Does Supporting the Ross Autograft with a Personalised External Aortic Root Support (PEARS) Graft Prevent Autograft Dilatation and Valve Failure?

2015-2022
50 patients
PEARS graft applied to support the autograft for the Ross operation

- Intraoperative data
- Complications
- Control with echocardiogram + MRI scan

- 2 patients required aortic valve replacement (no evidence of autograft dilatation)
- Aortic root measurements remain stable

PEARS graft support for the Ross operation is a safe and reproducible technique to prevent autograft dilatation and that can potentially expand the indications for the Ross operation to patients with aortic regurgitation or aorta dilatation.
Our 7-Year Experience Supporting the Ross Autograft with the Novel Technique of the Personalised External Aortic Root Support

Ana Redondo¹, MD, Conal Austin¹ MD

1. Evelina London Children’s Hospital. Guy’s and St Thomas’ NHS Foundation Trust.
   Congenital Cardiac Surgery Department

Disclosure statement: Authors have nothing to disclose

Funding statement: There is no funding source for this work nor for any author

Corresponding author contact:
Ana Redondo
Evelina London Children’s Hospital. Westminster Bridge Road
SE1 7EH. London. United Kingdom
Congenital Cardiac Surgery Department.
Ana.redondo@gstt.nhs.uk
+44 020 7188 7188

Word count: 3700

Central Message
Supporting the Ross autograft with a Personalised External Aortic Root support, can prevent dilatation which can lead to potential valve failure. This is a safe and reproducible technique

Perspective Statement
Ross procedure indications can be expanded if a correct support for the autograft is provided. We believe the Personalised External Aortic Root Support is an excellent option, that in our experience, has prevented aortic root dilatation. This would allow to perform this operation in multiple and complex clinical scenarios such as repeat aortic valve surgery or aortic root dilatation.

Central Picture Legend
Surgical picture after having performed a Ross-PEARS operation
Abstract

Objective
Ross operation is a widely accepted option for aortic valve replacement in children, and evidence shows its excellent results in terms of haemodynamics and durability. However, indications are still limited due to the fact that it is a technically demanding procedure, only performed by specialized surgeons. On top of that, and despite numerous techniques have been described, we still haven't been able to overcome its main disadvantage: the autograft dilatation leading to graft failure. On the other hand, the Personalised External Aortic Root Support (PEARS) has proven to be a safe and effective option to prevent aortic root dilatation in all sort of aortopathy scenarios.

Methods
During the past 7 years we have used the PEARS graft, manufactured from the patients' pulmonary artery measurements from CT scan, to support the pulmonary autograft in the Ross operation. This graft is implanted at the same time as the autograft implantation. We have reviewed all the patients who underwent this technique, including demographic data, aorta measurements, operative data, and follow-up assessment consisting of periodic echocardiograms and MRI scans.

Results
50 patients were included in the study. Mean age at the time of the operation was 29.84, being the youngest patient 9 years-old. 19 patients (38%) had previous sternotomies, having 11 of them had a previous aortic valve replacement. 72% of patients had initially a bicuspid aortic valve. Mean diameter of ascending aorta was 3.83 cm. 44% of patients required a
concomitant reduction aortoplasty due to mismatch sizes between the ascending aorta and the autograft. Mean bypass and cross-clamp times were 200.66 and 151.14 minutes respectively. Median length of stay was 6 days. Mean follow up was 16.88 months. Two patients required subsequent aortic valve replacement (one had rheumatic valve disease and the other had iatrogenic damage in his autograft valve leaflet). Ascending aorta dimensions remain stable when compared to immediate postoperative studies. There were no deaths

Conclusions

PEARS graft has proven to be an excellent support in the Ross operation to prevent the autograft failure related to autograft dilatation, which can offer several advantages compared to other techniques described in the past. With this type of support, we believe the Ross indications can be expanded to multiple clinical scenarios, given the good long-term results this operation offers in terms of durability, life expectancy and haemodynamics
Glossary of Abbreviations:

RV-PA: Right Ventricle to Pulmonary Artery; PEARs: Personalised External Aortic Root Support; CT: Computed Tomography; MRI: Magnetic Resonance Imaging; ECG: Electrocardiogram; LAD: Left Anterior Descending Artery; AV: Atrio-Ventricular

