Current approaches to pulmonary regurgitation

Alessandra Frigioia,b, Victor Tsanga,c,*, Johannes Nordmeyer a,d, Philipp Lurza,d, Carin van Doorn a,c, Andrew M. Taylora,d, Philipp Bonhoeffer a,c, Mark de Levala

Abstract

Objective: To evaluate the effects on ventricular function and volumes following right ventricular outflow tract reconstruction (RVOTR) with pulmonary homograft replacement (PVR) and percutaneous pulmonary valve implantation (PPVI) for predominant pulmonary regurgitation. This study was not intended to compare the two approaches. Methods: We prospectively examined 25 patients (mean age 21 ± 13 years, 96% tetralogy of Fallot, 1/25 with conduit dysfunction) who had PVR with RVOTR for severe pulmonary regurgitation (PR), and 11 patients (mean age 20 ± 9 years, 64% tetralogy of Fallot, 9/11 with conduit dysfunction) who underwent PPVI for predominant PR. Mean age at primary repair in both groups was 4.3 ± 6.6 years. Magnetic resonance imaging was performed prior to, and 1 year following, interventions. Results: Before procedure, NYHA classification was similar in both groups 2.1 ± 0.5. Following interventions, there was a significant reduction in RV volumes in both groups. In the surgical (PVR) group, RV end-diastolic volume (EDV) decreased from 151 ± 49 to 97 ± 32 ml/m² (p < 0.0001) whereas end-systolic volume (ESV) decreased from 80 ± 43 to 46 ± 23 ml/m² (p < 0.0001). In the PPVI group, RV EDV decreased from 106 ± 27 to 89 ± 25 ml/m² (p = 0.002) and RV ESV from 49 ± 20 to 40 ± 16 ml/m² (p = 0.034). Both groups had a significant improvement in RV (63 ± 20 to 72 ± 16 ml/beat, p = 0.003 (PVR group); 53 ± 14 to 67 ± 16 ml/beat, p = 0.030 (PPVI group)) and LV effective stroke volume (61 ± 18 to 73 ± 16 ml/beat, p = 0.001 (PVR group); 59 ± 24 to 75 ± 16 ml/beat, p = 0.009 (PPVI group)). Conclusions: Following either PVR with RVOTR or PPVI, there was a significant reduction in RV volumes and an improvement in RV function. Importantly, in both groups, LV effective SV increased, and this may be the parameter to judge the benefit of the procedure. These results also support PPVI as an extra dimension in complex RVOT management.

Keywords: Pulmonary regurgitation; Pulmonary homograft; Percutaneous pulmonary valve implantation; Magnetic resonance imaging

1. Introduction

The number of patients requiring re-intervention for right ventricular outflow tract (RVOT) dysfunction following initial repair of a wide spectrum of congenital heart diseases is constantly increasing. This is secondary to improved survival combined with growing awareness of the detrimental long-term effects of pulmonary regurgitation. Long standing pulmonary regurgitation is now widely recognised to have adverse effects on exercise tolerance, right ventricular function, and ventricular and atrial arrhythmia susceptibility [1–5]. Furthermore, the current inclination is to insert a competent valve at an earlier stage in order to preserve right ventricular (RV) function [6]. Surgical intervention remains the preferred option for re-intervention; however, the longevity of the RV to PA conduits is an important limiting factor when considering surgical pulmonary valve replacement. Conduit degeneration leading to stenosis and/or regurgitation exposes the patient to a high number of re-interventions with the related risks. Therefore timing for intervention is crucial in the patient management and the possibility of a percutaneous approach to correct RVOT dysfunction is an attractive solution which has recently become available with promising results [7–10]. Furthermore, assessment of the RV response to treatment has to be interpreted with caution, as there is often a physical reduction in the size of the RV body during surgery. Since the percutaneous approach is free from any intervention on RV cavity itself, this represents a good model to assess the effect of a competent valve on cardiac function.

