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BRIEF COMMUNICATION

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Tetralogy of Fallot: T-shaped infundibulotomy for pulmonary valve-sparing procedure

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Abstract

This new and easily reproducible pulmonary valve-sparing technique for the correction of Tetralogy of Fallot is based on a conservative management of the native pulmonary valve to preserve its growth potential. From July 2015 to December 2019, 67 children presenting with a Tetralogy of Fallot were operated consecutively in a single centre using this technique in all cases. A T-shaped infundibulotomy is used to release the anterior pulmonary annulus from any muscular attachment. After myocardial resection and ventricular septal defect closure, an extensive commissurotomy is achieved. Finally, the right ventricular outflow tract remodelling is completed by a shield-shaped bovine patch with an oversized square superior edge, attached directly on the pulmonary valve annulus, with an effect of systolic traction. Sixty patients (89.5%) had a Tetralogy of Fallot repair with preservation of the pulmonary valve. To date, with a median follow-up of 38.2 [14–64] months, no patient has needed a surgical or interventional procedure for pulmonary valve stenosis or regurgitation, with low residual gradients. This procedure could provide a significant increase in native pulmonary valve preservation. Long-term studies are needed to assess pulmonary valve growth and the consequent reduction in surgical or interventional reoperations.

Keywords: Tetralogy of Fallot • Surgical repair • Pulmonary valve-sparing

INTRODUCTION

Tetralogy of Fallot (ToF) repair often leads to significant pulmonary valve insufficiency, with well-established long-term complications [1, 2]. Most attempts to reconstruct the pulmonary valve at the initial repair stage fail to provide an effective long-term result [3]. We present a new pulmonary valve-sparing technique offering an easily reproducible approach, based on a conservative management of the pulmonary valve to preserve its growth potential.

PATIENTS AND METHODS

After analysis of our surgical practices, we defined a new technical strategy using a T-shaped infundibulotomy for pulmonary valve-sparing procedure (TS-PVSP), which we have routinely applied since July 2015. From this date to December 2019, 67 children with ToF were operated consecutively in a single centre using this technique in all cases. At the time of surgery, their median age and weight were, respectively, 8.3 months [2.9–148] and 7.6 kg [4.8–40]. The sex ratio was 0.47. The preoperative pulmonary annulus Z-scores were evaluated on transthoracic echocardiography, but were not considered as criteria for TS-PSVP, as all patients were supposed to benefit from this routine technique.

This new technique consists of 2 main steps (Video 1).

Right ventricle outflow tract remodelling

To prevent the section of a significant coronary artery, the infundibular incision is marked by sutures. On cardiopulmonary bypass (CPB), after aortic clamping and cold blood cardioplegia, a T-shaped incision of the infundibulum is performed (Fig.1A). The longitudinal incision is made until the pulmonary annulus is reached. A transversal incision is then made, detaching the fibrous pulmonary annulus from the myocardium. Contrarily to an other reported T-shaped incision within muscle [4], this transversal incision provides a complete release of the anterior half of the pulmonary annulus. Care should be taken to avoid damaging the pulmonary valve or the left descending artery. Following this, the edges of the infundibulotomy are partially resected longitudinally to give a perfect profile of the right outflow tract. Muscular

