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Left Anterior Mini-Incision for Pulmonary Valve Replacement Following Tetralogy of Fallot Repair

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Abstract

Pulmonary insufficiency is a known complication following Tetralogy of Fallot repair. With over 90% of patients now surviving to adulthood, surgeons are once again faced with the question of when, and more importantly, how to reintervene. We developed a novel approach to pulmonary valve replacement in this population through a 5-cm left anterior mini-incision. The incision is optimized for exposing and operating on the right ventricular outflow tract and the main pulmonary artery in patients with a history of median sternotomy. Early outcomes are reassuring, and we believe our approach is a safe and reliable alternative to median sternotomy within this patient population, with the ability to quickly convert intraoperatively when needed.

Keywords

pulmonary valve replacement, Tetralogy of Fallot, congenital heart defect, minimally invasive congenital cardiac surgery

Central Message

Our early results suggest that a minimally invasive approach to pulmonary valve replacement following Tetralogy of Fallot repair is a safe and reliable alternative to median sternotomy.

Introduction

Pulmonary insufficiency is a known late complication following Tetralogy of Fallot (ToF) repair. Symptoms include tachyarrhythmia, dyspnea, exercise intolerance, and if left untreated, right ventricular enlargement and heart failure.[1–3] With over 90% of ToF patients now surviving to adulthood, surgeons are once again faced with the question of when, and more importantly, how to reintervene.[4–6]

Surgical and percutaneous options exist for pulmonary valve replacement (PVR) following primary ToF repair. The standard surgical approach for PVR in this population is a median sternotomy. For the first or second median sternotomy, this risk may be acceptable.[7] However, when patients are expected to require multiple PVRs throughout their lifetime, this risk quickly compounds.[7–11] Percutaneous approaches avoid a median sternotomy, yet they are not always possible given patient anatomy.[12–14] ToF patients who do undergo percutaneous PVR often require complex stent-in-stent constructs and have an increased risk of coronary compression (5% to 6%), stent fracture (16% to 34%), and infective endocarditis (2.4% annually).[15–17]

To avoid these risks, we have developed a novel approach to PVR following primary ToF repair through a left anterior mini-incision (LAMI), when possible. The following article summarizes our first year with this approach and how a technique adopted from adult cardiac surgery avoids repeat sternotomy, while providing excellent visualization of the right ventricular outflow tract (RVOT) and main pulmonary artery (MPA) during valve replacement.

Preoperative Evaluation

Candidates for PVR via LAMI are patients who underwent ToF repair via sternotomy in infancy. Most patients considered for this approach are 10 to 20 years old and ideally weigh greater

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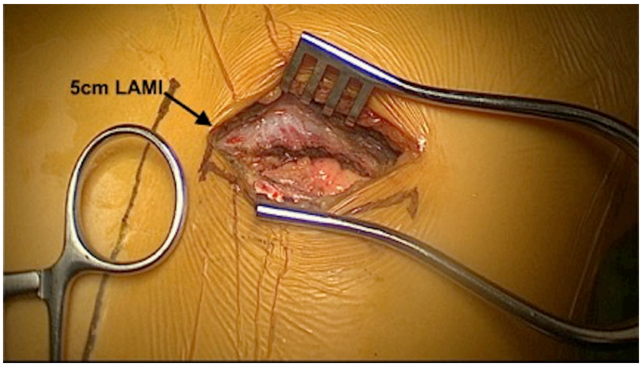

Fig. 1. Left anterior mini-incision (LAMI) relative to midline. The incision is 5 cm in length and positioned over the third rib with the ability to complete the dissection inferiorly into the second or third intercostal space in order to provide the best exposure.