Key words: Ross; aortic root; aortic valve; Personalised External Aortic Root Support

1. Background

The Ross procedure was developed in the 1960s and since then has been the procedure of choice for aortic valve replacement in children and even young adults. For older patients, despite other options, such as mechanical or biological valves, it has progressively gained popularity and one of the main reasons for this is the evidence that it offers major advantages when compared to prosthetic valves. These advantages include better haemodynamics, no need for anticoagulation, reduced risk of endocarditis, and an equivalent survival when compared to the general population. However, Ross is a more technically demanding procedure, generally associated with longer operative times, and usually performed in small numbers or by highly experienced surgeons and centers. For all those reasons, there is still a large number of surgeons who are reluctant to perform this operation as a first option. Furthermore, there are mid to long-term complications that are typically associated with the Ross procedure, and that make it a less appealing option in many scenarios. First of all, the failure of the homograft or the RV-PA conduit, which may end up in further reinterventions.
for replacement or transcatheter procedures. And secondly and most feared complication, the autograft failure.

The most common and classical approach for the Ross operation is the free root implantation, that, without any kind of further support, may end up in autograft dilatation and a concerning valve failure due to leaflet coaptation problems in 10 to 20% of patients at 10-15 years⁴. In order to overcome this, several techniques have been developed aiming to support the autograft: the so-called “inclusion technique” with the patient’s native aorta, Dacron cylinder autograft wrapping, external aortic annulus support suture, or even reabsorbable sino-tubular junction support suture⁵.

In our institution we have been successfully using the Personalised External Aortic Root Support technique since 2013 (although the first PEARS operation for a Marfan’s patient was performed in 2004) for prevention of aorta dilatation in all sort of genetic conditions and scenarios, including dilated aortas related to congenital heart disease. This technique consists of a personalized polyethylene macroporous mesh, created from the exact measurements of the patient’s aorta CT scan, which provides a soft and pliable support for the aortic root. In the other hand, it has a strong hem which is externally anchored to the aortic annulus that potentially prevents its dilatation⁶,⁷. Given the good results offered by the PEARS⁸ technique, our institution was the first one to apply this graft as a support for the autograft in the free-root Ross operations.

In this paper we aim to present the results of this combined technique since we first applied it in 2015.

2. Material and methods

2.1 Patients
We have included all the patients in our institution who underwent a Ross procedure supported by a PEARS graft. The first patient had this procedure done in 2015. Since then, 50 patients have been included in our database. All patients were operated by the same surgeon, and there was always a surgical indication for aortic valve replacement, which was discussed and agreed in a multidisciplinary meeting. Only Ross operation supported with a PEARS prosthesis were included in this study. Follow-up consisted of a surgical review in the outpatient clinic 6 weeks after discharge to assess the clinical situation, and then an Adult Congenital Cardiology review, either in our center or in the patients’ referral unit, 3 months after discharge (unless any different indication), with a routine echocardiogram to assess the pulmonary and neo-aortic valve function and the changes in ascending aorta dimensions. An MRI was done in most cases one year after the Ross-PEARS procedure, unless clinical contraindication (permanent pacemaker). After that, echocardiogram was performed yearly, and MRI if considered necessary, every two years. Only data from the latest echocardiogram and MRI was recorded in the database. Data was collected retrospectively and recorded in a database. Reports and results were obtained from the hospital’s electronic patient record system. Data was requested for those patients who were referred from other units and followed-up externally. Patients signed a specific and detailed informed consent form with the details of this operation, and they were aware of the novelty of this technique and the possibility of inclusion of their data in research databases. This procedure was also reviewed and discussed in the Patient Safety Group and the TRAQ meetings, and is under continual and independent review at our institution. No formal IRB review was required as it is a retrospective data collection and analysis.
2.2 Data collection

Preoperative data was obtained from referral forms, preoperative reports and multidisciplinary meeting reporting forms. Imaging and CT-scan, MRI and echocardiogram reports were also reviewed.