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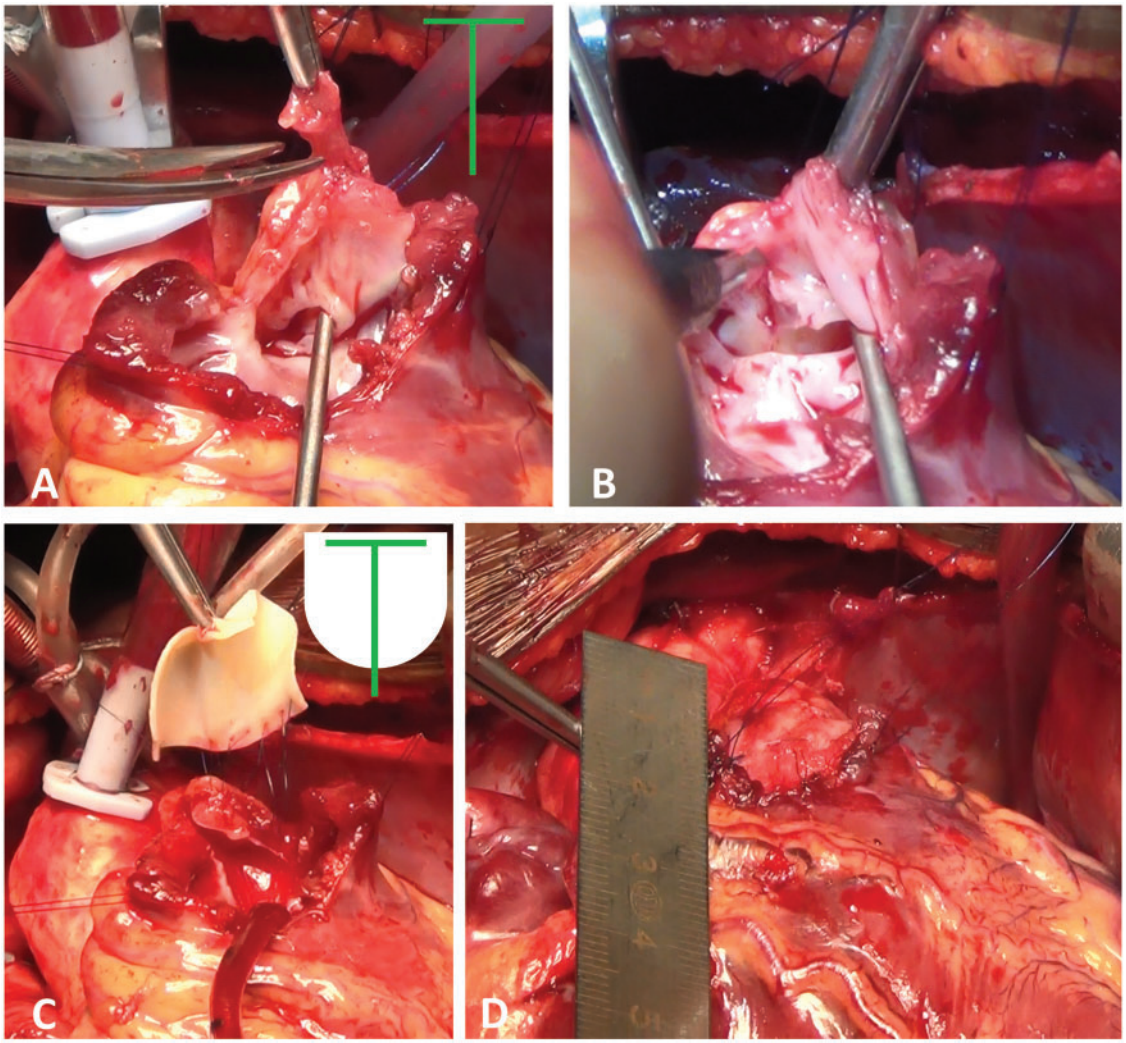


Figure 1: Surgical technique of the T-shaped pulmonary valve-sparing procedure. (**A**) A longitudinal infundibulotomy is performed up until the pulmonary annulus. The anterior part of the annulus is released by a transversal incision, detaching muscle from the annulus. (**B**) After muscular resection and ventricular septal defect closure, an extensive commissurotomy is achieved. (**C**) A bovine pericardial patch, with an oversized square superior edge, is sutured directly on the anterior part of the pulmonary annulus. (**D**) The excess of the patch is resected giving the shape of a shield on the final result.

resection of the right ventricle (parietal band) and closure of the ventricular septal defect with a bovine pericardial patch are then carried out through the infundibulotomy or right atriotomy.

