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Personalised External Aortic Root Support (PEARS): a narrative review.

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CENTRAL MESSAGE

PEARS is an operation to prevent dilatation and to maintain aortic valve function in Marfan and other aortic root aneurysms.

PERSPECTIVE STATEMENT

Due to patient and family awareness and access to echo and radiological imaging, individuals with genetically triggered aortopathy with root aneurysm present earlier. For them PEARS complements root replacement surgery.

Abbreviated legend for Central Picture

The ExoVasc pliable macroporous mesh sleeve as presented to the surgeon for implantation

Key words

Personalised external aortic root support; aortic root aneurysm; computer-aided design; 3-D printing; Ross operation; pulmonary autograft.
We review the development and present status of personalised external aortic root support (PEARS) in a chronological narrative.

The genesis of a novel approach

PEARS was first proposed to the UK Marfan Association in 2000 by Tal Golesworthy, a developmental engineer with Marfan syndrome. His aortic diameter had increased from 44 mm to 49 mm over 12 years. He questioned what had been told by his cardiologist — that he should have his ascending aorta and aortic valve replaced, followed by life-long anticoagulation. He heard Treasure’s annual lecture to Marfan families which included timing of surgery with reference to correspondence with Vincent Gott in the New England Journal of Medicine. In the post lecture Q&A Golesworthy challenged the need for extirpative surgery. He envisaged the application of modern science to revisit the then 30 year old idea of externally supporting an aortic aneurysm. He foresaw computer modelling with data from digital images being used to generate a physical replica of the individual’s aorta by 3-D printing. On that former a personalised well-fitting sleeve would be fashioned to prevent further expansion.

Preclinical basic science

During the following few years Golesworthy and Treasure investigated the feasibility of the idea. Golesworthy came to the operating theatres to see what was entailed in total root replacement. Together they went to Robert Anderson to take a focussed look at the morphology of the aortic root. Golesworthy collaborated with Michael Lampérth and Warren Thornton of Imperial College developing computer aided design (CAD modelling) for rapid prototyping, now known as 3-D printing.
Because the intention was to support rather than to replace the aorta, a porous knitted fabric was chosen to avoid graft migration and vascular erosion, the known consequences of wrapping with stiff low-porosity material. It was decided to use the same polymer, polyethylene terephthalate (Dacron®) because of its proven biocompatibility.

**Development and clinical trial of the PEARS operation**

With John Pepper we discussed the surgical method of implantation, repeatedly and in detail. Pepper negotiated with the Royal Brompton Hospital a trial of the new procedure in twenty patients, conducted in accordance with the requirements of the Research Ethics Committee. All patients were informed that this was innovative surgery and discussed risks and benefits with the operating surgeon. The first operation, on Golesworthy, appeared as a research letter in *The Lancet.*

Surgeons embarking on PEARS are proctored by experienced operators and must study the instructions for use. In addition to the published method of implantation, two teams in the PEARS diaspora have contributed “How to do it” papers which provide further expert insights. The ExoVasc® device and the steps in the operation have remained unchanged which we attribute to the credit time spent in basic research collaboration and careful planning. Bentall’s total root replacement and David’s valve sparing operation were conceived at the operating table and then progressively evolved in clinical practice.

**Operative method**

The aorta is mobilised from the aorto-ventricular junction to beyond the brachiocephalic artery. Dissection is straightforward in the non-coronary sinus. It is more difficult in the right coronary sinus because of the proximity of the muscular free-wall of the right ventricular.
The challenge in the left coronary sinus is the close proximity of right ventricular outflow tract and the pulmonary artery. Details are shown in elegant and informative drawings in Kenny’s description.\textsuperscript{6}

Dissection is made easier by avoiding cardiopulmonary bypass and anticoagulation — as has been done in 79\% of cases to date — and by lowering the blood pressure and heart rate, and exercising great patience. It is also facilitated by the greater length of aortic root proximal to the coronary origins which is a feature of Marfan morphology. Once the ExoVasc sleeve is in place laminar flow in the coronary arteries is confirmed by transoesophageal echocardiography.