* Corresponding author. Address: Cardiothoracic Unit, Great Ormond Street Hospital for Children, Great Ormond Street, WC1N 3JH, London, United Kingdom. Tel.: +44 2078138106; fax: +44 2078138262.
E-mail address: tsangv@gosh.nhs.uk (V. Tsang).
With the following study we wanted to assess the impact on right and left ventricular function following two different techniques, a surgical (PVR) and a percutaneous pulmonary valve implantation (PPVI). This study was not intended to compare the two different strategies because of differences in baseline characteristics and criteria for re-intervention.

2. Materials and methods

Since October 2002, PPVI has been available for use in the clinical setting at our institutions (Great Ormond Street Hospital for Children and The Heart Hospital, London, UK) as possible complementary treatment to surgery for RVOT dysfunction. All patients presenting in the clinical setting with evidence of significant pulmonary regurgitation were fully investigated with magnetic resonance (MR) imaging, echocardiography and exercise testing. Symptoms (NYHA class) and presence of arrhythmias were also recorded.

Indications for surgical pulmonary valve replacement (PVR) were the presence of severe pulmonary valve regurgitation (regurgitant fraction (RF) ≥ 35% on MR imaging) in a dilated pulmonary trunk, reduced exercise capacity, atrial and/or ventricular arrhythmias, progressive RV dilatation and dysfunction, a RV/LV ratio ≥ 1.5 in the presence of symptoms and ≥ 2 in asymptomatic patients.

Patients who underwent PPVI were characterised by RVOT dysfunction with predominant pulmonary regurgitation (RF ≥ 30% and RVOT peak velocity on continuous Doppler wave < 3 m/s); they also had evidence of RV dysfunction, reduced exercise capacity and/or documented atrial and/or ventricular arrhythmias. These patients represent only a sub-group between those who have had PPVI for RVOT dysfunction. The majority of these patients had an RV-PA conduit as result of complete repair. As we have previously described [7], a calcified conduit with an internal diameter < 22 mm represents a suitable substrate/anchorage for PPVI; a body weight less than 20 kg is a relative contraindication. The presence of a transannular patch often results in a very dilated and dynamic RVOT, generally therefore representing another relative contraindication to such approach at present.

At 1 year after intervention, whether PVR or PPVI, all investigations were repeated and the results compared within each group to the baseline data obtained pre-procedure.

The local research ethics committees approved the study, and all subjects (and/or a parent/guardian) gave informed consent.

3. Magnetic resonance imaging

MR imaging was performed at 1.5 T MR scanner (Avanto, Siemens Medical Systems, Erlangen, Germany).

3.1. Assessment of ventricular volumes and function

Retrospective gated steady-state free precession (SSFP) cine MR images of the heart were acquired in the vertical long-axis, 4-chamber view and the short-axis view covering the entirety of both ventricles [11].

Assessment of left ventricular (LV) and RV volumes was performed by manual segmentation of short-axis cine images with endocardial outline at end diastole and end systole (Argus; Siemens Medical Systems, Erlangen, Germany). End-diastolic and end-systolic volumes were calculated by use of Simpson’s rule for each ventricle, and from these volumes, stroke volume (SV) and ejection fraction (EF) were calculated. Where pulmonary regurgitation was present, an effective RVSV was calculated to reflect the net forward blood flow into the pulmonary arteries.

3.2. MR flow quantification

Pulmonary blood flow was calculated from phase contrast images by use of a semiautomatic vessel edge-detection algorithm (Argus; Siemens Medical Systems, Erlangen, Germany). Pulmonary regurgitant (PR) fraction was calculated as percent backward flow over forward flow.

All volume and flow measurements were indexed for body surface area and expressed in ml/beat/m².

4. Surgical pulmonary valve replacement (n = 25 patients)

The surgical technique has been previously described [12]. Most cases were performed under normothermic cardiopulmonary bypass on the beating heart with ascending aortic and bicaval cannulation. In case of residual ventricular septal defect or other intra-cardiac lesion requiring attention, aortic cross-clamping with cold blood cardioplegia was used. All patients had a pulmonary homograft insertion. The native main pulmonary artery was dissected out and transected proximally. The branch pulmonary arteries were sized, and stenosis could be dealt with if necessary (n = 6). Any obstructive hypertrophied muscular trabeculations in the outlet region would be divided to create a widely open pathway (n = 3). In patients with aneurysmal RVOT patch, the akinetic area was excised, followed by plication to reconstruct the outflow tract (RVOTR) (n = 20). This infundibuloplasty aims to improve the distorted right ventricular outflow tract geometry and reduce the cavity size. Finally the pulmonary homograft was tailored in length to connect with the distal pulmonary artery. The proximal end of the homograft was placed orthotopically within the newly created muscular ‘sleeve’ for functional support. Additional lesions were dealt with if necessary.