Pulmonary valve plasty

This combines the described pulmonary annulus release and a valve commissurotomy. After mobilization of the leaflets, the commissurotomy is achieved extensively to the pulmonary artery wall (Fig.1B). The size of the annulus, pulmonary trunk and branches is then assessed by dilatators. If necessary, an enlargement of the root, sinotubular junction, trunk or branches of the pulmonary artery is associated. After de-airing the left cavities and removing the aortic clamp, the right ventricle outflow tract (RVOT) remodelling is completed with a shield-shaped infundibular bovine pericardial patch. The superior edge sutured directly on the anterior part of the pulmonary annulus is straight and oversized by one-third, to tract the annulus when the heart is loaded (Fig.1C). The 2 other edges are curved and shorter than the infundibulotomy to limit the patch surface (Fig.1D). After weaning from CPB, the transoesophageal echocardiography and direct measurement of the pressures led in a few cases (when right ventricular systolic pressures were superior to 2/3 of systemic pressures or the right ventricle to pulmonary artery (RV/PA) systolic gradient was above 40 mmHg) to resume CPB for the pulmonary valve section and implantation of a trans-annular patch .

RESULTS

From July 2015 to December 2019, 67 consecutive patients were treated with our routine TS-PVSP procedure. There were no postoperative or late deaths related to surgery. Sixty (89.5%) had a ToF repair with preservation of the pulmonary valve. Seven patients (10.5%) had a trans-annular patch repair after a failed TS-PVSP attempt with a significant residual gradient on intraoperative transoesophageal echocardiography or pressure measurement. If the right ventricle systolic pressure was superior to

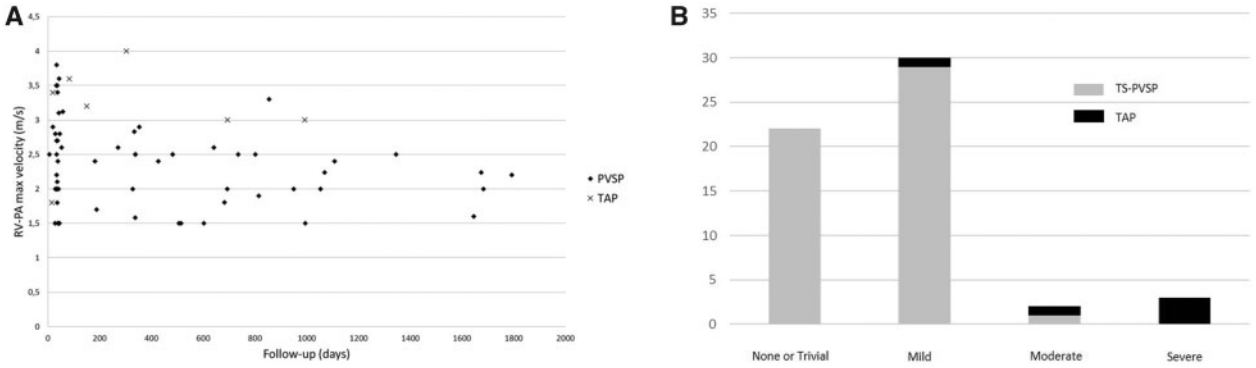


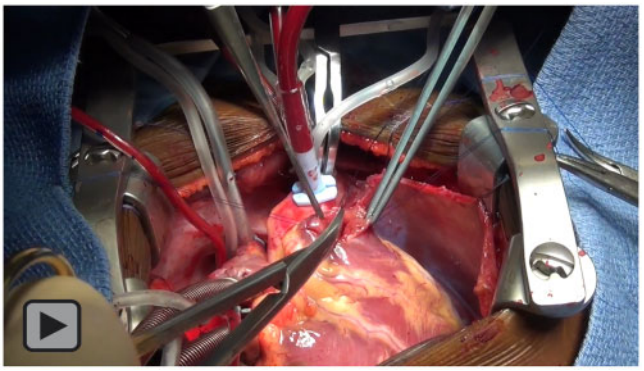
Figure 2: Initial mid-term results. (**A**) Maximal velocity at last echo-Doppler control. (**B**) Pulmonary valve insufficiency on last echocardiography. TAP: trans-annular patch; TS-PVSP: T-shaped infundibulotomy for pulmonary valve-sparing procedure.

2/3 of the aortic systolic pressure, or the RV/PA systolic gradient was above 40 mmHg, whatever the size of the annulus, CPB was resumed, and a trans-annular patch repair was achieved (in all 7 cases).