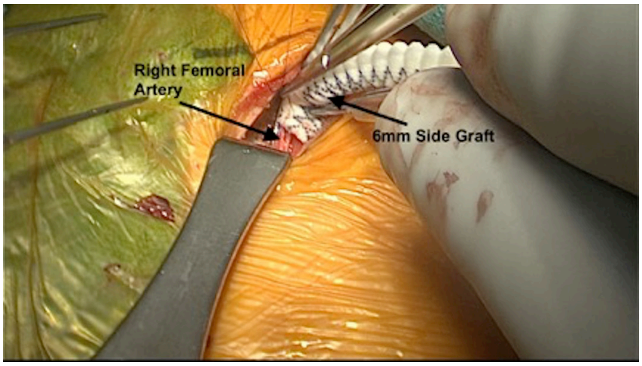

Fig. 2. Arterial cannulation via right femoral artery. Through a 3-mm cutdown incision in either groin, a 6-mm dacron graft is sewn end-to-side to the femoral artery for arterial cannulation.

than 30 kg, at which point cannulation of femoral vessels is considered feasible. All patients undergo preoperative echocardiogram with bubble study to confirm the absence of septal defects prior to a beating-heart operation. Minimally invasive approaches to PVR are also usually avoided in patients who are morbidly obese or those who have undergone prior repair or palliation with conduits that may be injured when dissecting through adhesions.

Surgical Technique

The chest and bilateral groins are prepped and draped. Of note, the primary surgeon is positioned to the patient's left throughout the operation. A 5-cm incision is made just lateral to the sternum in the left third intercostal space. The dissection is carried down to the pericardium through the third intercostal space while preserving the internal mammary artery (Fig. 1). At this time, the degree of adhesions and exposure of the RVOT are evaluated and, if the minimally invasive approach is deemed appropriate, peripheral cannulation is pursued.

The patient's right femoral vein (and, in some instances, left subclavian vein) is percutaneously accessed via micropuncture technique. From the femoral access site, a guide wire is positioned in the right atrium and, after heparinization, a multistage venous cannula is advanced into position. Left subclavian access is secured in case additional venous drainage is needed intraoperatively. A 3-cm oblique incision is then made in the right groin and the femoral artery is exposed and controlled with vessel loops. The femoral artery is cannulated with a 6-mm Dacron branch sewn end-to-side (Fig. 2). Although ipsilateral femoral vein and artery are typically used, the contralateral artery may be used in smaller patients. Cardiopulmonary bypass is then established.

With the right heart now decompressed, adhesions are divided and pericardium opened. The RVOT, MPA, and branch pulmonary arteries are exposed. A longitudinal incision is then made in the RVOT extending up the MPA to the level of the bifurcation (Fig. 3). Coordination with the perfusion team as well as suction catheters in the RVOT and bilateral branch PAs are crucial for achieving a near-bloodless field during beating-heart operation.

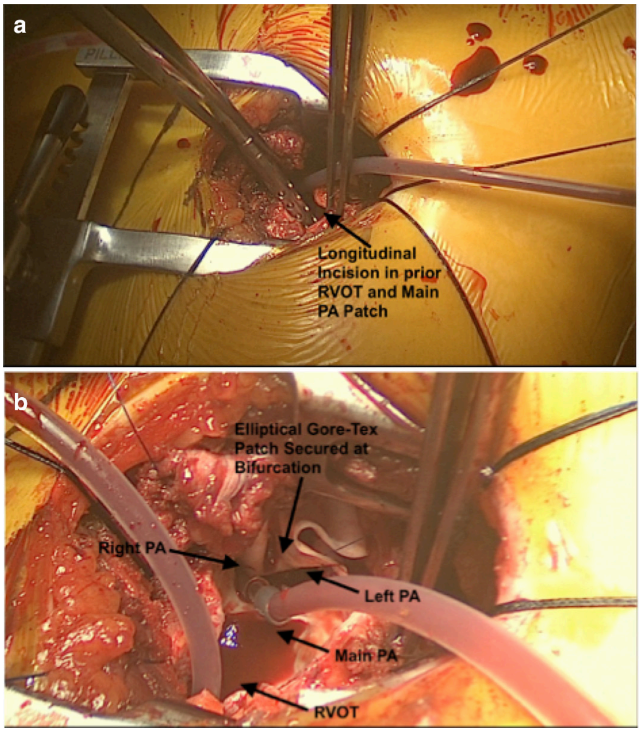

Fig. 3. Exposure of right ventricular outflow tract (RVOT) and pulmonary artery (PA) via left anterior mini-incision (LAMI). a) View of mini-rib retractor, pericardial retention sutures to provide appropriate exposure. b) View of drop suction placement inferiorly into the RVOT and superiorly into the main PA. The apex of the patch has been secured to bifurcation.