For the aorta and pulmonary artery measurements, the greatest diameter in centimeters for the aortic annulus, sinuses of Valsalva, sino-tubular junction, ascending aorta at the level of the right pulmonary artery, pulmonary annulus and main pulmonary artery were collected. All the CT scans were done under the same Ross-PEARS protocol by the same specialized Radiology team. Once the images of the CT scan were sent for manufacturing, the production of the graft usually took around 3 weeks.

The echocardiograms were performed and reported by a specialized Adult Congenital Heart Disease Team. Following the same criteria, the valvular stenosis and regurgitation was classified in less than mild (trivial or trace), mild, moderate or severe. The ventricular function was also classified in normal, mildly, moderately and severely impaired.

Images were double reviewed and went through the same classification process in those cases when they were transferred from other units.

2.3 Operative technique

All cases were performed via midline sternotomy. By-pass was established with central cannulation (proximal aortic arch, superior and inferior vena cava). In some cases the autograft was harvested under induced ventricular fibrillation before the instillation of cardioplegic solution.
Once the heart was arrested with cold blood cardioplegia, the aorta was opened and the native aortic valve or the previous prosthesis was excised. In cases of small aortic valve annulus with associated narrowed left ventricular outflow tract, an enlargement of the annulus was performed in the following way: after excision of the aortic root, an incision was then made into the ventricular septum down the commissure between the right and the left sinuses of Valsalva, cutting towards the pulmonary outflow; this was continued into the base of the heart until the annulus was sufficiently enlarged, but not creating any ventricular septal defect. Then coronary buttons were harvested.

The PEARs graft hem was marked with three equidistant Prolene stitches, corresponding to the three valve commissures. The axial seam was opened. The pulmonary autograft was sutured to the aortic annulus with the invagination technique, using a continuous running suture line of 4/0 Prolene, which incorporates both the autograft and the hem of the PEARs graft simultaneously. This is believed to completely reinforce the aortic annulus. The coronary buttons were re-implanted in the autograft at an appropriate height level, through two cutting apertures in the posterior and anterior leftward sinuses of the PEARs graft.

In cases with high discrepancy between the pulmonary artery autograft and the ascending aorta due to aortic dilatation, a reduction aortoplasty was performed. This consisted of making an excision of the excess tissue in the right lateral aortic wall, which was roughly calculated by measuring the ascending aorta and the autograft with Hegar dilators in cases where there was a documented ascending aorta dilatation.

A pulmonary valve homograft obtained via the National Heart Valve Bank was then implanted in the pulmonary position, starting with the distal anastomotic suture at the level of the bifurcation. Following this, the autograft was anastomosed to the ascending aorta.
The proximal pulmonary homograft anastomosis can be performed in most cases with the beating heart. Once patient was successfully off bypass and haemostasis was achieved, the PEARs graft was closed over the aorta by re-suturing the longitudinal axial seam along the non-coronary aspect of the aorta, with single interrupted Tycron stitches. The length of the PEARs graft can be trimmed distally as desired, but it is advisable to go over the whole autograft and ascending aorta, especially after a reduction aortoplasty has been done.

2.4 Statistical analysis

Descriptive data is used with no statistical analysis. Frequency described in absolute number and in percentages. For any data analysis, Stata 14 was used (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LLC).

3. Results

3.1 Patient characteristics

50 patients were included in the study. Main principal characteristics are reflected in table 1. Median age at the moment of surgery was 26 years old (age range 9 to 54 years-old). 14% of the patients (n=7) were 18 years-old or younger. 19 patients (38%) were redo sternotomies, having 11 of them previous aortic valve replacements with current prosthetic failure (22%). 1 patient had a previous Ozaki repair with indication for aortic valve replacement due to repair failure. 72% of patients had a background diagnosis of bicuspid aortic valve, and the main current lesion was stenosis in 30% of patients, regurgitation in 22% and mixed aortic valve
lesion in 24%. Mean maximum aortic valve annulus size was 2.53 cm (mean Z score +1.97 -
minimum -1.67, maximum +6.42), mean maximum diameter of sinus of Valsalva, sino-
tubular junction and ascending aorta were 3.40 (mean Z score +1.67) , 3.11 (mean Z score
+2.3) and 3.83 cm (mean Z score +3.18) respectively. Mean maximum size of pulmonary
valve and diameter of pulmonary artery were 2.64 and 2.91 cm respectively. Left ventricular
function was normal in most cases (91.30%), while one patient had preoperatively a
moderately impaired left ventricular function.