Seventy-eight per cent (52/67) of the pulmonary valves were bicuspid with variable levels of dysplasia. Nevertheless, the anterior release of the pulmonary annulus associated with extensive commissurotomy resulted in annulus expansion with an acceptable intraoperative size (Z-score values greater than -2.5) in all cases. There were 12 pulmonary trunk enlargements and 5 branch enlargements, in 12 patients.

Retrospectively, the average Z-score value was -2.42 (± 1.18) on preoperative transthoracic echocardiography. Despite a trend, there was no significant difference between patients who underwent TS-PVSP (-2.36 ± 1.21) and those who had a trans-annular patch (-3.14 ± 0.72), $P = 0.13$.

The median follow-up was 38.2 [14–64] months. No patient who underwent TS-PVSP needed a further surgical or interventional procedure for pulmonary valve stenosis or regurgitation. One patient underwent a reintervention 12 months after the initial repair for significant residual ventricular septal defect and branch stenosis, but no additional correction was necessary on the pulmonary valve presenting a normal growth (from 9 to 13 mm, on intraoperative measurements). For the 60 patients with TS-PVSP, based on the latest echographic evaluation, the average maximal velocity on the pulmonary valve was 2.41(±0.68) m/s (Fig. 2A). In this group of patients, all pulmonary regurgitations (except one) were less than moderate (Fig. 2B).



Video 1: In this regular Tetralogy of Fallot, the right ventricle outflow tract narrowing is marked by sutures away from the coronary arteries. A short longitudinal infundibular incision is achieved up until the pulmonary annulus. The right ventricle outflow tract remodelling starts with careful resection of the muscular trabeculae and refining of the edges. The parietal band is then resected giving easy access for the ventricular septal defect closure using a bovine pericardial patch. Complete release of the anterior half part of the pulmonary annulus achieves the T-shaped infundibulotomy. A square retractor is introduced under the valve leaflet to precisely locate the annulus. The section between the muscle and fibrous annulus is performed carefully to avoid damaging the valve or LDA. An extensive anterior and posterior commissurotomy is achieved on this sagittal bicuspidy. The valve then easily admits a full-size dilatator. The bovine pericardial patch is shaped like a shield with an upper straight edge, one-third larger than the anterior edge of the pulmonary annulus. This right ventricle outflow tract enlargement patch can be implanted under aortic cross-clamping or on a beating heart. The final result shows low pressures in the right ventricle, respected coronary vascularization and a small infundibular bulging patch with a systolic traction effect on the annulus.

DISCUSSION

Right ventricle incision is often criticized because it induces late ventricular dysfunction and arrhythmia [5]. However, it remains the most effective way to correct non-circular narrowing of the RVOT, due to the anterior displacement of the conal septum [6]. In TS-PVSP, the short length of this incision and cautious coronary arteries preservation, aim to preserve right ventricle function, in association with an effective pulmonary valve.

RVOT remodelling by muscular resection and a shield-shaped infundibular patch prevents the recurrence of RVOT muscular stenosis. The residual gradients are mostly valvar and could be treated by conservative balloon valvuloplasty, if needed on long-term follow-up [7].

We hypothesize that to ensure maximal growth of the pulmonary valve, we should avoid sutures and adjunction of material on the valve tissue (such as pericardial or homograft neo-cusp), optimize opening by effective commissurotomies and release the pulmonary annulus as much as possible. Furthermore, the shield-shaped infundibular patch, with a square oversized superior edge, achieves a systolic traction on the anterior part of the annulus and could favour valvar growth.

Finally, the suture of the infundibular patch on the fibrous annulus suppresses muscular isthmus and the risk of re-entry around the patch and related arrhythmia [5].

CONCLUSION

This new and easily reproducible pulmonary valve-sparing strategy should provide a significant increase in native pulmonary valve preservation. Long-term studies are needed to assess

pulmonary valve growth and the reduction of surgical or interventional reoperations with possible improvement in the long-term prognosis of ToF.

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Conflict of interest: none declared.

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