5. Percutaneous pulmonary valve implantation (n = 11 patients)

Percutaneous pulmonary valve (PPV), a bovine jugular venous valve sutured inside a platinum iridium stent (NuMED Inc., Hopkinton NY, USA), was implanted under general anaesthesia as previously described with the guidance of biplane angiography [7]. A full aseptic technique to surgical standards was used. The vascular access was achieved under general anaesthesia as previously described with the guidance of biplane angiography [7]. A full aseptic technique to surgical standards was used. The vascular access was achieved under general anaesthesia as previously described.
monitoring was undertaken for haemodynamic assessment pre- and post-procedure.

6. Statistical analysis

Data are presented as mean ± standard deviation. The median is also mentioned when relevant. The preoperative and 1 year results were compared within each group using a paired Student’s test. For categorical data the McNeamar’s test (IFA Services Amsterdam, the Netherlands) was used to calculate a statistical significance [13]. Statistical significance was reached when \( p < 0.05 \). We analysed the data using SPSS version 14.0 for Windows (SPSS, Chicago, Illinois).

7. Results

7.1. RVOTR/PVR

From January 2004 till April 2005, PVR has been performed in 25 consecutive patients, 12 male, with a primary diagnosis of tetralogy of Fallot (n = 21), absent pulmonary valve syndrome (n = 1), pulmonary atresia with (n = 1) and without (n = 1) VSD and congenital pulmonary stenosis (n = 1). Nine patients (36%) received palliation prior to complete repair and the mean number of previous surgery was 1.5 ± 0.7. Mean age at the time of complete repair was 4.5 ± 7.7 years and 72% of patients had a transannular patch, whereas only one patient had an RV-PA conduit. Mean age of PVR was 21 ± 13 years. On clinical assessment eight patients were in NYHA class I, seven in class II, nine in class III and one in class IV.

All patients received a pulmonary homograft, mean size 21 ± 5 mm. In 20 patients, the aneurysmal right ventricular out-flow tract has been excised (RVOTR). Six patients required a further enlargement of the pulmonary arteries (1 RPA, 2 LPA, 3 enlargement of pulmonary artery bifurcation or both branches). A further resection of hypertrophied muscular trabeculations in the subjunctional region was performed in three patients in order to create a widely open pathway. A residual VSD was present in one patient and needed to be addressed. One patient with severe tricuspid regurgitation underwent concomitant tricuspid valve annuloplasty; an atrial septal defect was closed in the same patient. One patient with significant atrial arrhythmia received anti-arrhythmic surgery via cryoablation of the right atrial isthmus.

Before intervention PR fraction was 41 ± 8%, indexed RV end-diastolic volume (EDV) was 151 ± 49 ml/m². At 1 year following PVR, there was a normalisation of RV volumes (Fig. 1A) and a significant improvement in right and left ventricular indexes of systolic function: effective stroke volume (Fig. 2A) and ejection fraction. The left ventricular EDV also increased although not significantly suggesting better filling of the ventricle. Patients reported a subjective improvement in their symptoms (NYHA class <2, \( p = 0.02 \) vs baseline). MRI results are summarised in Table 1. There were no re-interventions or mortality at 1-year follow-up.

7.2. PPVI

From March 2003 till May 2005, 70 patients underwent PPVI. Of these, 11 patients (7 female) had predominant PR and inclusion criteria for our study as described in the methods section. These patients had: initial repair of tetralogy of Fallot (n = 4), pulmonary atresia with VSD (n = 3), truncus arteriosus (n = 3) and transposition of the great arteries (n = 1). Six patients (54%) were palliated prior to complete repair and the mean number of previous surgery was 2.2 ± 1.1. Mean age of complete repair was 4.2 ± 2.4 years. Eight patients had a RV-PA homograft as results of previous repair, one had a Hancock conduit and two had a transannular patch. Mean age at the time of PPVI was 20 ± 9 years. Clinically one patient was in NYHA class I, eight patients in class II and two in class III.