3.2 Intraoperative data

Intraoperative data is collected in Table 2. The first two cases were performed with a
different technique from the one that is currently used as a standard one, using the inclusion
technique to provide further external support to the PEARS. From then on, all patients
underwent a free-root Ross supported only by the PEARS graft. Eight patients had in addition
an aortic annulus enlargement. 44% of the patients had a reduction aortoplasty to facilitate
the match between the ascending aorta and the pulmonary autograft. 5 patients had
concomitant procedures such as mitral valve repair or septal myectomy. Mean cross clamp
time was 151.14 minutes, and mean cardio-pulmonary bypass time was 200.66 minutes.

3.3 Early postoperative outcomes

There were no deaths during the early postoperative period. Three patients among the first six
in our series, had chest re-exploration within the first 24 hours, two of them for suspected
coronary injury based on ischemic ECG changes: one had partial kinking of the proximal
LAD due to proximity of the suture line of the RV-PA conduit anastomosis; the other patient
had no compromise of the coronary arteries and the ECG eventually normalized. The third
patient was re-opened for post-operative bleeding.

Two patients required permanent pacemaker due to complete AV block, both having had a
previous aortic valve replacement.

One patient required a post-operative percutaneous coronary intervention with a left main
stem stent. This patient had undergone an aortic root replacement for endocarditis 15 years
before, presenting with complete heart block, and the coronary ostia were heavily calcified.

Median postoperative stay length was 6 days, ranging from 4 to 60 days (the longest was a
patient with severe scoliosis and restrictive respiratory function considered moderate to high
risk for cardiac surgery, and who required long-term invasive ventilation and tracheostomy).

Postoperative results are reflected in Table 3. All patients had a routine transthoracic
echocardiogram before discharge, for assessing the autograft valve and the ventricular
function. This showed mild degree or less of neo-aortic regurgitation in all cases. Regarding
the left ventricular function, two patients showed mildly impaired function (preoperatively
normal, both recovered during follow-up) and two showed moderately impaired function
(pre-operatively in both cases was at least mildly compromised).

### 3.4 Late postoperative outcomes

Mean follow-up was 16.88 months. The longest follow-up was nearly 7 years (83.9 months).
No patient died during this period of time.

In two patients follow-up was interrupted as they required aortic valve replacement due to
autograft failure: the first one (who was the first patient in our cohort), had a rheumatic valve
disease, which ultimately affected the autograft, causing severe regurgitation. The second
case was a complex patient with three previous complex cardiac operations, and the autograft
damage was considered iatrogenic, occurring 3 months later due to left coronary leaflet
damage from internal knot of Prolene in the sub-coronary area.
All patients had a transthoracic echocardiogram performed within a specialized adult
congenital heart disease unit. Apart from the two patients who required aortic valve
replacement, three showed more than mild aortic regurgitation: two of them had a later MRI
which confirmed the regurgitation was actually not greater than mild, and the third one has no
current indication for intervention at the moment as she remains asymptomatic. The
composite for Ross failure (mortality, autograft valve insufficiency and need for aortic valve
replacement) curve is reflected in Figure 2. In all cases the pulmonary homograft is well-
functioning and no patient has required re-intervention for autograft dilatation as evidence by
echocardiogram and MRI scans showing no significant change on aortic root and ascending
aorta dimensions (mean maximum aorta dimensions during follow-up 2.84 cm, SD 0.32;
mean Z score +0.2 (minimum -3.6, maximum 2.57) (comparative dimensions in Figure 1).

4. Discussion

The Ross operation has some of the advantages that makes it an excellent option compared to
the prosthetic valves, as it is a “living” valve, offering at the same time better
haemodynamics and avoiding some of the most feared complications, such as anticoagulation
related and endocarditis. For this reason its indications and uses have been expanded, and there is good evidence of its
safety in other scenarios outside the classical indications, such as aortic regurgitation and
bicuspid aortic valves.
In terms of complications related to this procedure, the pulmonary homograft failure with subsequent need for pulmonary valve replacement is a well-documented adverse event \(^{12}\), although we have not found this type of complication in our series.