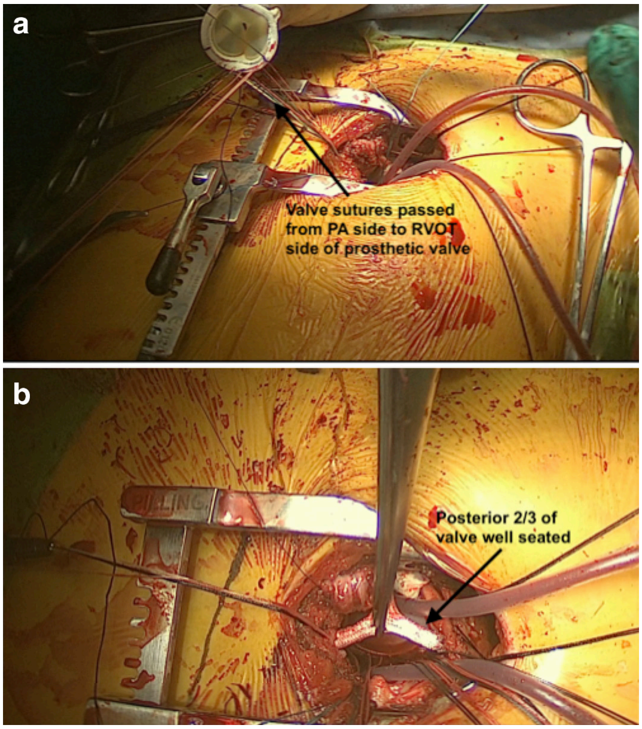

Fig. 4. Parachuting and seating the pulmonary valve. a) Double-arm nonabsorbable braided valve suture is placed through the annulus posteriorly such that pledgets are on the main pulmonary artery (PA) side of the annulus and the free arms arm brought through the sewing cuff to exit on the right ventricular outflow tract (RVOT) side of the valve. b) The posterior two-thirds of the valve sewing ring is being secured.

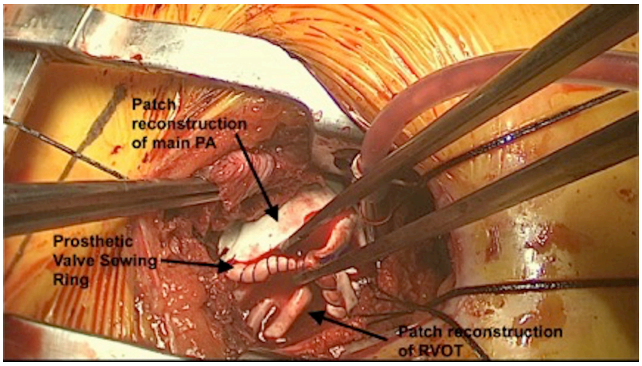

Fig. 5. Completed pulmonary valve replacement (PVR) with patch augmentation prior to closure through a left anterior mini-incision (LAMI). View of completed PVR and right ventricular outflow tract (RVOT) patch augmentation. The pickups are grasping the sewing ring of the bioprosthetic valve, the anterior one-third of which has been secured to the trans-annular Gore-Tex patch with looped running nonabsorbable monofilament suture.

An elliptical patch of 0.5-mm Gore-Tex is then cut to size and secured with a double-loaded suture to the PA bifurcation. The patch is sewn down each side of the main PA to the level of the pulmonary valve. A bioprosthetic valve is then sized to the RVOT using sizers upside-down to best navigate the incision. Interrupted horizontal mattress nonabsorbable braided sutures with pledgets are then placed along the posterior two-thirds of the native annulus. Note that suture is passed through the annulus "top down" with pledgets on PA side and with the free ends directed inferiorly into the RVOT. Sutures are then passed through the prosthetic valve sewing ring to ultimately position the valve at or just below the native annulus (Fig. 4). The posterior two-thirds of the valve is secured into position using CorKnot (LSI Solutions, Victor, NY, USA), such that the knots are on the RVOT aspect of the valve, as the ideal approach angle through LAMI is toward the underside of the valve.