Pre-PPVI, pulmonary regurgitant fraction was 34 ± 13%, indexed RV end-diastolic volume was 106 ± 27 ml/m². At 1 year following implantation of a competent valve, there was a significant improvement in biventricular volumes (Fig. 1B) and in RV and LV (Fig. 2B) indexes of systolic function. Similarly to the surgical group, there was a trend toward an increased LV EDV suggesting a better LV filling.

NYHA class also improved (class <2, \( p = 0.016 \) vs baseline).

MRI results are summarised in Table 2. There has been no mortality or need for re-intervention during this first year follow-up.

8. Discussion

This article addresses the current approaches to right ventricular out-flow tract dysfunction, predominately characterised by significant pulmonary regurgitation using RVOTR/PVR or PPVI.

Causes of pulmonary valve regurgitation differ between different pathologies and modalities of primary repair. In
ventricular out-flow tract gradient. EDV, end-diastolic volume; ESV, end-systolic volume; effSV, effective stroke volume; EF, ejection fraction; PR, pulmonary regurgitant fraction; RVOT, right ventricular out-flow tract gradient.

patients who received a wide transannular patch, the lack of proper coaptation of the valve leaflets is the main mechanism for valve incompetence. In patients who have had a RV-PA conduit, calcification and degeneration occur with time thus causing usually a mixed lesion, i.e. a combination of stenosis and regurgitation. Patients were eligible for this study when the lesion was predominately characterised by pulmonary regurgitation. Finally, pulmonary valvotomy often leaves the patients with some degree of PR from the time of treatment, which tends to increase over time.

In our institutions, indications for surgical pulmonary valve replacement were the presence of significant pulmonary regurgitation (regurgitant fraction ≥35% on MR), with evidence of progressive RV dilatation and dysfunction (RV/LV end-diastolic ratio ≥1.5 in symptomatic patients and ≥2 in asymptomatic patients), reduced exercise capacity with or without documented arrhythmias. Indications for PPVI were the presence of RV out-flow tract dysfunction in combination with evidence of progressive RV dysfunction and reduced exercise capacity. Patients were eligible for this study when the lesion was predominately characterised by pulmonary regurgitation: pulmonary regurgitant fraction ≥30% and a peak velocity across the out-flow tract less than 3.5 m/s.

For both approaches, an asymptomatic status did not represent a contra-indication to intervention since symptoms are difficult to interpret as the perception of physical limitation is altered in these patients who adapt their life style to a less demanding physical activity.

An accurate study of the RVOT anatomy was essential in the decision-making [14,15]. As we have previously described [7], only pulmonary trunks with a diameter between 14 and 22 mm can potentially be treated with a percutaneous approach; RV-PA conduits represent an ideal substrate, particularly in the presence of some degree of calcification. The transannular patch generally represents a contra-indication, since these RVOTs are often very dilated and dynamic out-flow tract [14].

There is no doubt that pulmonary regurgitation, although well tolerated for a long time, represents a progressive lesion with deleterious and irreversible effects on RV function [1,2,4—6,16]. The need to address it has been widely recognised with numerous studies in the literature suggesting an improvement in RV parameters if surgery is performed 'relatively' early [17,18]. Buechel et al., in a children population, emphasises that prompt RV remodelling occurs when surgery is performed when RV end-diastolic volume is less than 150 ml/m²; Therrien in an adult population suggests a cut-off of 170 ml/m² in order to achieve 'normalisation' of RV volumes.