Other studies also highlighted the low incidence of homograft dysfunction, especially when using decellularized homografts \(^{13}\). Furthermore, in those cases, the advanced percutaneous techniques would allow replacement of the valve with no need for a new sternotomy \(^{14}\).

The autograft failure, on the other hand, is a more feared complication, which can lead to valve failure. This seems to be directly related to the autograft dilatation when this gets implanted as an unsupported free-root, as it is exposed to systemic pressures compared to pulmonary pressures, and it can be as frequent as 40 to 60\% \(^{15}\). Free-root Ross is the most widespread technique due to its simplicity, compared to other techniques such as the sub-coronary Ross, which is considered more challenging as it risks losing the structure of the valve, and offers less support to the annulus \(^{16}\).

The latest trends for improving the Ross operation have been, unsurprisingly, focused on supporting the autograft to prevent its dilatation. Several techniques have been described in the literature: from inclusion technique \(^{17}\) (which we had used in the past), to annular external reinforcement suture or Dacron cylinder graft autograft wrapping \(^{18}\). However, and after our experience, we have seen that the PEARS graft offers some important advantages compared to these other options. First of all, it adapts perfectly to the patients’ anatomy, thanks to the personalized manufacturing process and the soft and pliable material used. In fact, the importance of preserving the aortic root haemodynamics has been highlighted in numerous occasions \(^{19}\). Second, we have experienced it is technically less complex compared to, for example, the inclusion technique, especially for the coronary transfer. Also, the fact that is a macroporous mesh and that it is implanted as an open graft, allows a better inspection of the
autograft to achieve haemostasis and the graft is only closed over the aorta once any bleeding source has been sorted out. And lastly, the PEARs graft can provide support for all the ascending aorta up to the mid-aortic arch in cases of aortic dilatation related to, for example, bicuspid aortic valve.

The development of the PEARs supported Ross has been a project in evolution. As such, the development and size of the PEARs prosthesis has evolved in the following way: Our past Ross technique was the inclusion, which is for highly selected patients without significant aortic insufficiency nor asymmetry or dilatation of the aortic root. The first two patients in this cohort had an inclusion Ross, with the PEARs manufactured on the size of the aorta. After that, we changed to a free-root Ross with a PEARs prosthesis made out of the size of the pulmonary artery. Patients 3 to 8 had a 100% sized PEARs graft manufactured by this technique; however, at implantation it was found that the graft was too small. The reason for this was thought that the CT scan only demonstrates the internal lumen of the vessel, and does not take into account the thickness of the pulmonary artery wall and its associated fatty adventitia. Subsequently, we manufactured 120% prosthesis (a 20% uniform increase in size) for the following five patients; this was eventually found to be too big. Cases 14 and 15 had a 105% prosthesis manufactured, and finally after case 16 we settled on a 115% prosthesis, which is now the main stay of our PEARs support for the Ross operation.

The results are very promising. In the only two cases where the autograft failed, it could not be demonstrated any autograft dilatation (Z score of the autograft root in the last measurements were -0.46 and -0.91) leading to the valve failure, rather than a leaflet issue causing the problem. These cases are among the first eight cases in our cohort (the ones receiving the 100% sized graft).

The first patient was, in fact, our first failure as he had severe aortic insufficiency on the basis of rheumatic disease. The pulmonary autograft failed within 6 months and the leaflets of the
autograft retracted, leading us to confirm that rheumatic patients are not good candidates for the Ross operation as the pulmonary can be similarly affected, which has also been reported by other groups. The second autograft failure was also an early patient in the series and he had left coronary leaflet tear which occurred after 3 months when an internal sub-crownary knotted suture split the leaflet. Both patients had mechanical aortic replacements in a similar way to a failed biological root replacement.