The Gore-Tex patch is then folded over the sewing ring of the valve and secured to the anterior one-third of the sewing ring with looped running nonabsorbable monofilament suture to complete seating of the valve. Finally, patch augmentation of the RVOT is performed by continuing the original suture line along the sides of the MPA down each side of the RVOT to the nadir of the elliptical patch (Fig. 5).

With the repair complete, the patient is weaned off cardiopulmonary bypass and the adequacy of the repair evaluated by transesophageal echocardiography. If the repair is sound without significant pulmonary insufficiency or paravalvular leak, the femoral venous cannula is removed. For the femoral arterial side graft, we favor removing the graft and repairing the vessel rather than clipping/oversewing as there is concern for narrowing the vessel with this approach. Typically, a patch repair of the arteriotomy is performed with bovine pericardium. For patients without prior sternotomy, drains are left in the left pleural and pericardial spaces. For patients with prior sternotomy, only a left pleural drain is left. The incision is closed in layers and the patient is extubated in the operating room before transporting to the intensive care unit (ICU).

Results

Seven patients underwent 8 PVRs for pulmonary insufficiency following ToF repair between July 2018 and June 2019. Patients had undergone 1 to 3 prior median sternotomies and their ages ranged from 11 to 54 years with 5 of the 7 patients being younger than 18 years. The median time since their primary ToF procedure was 14.7 years (interquartile range [IQR] 12.8 to 30.4 years). The median cardiopulmonary bypass time was approximately 2.5 hours (IQR 2.3 to 3 hours), and the median operating time was 5 hours (IQR 4.7 to 5.6 hours). Two patients experienced complications. One was taken back to the operating room for paravalvular leak requiring redo PVR and the other was converted from LAMI to median sternotomy due to dense adhesions.

The median ICU stay was 2 nights (IQR 1 to 4.5 days) while median hospital stay was 5 nights (IQR 3.5 to 6 days). The average pain score on postoperative day 1 and 3 was 3.6 and 1.9 out of 10, respectively, requiring on average 35 and 13 morphine equivalents per day.

During the most recent follow-up after hospital discharge (351 days, IQR 60 to 406 days), there were no evidence of phrenic nerve injury, wound infection, pericardial effusion, musculoskeletal impairment or other late complication.

Discussion

Pulmonary insufficiency is a known complication following primary ToF repair. Given the young age at which patients undergo their first PVR, it is expected that they will require multiple PVRs over their lifetime. Historically these repairs have been done through a median sternotomy, although recently endovascular as well as minimally invasive techniques are becoming more common. Over the last year, we started performing our PVRs following primary ToF repair through an LAMI when possible.

Intraoperatively, an LAMI provides many advantages over a traditional median sternotomy. Once the pericardium is opened, an LAMI is paradoxically optimized for patients with previous sternotomy. Due to the dense scar tissue in these redo cases, the heart naturally rotates in a clockwise fashion with the pulmonary artery sitting more anterior than would be expected in patients who have not previously undergone median sternotomy. From the left third intercostal space, this places the incision directly over the PA and RVOT. Being in line with the RVOT, we have found it easier to position the valve and knots below the annulus. Although technically challenging at first, this approach improves apposition of the valve and RVOT wall and avoids paravalvular leak in our experience. Furthermore, as we demonstrated, this technique does not preclude conversion to a median sternotomy.

A technical limitation of this approach is the ability to perform a beating-heart surgery through such a small incision. Entry into the chest is significantly improved by initiating cardiopulmonary bypass before entering the pericardium, which allows the right ventricle and PA to decompress. Once the pericardium is open, a near-bloodless field is critical. We vent the pulmonary arteries and right ventricle with drop suction. If this approach is insufficient, we add a single-stage venous cannula through our left subclavian vein access. It is critical to communicate with the perfusion team and work together to create a near-bloodless field.

Postoperatively, early trends suggest that patients tolerate this approach well with limited use of narcotics. Although a small sample size, we believe our approach is a safe and reliable alternative to median sternotomy for this patient population. As our experience grows, we anticipate that our results will continue to improve with time and we will develop a more robust understanding of who is and is not an ideal candidate for this approach.

Declaration of Conflicting Interests

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