Less attention has been given to the left ventricular function, although the biventricular interaction has been widely described in the literature [19]. In the present study, the patients who underwent surgery had a pre-procedure RV EDV of 151 ml/m². We described a normalisation of RV volumes and improvement in parameters of RV systolic function, therefore confirming the good outcome after 'early' intervention. Following restoration of a competent valve, there was an increased LV end-diastolic volume and this is a reflection of a better filling due to an improved pulmonary forward flow and a left to right shift of the interventricular septum as the RV volumes overload is relieved. Although this increase did not reach a statistical significance, we believe that this is just the reflection of a small number of patients per group. Furthermore, regardless of the technique used to address the RV outflow tract dysfunction, PVR or PPVI, there was an improvement in parameters of LV systolic function. In our opinion, studying the outcome of the left ventricle is a good marker to assess the success of the procedure since the right ventricular volumes are of difficult interpretation as, when surgery is performed, the aneurysmal out-flow tract is excised with a strong impact on RV volumes. RV ejection fraction needs, therefore, to be interpreted with caution.

We cannot over-emphasise the fact that this paper was not written to compare two different approaches but to highlight the possibility to treat successfully such detrimental lesion, pulmonary regurgitation, with different techniques that can be complementary. Our method of anatomic placement of pulmonary homograft may offer better conduit longevity. This is supported by the sub-pulmonary homograft data in the recent article by Selamet Tierney et al. [20] comparing the Ross and the non-Ross patients. Nevertheless any RV-PA conduit has a limited life span [21,22], and will need to be replaced, therefore exposing the patients to a high number of risky procedures. The availability of a percutaneous approach represents a promising alternative to surgery in

<table>
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<tr>
<th>Table 1</th>
<th>Right and left ventricular volumes and indices of systolic function before and after surgical pulmonary valve replacement</th>
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<tbody>
<tr>
<td></td>
<td>Pre-PVR</td>
</tr>
<tr>
<td>RV-EDV (ml/m²)</td>
<td>151 ± 49</td>
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<tr>
<td>RV-ESV (ml/m²)</td>
<td>80 ± 43</td>
</tr>
<tr>
<td>RVeffSV (ml/beat)</td>
<td>63 ± 20</td>
</tr>
<tr>
<td>RV EF (%)</td>
<td>49 ± 11</td>
</tr>
<tr>
<td>LV-EDV (ml/m²)</td>
<td>68 ± 12</td>
</tr>
<tr>
<td>LV-ESV (ml/m²)</td>
<td>28 ± 10</td>
</tr>
<tr>
<td>LV effSV (ml/beat)</td>
<td>61 ± 18</td>
</tr>
<tr>
<td>LV EF (%)</td>
<td>60 ± 10</td>
</tr>
<tr>
<td>RV/LV EDV</td>
<td>2.2 ± 0.5</td>
</tr>
<tr>
<td>PR (%)</td>
<td>42 ± 8</td>
</tr>
<tr>
<td>RVOT</td>
<td>1.8 ± 0.9</td>
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</table>

EDV, end-diastolic volume; ESV, end-systolic volume; effSV, effective stroke volume; EF, ejection fraction; PR, pulmonary regurgitant fraction; RVOT, right ventricular out-flow tract gradient.

<table>
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<tr>
<th>Table 2</th>
<th>Right and left ventricular volumes and indices of systolic function before and after percutaneous pulmonary valve implantation</th>
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<tbody>
<tr>
<td></td>
<td>Pre-PPVI</td>
</tr>
<tr>
<td>RV-EDV (ml/m²)</td>
<td>106 ± 27</td>
</tr>
<tr>
<td>RV-ESV (ml/m²)</td>
<td>49 ± 20</td>
</tr>
<tr>
<td>RVeffSV (ml/beat)</td>
<td>53 ± 14</td>
</tr>
<tr>
<td>RV EF (%)</td>
<td>55 ± 9</td>
</tr>
<tr>
<td>LV-EDV (ml/m²)</td>
<td>71 ± 17</td>
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<tr>
<td>LV-ESV (ml/m²)</td>
<td>30 ± 9</td>
</tr>
<tr>
<td>LV effSV (ml/beat)</td>
<td>56 ± 19</td>
</tr>
<tr>
<td>LV EF (%)</td>
<td>59 ± 7</td>
</tr>
<tr>
<td>RV/LV EDV</td>
<td>1.2 ± 0.4</td>
</tr>
<tr>
<td>PR (%)</td>
<td>34 ± 13</td>
</tr>
<tr>
<td>RVOT</td>
<td>3.1 ± 0.6</td>
</tr>
</tbody>
</table>

