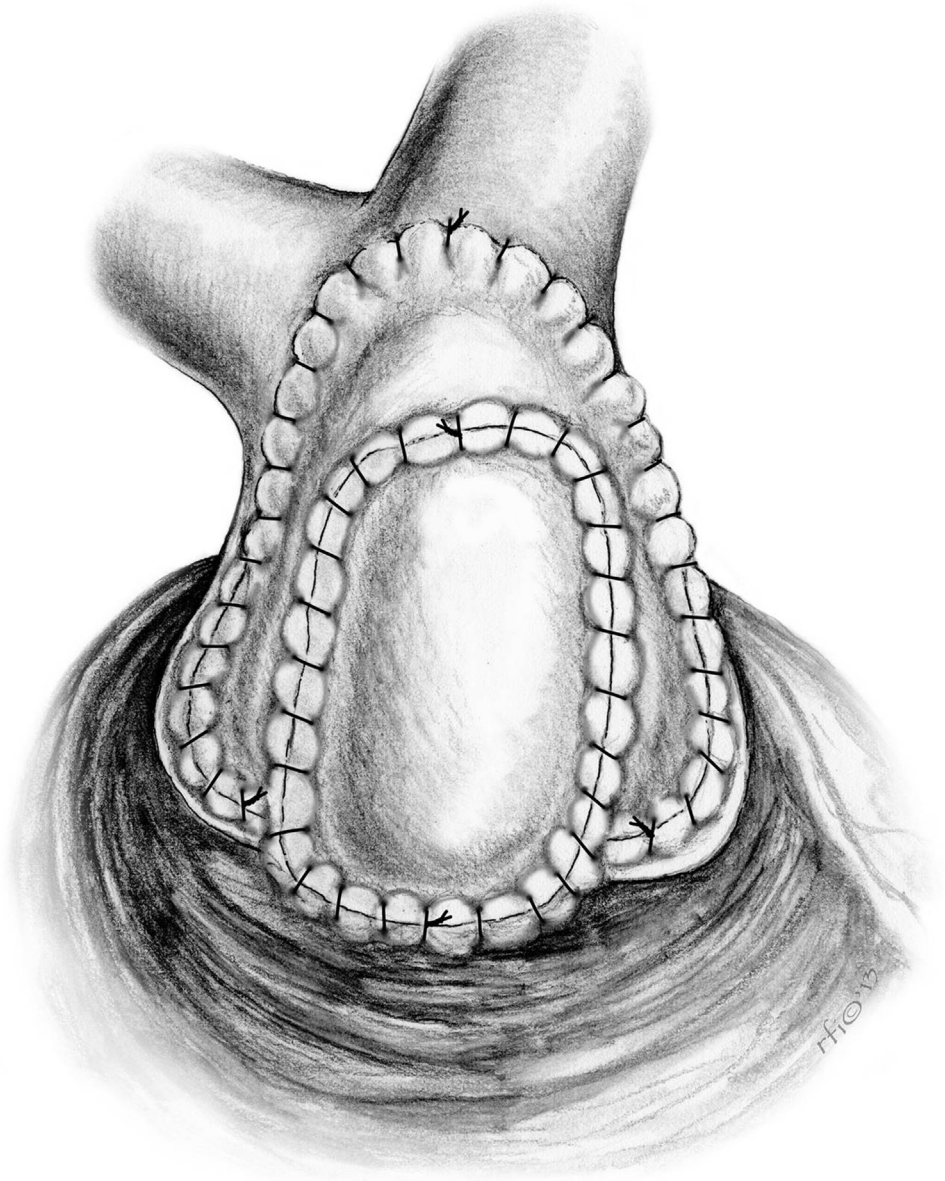

Figure 8 Artist's representation of the completed RVOT reconstruction with a patch-on-patch configuration.

Discussion

The described technique herein shows how the pantaloon pericardial patch arterioplasty can be performed in the presence of a bicuspid pulmonary valve oriented in an anterior-posterior position. With some adjustments, the same can be accomplished in a tricuspid pulmonary valve. In the case of a bicuspid pulmonary valve oriented in a horizontal position, a pericardial pulmonary artery arterioplasty into the anterior sinus of Valsalva can be completed without the pantaloon adaptation. One could add a separate pericardial arterioplasty for the posterior sinus of Valsalva; however, the technical challenge and possibility of bleeding complications have mitigated against this strategy for the time being. The basic strategy for this operation is to relieve the supravalvar stenosis, preserve the function of the pulmonary valve, and allow for the possibility of somatic growth.

Usually the supravalvar pulmonary artery arterioplasty is performed after VSD and atrial septal defect or patent foramen ovale closure during cardioplegic arrest. This allows careful suture placement especially at the pulmonary annulus and sinuses of Valsalva. The surgeon has the option of removing the cross clamp at any time during this reconstruction if the ischemic arrest time becomes excessive.

Relief of subvalvar stenosis is an important part of the RVOT reconstruction as any stenosis below the valve will mask the success of the valve preservation operation. Oftentimes, a separate prosthetic patch will be necessary to ensure an unobstructed pathway to the pulmonary annulus. In general, the only stenosis of the RVOT that should be tolerated in this situation is at the pulmonary valve annulus.

Although this valve preservation strategy would be successful for most patients, there are some patients who would require a transannular patch as noted in Figs. 7 and 8. Recent advances in native pulmonary valve intervention late after tetralogy of Fallot repair have highlighted various techniques that can restore the function of the pulmonary valve [15-20] without resorting to valve-replacement strategies.[21,22] For these valve preservation strategies to be applicable, the conduct of pulmonary valve manipulation at the original operation is foundational. The original pulmonary valvar anatomy must be respected and includes maintenance of pulmonary valve commissural attachments during the transannular incision in anticipation of somatic growth and the possibility of future restoration. This is best accomplished when a bicuspid pulmonary valve oriented in an anterior-posterior position is encountered allowing for an accurate and pinpoint transannular incision at the point of the commissural attachments. The resultant incision would usually be centered in the RVOT away from the respective locations of the left anterior descending coronary artery and the right coronary artery, assuming of course that there are no anomalous coronary origins or courses. A horizontal orientation of the pulmonary valve that would require a transannular incision represents the most challenging situation of first-time management with the thought of future restoration. Some authors[19] have incised the anterior leaflet at its middle portion and augmented it with a polytetrafluoroethylene membrane patch in association with the transannular patch, the idea being that the remaining incised valve leaflets would be the substrate for future valve restoration. Although this technique is an attractive potential solution, no long-term reports of restoration have been published to date. Small tricuspid pulmonary valves that require a transannular patch represent complex solutions dependant on the extant anatomy and the respective sizes of the cusps. Oftentimes, the anterior cusp is small with a correspondingly small leaflet. In these situations, the anterior leaflet can be resected in association with a transannular patch with a reasonable possibility that the remaining valve leaflets, if not sacrificed, would be available for a valve restoration procedure by bicuspidization.[18] The other theoretical options not yet reported are to incise the annulus at the medial or lateral commissure. This approach requires an off-center transannular incision owing to the location of the extant cusps, which endangers the respective coronary arteries and challenges the exposure for an adequate subvalvar muscle resection and relief of the RVOT obstruction. Practical wisdom and clinical experience would determine whether this approach would be attempted in the future.

Valve-sparing techniques for repair of tetralogy of Fallot are being evaluated and are the subject of intense study for both the initial operation and any subsequent restorative procedures. Even so, there would always be patients who would require bioprosthetic alternatives. The search for a durable valve leaflet that can undergo appropriate somatic growth and maintain proper function over the long term is still the goal for those unfortunate patients who require a transannular patch.

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