The technique of PEARS supported Ross surgery we believe will enable consideration to be given to those cases traditionally felt to be poor Ross candidates i.e. aortic root and ascending aorta dilatation with severe aortic valve insufficiency. Furthermore, in cases where there is a disparity between annulus sizes of the aortic compared to the pulmonary, the PEARS hem which is incorporated into the proximal autograft suture line, would stabilize and reduce the annulus to that of the slightly enlarged autograft.

Ross supported PEARS also is very applicable to resolving failed biological and mechanical aortic valve prosthesis as seen in over 20% of our cohort.

The operative times and postoperative stays compare to those for simple free-root Ross procedure, which proves that the PEARS application doesn’t add any more difficulty to the operation. Furthermore, in both cases who required reintervention, it was found that the PEARS graft didn’t pose an extra challenge in terms of adhesions.

Nevertheless, we have to recognize this is a technically demanding procedure, which has a learning curve, and it has to be done by experienced surgeons who are familiar with the Ross operation.

Our experience is still limited to 50 cases, but we also have increasing numbers of patients being referred (either from our own unit, from other units all over the world, or even self-referred), as they become more familiar with the technique.
There are some limitations to this study, however. First of all, we haven’t been able to compare this cohort to our previous Ross patients done before 2015. Most of these patients had the inclusion technique and, therefore, the inclusion criteria for having the operation was very strictly limited. With the Ross-PEARS we have expanded the indications, including patients with dilated aorta, severe valve regurgitation or previous aortic valve replacement, so we consider the two groups are not comparable.

Also, the fact that a significant number of patients have been referred from other parts of the country, or even other parts of the world, can make follow-up more challenging. Although we try to unify the surveillance protocol, this cannot always be properly followed, especially considering the pandemic global situation we all endured in the past 3 years.

Furthermore, we need to point out that the initial aortic measurements were mostly obtained from the CT scan while the follow-up imaging is based on echocardiogram and MRI measurements, which could affect in some way to the dimensions obtained. We still advocate for a follow-up based in MRI imaging, to avoid excess dose of radiation in this relatively young cohort of patients.

We would recommend a more unified study strategy, with multiple collaborations with units around the world who are interested in going on with this technique, and that can provide the data to assess results in an effective and reliable way.

5. Conclusions

The supported Ross procedure is gaining popularity and we have worked on a method which we believe simplifies the support and makes the operation more reproducible. Our experience with PEARs for dilatational aortopathies led us to utilize 3D printing to produce an anatomical support for the autograft based on a CT pulmonary angiogram.
The PEARS support is incorporated into the proximal suture line and it covers entirely the autograft and the ascending aorta to the level of the proximal aortic arch.

However, it is still a technically complex technique performed by experienced surgeons, mostly congenital disease specialized.

We believe that this application of exact anatomical support for the autograft in the Ross will expand the role of Ross operations in complex aortic valve regurgitation with root and ascending aorta dilatation, and unfavorable commissure geometry that besets inclusion techniques.

This technique doesn’t add any extra complexity to the operation, and in our initial experience of 50 patients, it has offered good results, maintaining stable neo-aortic root and ascending aortic dimensions.

6. References


<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery (median)</td>
<td>26</td>
<td>(IQR 20-36)</td>
</tr>
<tr>
<td>Male (%)</td>
<td>52 (n=26)</td>
<td></td>
</tr>
<tr>
<td>Reoperation (%)</td>
<td>38 (n=19)</td>
<td>(number of previous sternotomies ranging 1 to 4)</td>
</tr>
<tr>
<td>Initial aortic lesion (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stenosis</td>
<td>58 (n=29)</td>
<td></td>
</tr>
<tr>
<td>Regurgitation</td>
<td>16 (n=8)</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>18 (n=9)</td>
<td></td>
</tr>
<tr>
<td>Endocarditis</td>
<td>4 (n=2)</td>
<td></td>
</tr>
<tr>
<td>Bicuspid aortic valve (%)</td>
<td>72 (n=36)</td>
<td></td>
</tr>
<tr>
<td>Current aortic lesion (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stenosis</td>
<td>30 (n=15)</td>
<td></td>
</tr>
<tr>
<td>Regurgitation</td>
<td>22 (n=11)</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>24 (n=12)</td>
<td></td>
</tr>
<tr>
<td>Prosthetic failure</td>
<td>22 (n=11)</td>
<td></td>
</tr>
<tr>
<td>Repair failure</td>
<td>2 (n=1)</td>
<td></td>
</tr>
<tr>
<td>Grade of aortic stenosis (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>22 (n=11)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>6 (n=3)</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>16 (n=8)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>14 (n=7)</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>42 (n=21)</td>
<td></td>
</tr>
<tr>
<td>Grade of aortic regurgitation (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>22 (n=11)</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>2 (n=1)</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>30 (n=15)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>12 (n=6)</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>34 (n=17)</td>
<td></td>
</tr>
<tr>
<td>Left ventricular function (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>92 (n=46)</td>
<td></td>
</tr>
<tr>
<td>Mildly impaired</td>
<td>6 (n=3)</td>
<td></td>
</tr>
<tr>
<td>Moderately impaired</td>
<td>2 (n=1)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:** Preoperative patient characteristics. Data is reflected in percentages or in mean values when applicable.