EDV, end-diastolic volume; ESV, end-systolic volume; effSV, effective stroke volume; EF, ejection fraction; PR, pulmonary regurgitant fraction; RVOT, right ventricular out-flow tract gradient.
selected cases. We previously demonstrated that PPVI compares favourably with surgery in terms of morbidity and mortality [23]. While we wait for long-term follow-up data, our impression is that PPVI can be used as a bridge to delay surgery when applicable, without compromising the ventricular function. The anatomic platform for valve stent anchorage remains the key issue. At our institution, the preferred approach at primary infant repair of tetralogy of Fallot with very small transannular patches (if required) can preserve the RVOT substrate for future placement of valve stents. On the other hand, the strategy at other centres of neonatal repair of tetralogy with a high incidence of transannular patching may not be desirable from the point of future PPVI.

8.1. Study limitations

We reported an improvement of patient’s symptoms but there is not objective quantification of their exercise capacity. We also did not directly address the main issue, which is the timing for re-intervention. We are currently undertaking a prospective and longitudinal study to address the above issue of this very challenging topic. We confirmed a good outcome when surgery is performed relatively ‘early’ as previously described in the literature. We have also shown that by restoring a competent valve via a percutaneous approach, the same results can be achieved in the short-term.

8.2. Conclusions

Both PVR and PPVI treatment of pulmonary regurgitation are associated with improvements in RV and also in LV parameters of systolic function. In consideration of the surgical impact on RV volumes, LV parameters remain the best tool to judge the success of the procedure.

Acknowledgement

The research has been carried out at Great Ormond Street Hospital and at The Heart Hospital, UCLH, London, UK. The support from all the clinicians involved is much appreciated.

References

Appendix A. Conference discussion

Dr M. Gewillig (Leuven, Belgium): In your paper you say that reduction of right ventricular volume in your surgical group is slightly better than in the percutaneous group.

However, you do introduce also a selection bias in your patients. The 25 patients you treated surgically are almost free-floating PR, while obviously the percutaneous group has some stenosis to it. On the other hand, both ventricles do improve. Can you speculate on what the juncture is of the surgical percutaneous procedure? I mean the surgeon does more than just reevaluate. He also takes out the aneurysm and makes it look much, much nicer. The percutaneous procedure? I mean the surgeon does more than just reevaluate. He also takes out the aneurysm and makes it look much, much nicer. Percutaneous procedure? I mean the surgeon does more than just reevaluate. He also takes out the aneurysm and makes it look much, much nicer.

Dr Frigiola: This is absolutely true, but the study was not addressed to compare the two techniques. I wanted to highlight complementary approaches in right ventricular outflow tract dysfunction lesions. The indications were different for the two populations. If we have a dilated aneurysmal right ventricular outflow tract, there is no way the patient will escape surgery. At the time of surgery the aneurysmal RV out-flow tract will also be excised and this is what we call remodelling. Patients who underwent a percutaneous approach, as you said, didn’t have such high pulmonary regurgitation, they had some degree of stenosis, and also the ventricular volumes to start with were smaller compared to the surgical population. So basically at the time of the decision-making, we were facing a lesion predominately characterised by pulmonary regurgitation in a symptomatic patient or in a patient with progressive right ventricular dilatation; the decision-making, which was made in our multidisciplinary meeting, was purely related to that single patient in relation to the specific lesion. Therefore, whether the decision was for a surgical or a percutaneous approach, this was related to the right ventricular out-flow tract characteristics and the patient’s characteristics as well. So we are not comparing two techniques. We are just saying that there are two different approaches for these lesions, and in both cases we can see how the right and left ventricular function are improving following the procedure.

Dr Gewillig: The second question, apparently you have some stent fractures which undoubtedly are due to metal fatigue in a continuously moving heart. How do you see this problem being solved?