<table>
<thead>
<tr>
<th>Intraoperative data</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of operation (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-root Ross-PEARS</td>
<td>80 (n=40)</td>
<td></td>
</tr>
<tr>
<td>Inclusion Ross-PEARS</td>
<td>4 (n=2)</td>
<td></td>
</tr>
<tr>
<td>Free-root Ross-Konno-PEARS</td>
<td>16 (n=8)</td>
<td></td>
</tr>
<tr>
<td>Reduction aortoplasty (%)</td>
<td>44 (n=22)</td>
<td></td>
</tr>
<tr>
<td>Concomitant procedures (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitral valve repair / LAVV repair</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Septal myectomy</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Plication of ventricular septal aneurysm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cardiopulmonary bypass time (mean)</td>
<td>200.66 (SD 8.59)</td>
<td></td>
</tr>
<tr>
<td>Cross-clamp time (mean)</td>
<td>151.14 (SD 4.96)</td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Intraoperative data. Data is reflected in percentages, total values or mean values when applicable. PEARS (Personalised External Aortic Root Support); SD (Standard Deviation); LAVV (Left Atrio-Ventricular Valve)

<table>
<thead>
<tr>
<th>Post-operative data</th>
<th>Echocardiogram pre-discharge</th>
<th>Postoperative stay (median, days)</th>
<th>Follow-up echocardiogram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left ventricular function (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>89.58 (n=43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mildly impaired</td>
<td>4.17 (n=2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderately impaired</td>
<td>6.25 (n=3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree of aortic regurgitation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>12.50 (n=6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trivial / trace</td>
<td>54.17 (n=26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>33.33 (n=16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree of pulmonary regurgitation (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>45.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trivial / trace</td>
<td>28.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>22.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>2.86</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Postoperative data. Data is reflected in percentages or in median values when applicable.

Figure 1: Box plot graphic reflecting the maximum measurements obtained for the aortic root and ascending aorta in the preoperative imaging (echo or CT scan), in the follow-up MRI scan and in the follow-up echocardiogram. A general reduction of the diameters can be seen postoperatively compared to the preoperative values.
Figure 2: Kaplan-Meier survival curve for events (reoperation for aortic valve regurgitation or discovery of aortic valve regurgitation greater than mild)

Figure 3: Graphical Abstract
Does Supporting the Ross Autograft with a Personalised External Aortic Root Support (PEARS) Graft Prevent Autograft Dilatation and Valve Failure?

2015-2022
50 patients
PEARS graft applied to support the autograft for the Ross operation

- Intraoperative data
- Complications
- Control with echocardiogram + MRI scan

- 2 patients required aortic valve replacement (no evidence of autograft dilatation)
- Aortic root measurements remain stable

PEARS graft support for the Ross operation is a safe and reproducible technique to prevent autograft dilatation and that can potentially expand the indications for the Ross operation to patients with aortic regurgitation or aorta dilatation.
Our 7-Year Experience Supporting the Ross Autograft with the Novel Technique of the Personalised External Aortic Root Support. The ‘Ross PEARS’ operation

Ana REDONDO, Conal AUSTIN
Evelina London Children’s Hospital
Guy’s and St Thomas’ NHS Foundation Trust