Dr Frigiola: We recently presented our 6-year experience, and the stent fracture rate was 20%. So 20% of patients experienced a stent fracture, which has to be classified in three different types. There are stent fractures without loss of integrity, and these patients are just under observation, they don’t need anything done, and there isn’t even an increased gradient across the valve. There are stent fractures with loss of integrity, and these patients had a second valve, so they needed re-intervention, but the proportion of these patients is very small so far and a second valve has been put in with no problem. The third type of stent fracture is basically the embolisation of the valve, and it happened in only one patient who needed rescue surgery basically for the embolisation. The main determinants of stent fractures are the native outflow tract, the degree of calcification, and recoil after deployment of the stent valve. These are the main risk factors to predict the stent fracture, which is common but is not such a severe problem. Patients in the majority of cases are just followed under normal routine follow-up.

Dr Gewillig: I presume you avoid it by putting in first a bare stent; is that correct?

Dr Frigiola: No. There is a second percutaneous pulmonary valve put in.

Dr Gewillig: But I mean in order to prevent it in future patients.

Dr Frigiola: From what we have seen, the learning curve is extremely important in the patient selection, and, as I said, with a very stenotic calcified conduit, the incidence of stent fracture is really very low. So it’s during the patient selection that we are already putting a patient on a high or low risk of stent fracture.

Dr J. Brown (Indianapolis, Indiana): Obviously we’re comparing apples and oranges here; the percutaneous for PS primarily, with some regurgitation, and the surgical group is for pure regurgitation for the most part. It seems to me that the study that surgeons and cardiologists want to know the answer to is to compare the surgically implanted bovine jugular venous valve with the percutaneous one and which one is going to be more durable over the long-term. Can you tell us more about durability of the percutaneous bovine jugular venous valve compared to surgically implanted? Now, I noticed that these were all homografts. Why homografts when you had both available?

Dr Frigiola: The homograft has been the preferred choice of our institution. It’s the belief of the surgeon who performed the procedure that the results will be good in the long-term, in the long run. So we have to wait. A prospective longitudinal study was commenced in 2004. I would wait a few more years before drawing a conclusion about durability of the pulmonary homograft in this setting.

Going back to the percutaneous valve, the stent valve was used for the first time in the year 2000, so we are reaching our seventh year of experience. It’s still a short follow-up. We need to wait longer to give an answer on durability of the valve, future complications, and how to address the complications once the stent valve is in place.

You had another question.

Dr Brown: The surgical group is PI. The percutaneous group is PS.

Dr Frigiola: No, it’s not PS, and I’m quite confident in giving this answer. There are two very nice papers that we published. One paper has been written on a selected population who underwent percutaneous valve implantation for predominant obstruction, and what we have seen in terms of right ventricular physiopathology is completely different from what we have seen in the patient population that has been treated for predominant pulmonary regurgitation, and the results mirror those of the surgical population. I haven’t reported data about exercise parameters, which is one of the keys in the interpretation. But just knowing the results, I can say that these populations do behave similarly. Patients with predominant pulmonary stenosis have a sort of contractile reserve. Patients treated for predominant pulmonary regurgitation we think are in a decompressed limb of the Frank–Starling curve.

Editorial comment

The paper by Frigiola et al. is timely, dealing with a controversial issue [1]. An increasing number of patients, who have undergone right ventricular (RV) outflow tract repair for various malformations in infancy or childhood, need pulmonary valve implantation for severe pulmonary regurgitation when they reach adulthood. There is no doubt that pulmonary regurgitation, although well tolerated for a long time, does lead to increasing right ventricular volume, worsening exercise tolerance and ventricular arrhythmia. However, when and how should pulmonary valve implantation be performed remain a matter of debate. The paper by Frigiola et al. provides useful information regarding this issue and deserves several comments.

1. As stated by the authors themselves, this is not a comparative study between surgical and percutaneous pulmonary valve implantation. There are obviously two groups of patients. Some patients have, in addition to pulmonary regurgitation, associated lesions such as aneurysmal dilatation of RV infundibulum, residual stenosis of proximal pulmonary arteries, tricuspid regurgitation or residual septal defects. Only a conventional surgical approach can provide adequate repair of all lesions including, in addition to pulmonary valve implantation, RV remodeling, pulmonary artery augmentation, tricuspid valve repair or cryo-ablation surgery. The present study shows that the results are satisfactory with a very low