In two instances the surgeon did not properly dissect the aortic root and the root aneurysm continued to enlarge. At repeat operations it was discovered that the critical area of the aortic root, proximal to the coronaries, had never been dissected or supported. These breaches of the operative protocol — effectively sham operations — are mentioned to emphasise the importance of strict adherence to the method.\textsuperscript{10}

\textbf{Establishing technical efficacy of the PEARS implant}

In a study designed and implemented in the Clinical Operational Research Unit at University College London the MRI images of the aortic root, before and at 6, 12, 24 and/or 36 months after the first 10 PEARS operations were cropped to remove identifiers and dates. They were placed in random sequence with duplicate images of 37 unoperated Marfan patients. Three commissure to sinus measurements were made ‘blind’ by an independent vascular radiologist. No supported root had further enlarged and 8 of 10 were markedly reduced, and remained so, with preservation of the sinus morphology.\textsuperscript{11}
In studies in the Department of Engineering at Imperial College London 2015-16 the characteristics of the neo-aorta created by mesh incorporation were explored with finite element modelling. Both circumferential and axial wall stress were seen to be reduced by up to 52% after PEARS implantation. Most type A dissections originate from a transverse tear close to the sino-tubular junction. PEARS eliminates this process by reducing the axial displacement.

**Investigating peri-operative benefits of PEARS**

The first 20 PEARS patients were matched for age and root size with patients having conventional root replacement at other hospitals where PEARS was not available. Only one of 20 PEARS patients (the first) had cardiopulmonary bypass, none had myocardial ischaemia. They had shorter operations times, markedly less blood loss and only one had a blood transfusion. None needed platelets or clotting factors.

**Evidence of incorporation of the mesh to form a neo-aortic wall**

Surgeons and scientists in Leuven, Belgium performed recovery experiments (2013-2017) in sheep which found that the PEARS mesh was densely and consistently incorporated in the vascular adventitia. There has been only one opportunity to confirm incorporation in man. The 16th PEARS patient operated on in 2008 at the Royal Brompton Hospital died in his sleep of a presumed arrhythmia in 2013. The aortic valve was normal and competent. On histological examination the mesh was incorporated into the aortic adventitia. Characteristic medial degeneration was seen distal to the support but within the implant, there was normal
The pathological interpretation was that absence of stress in the media of the supported part of the aorta allowed recovery of collagen formation.

Evolving indications and new applications of PEARS

The tenth PEARS recipient was referred because her Marfan related aneurysm had expanded during pregnancy. She wanted a PEARS operation to protect her during a subsequent planned pregnancy. She described her “Patient’s Journey” in the BMJ. We know of 13 would-be mothers who have had PEARS without evidence of further aortic enlargement and 14 subsequent successful pregnancies. One had her operation (off-pump) during her 2\textsuperscript{nd} trimester. All are well and the number of pregnancies may be an underestimate because pregnancy and childbirth are not routine items for enquiry after aneurysm surgery.

Early in the experience two patients had a PEARS implant and mitral valve repair at the same operation. A total of 43 patients had had both procedures. In some cases mitral regurgitation is the driving indication.

PEARS has also been used to support the pulmonary autograft in the Ross operation. The first 50 patients to have a Ross PEARS operation by Conal Austin were presented at the AATS aortic meeting 2024 and are published.

Patient numbers, case mix and results

The thousandth patient landmark was reached in spring 2024 but due to an exponential rise in case numbers only 218 are five or more years after operation so analysis of long-term outcomes would be premature. However, in the 20 years of clinical experience to date no patient in whom the ExoVasc\textsuperscript{®} PEARS device has been correctly implanted has demonstrated
subsequent dilatation or dissection of the supported ascending aorta. The follow-up study of
the first 200 patients who had PEARs for aortic root aneurysm and a matched-pairs
comparison with valve sparing root replacement (VSRR) are summarised in Table 1.

The authors’ conclusions
Increased awareness of the possibility of root aneurysms in families affected by inherited
connective tissue disease has resulted in people presenting early in the natural history of their
disease. The PEARs operation is designed precisely for these patients. Outcomes in the
matched comparison are similar but there is a significant difference in progression of aortic
valve regurgitation.

We cannot predict aortic dissection. PEARs may be ideal for patients whom we consider to
be at high risk of dissection due to family history, a period of rapid enlargement, a wish to
become pregnant at an aneurysm size lower than a commonly accepted threshold. When we
embarked on PEARs the range that we set for operation was an aortic root diameter between
40 and 50mm. We are acutely aware that in an important minority of aortic dissections the
ascending aorta is not enlarged. Therefore, in our assessment of a prospective patient, we
advise operative intervention if there is enlargement of 5 mm in 1 year even if the aortic
diameter is less than 40mm.
<table>
<thead>
<tr>
<th>Variable</th>
<th>PEARS 200</th>
<th>PEARS 80</th>
<th>VSRR 80</th>
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<tr>
<td></td>
<td>N (% or IQR)</td>
<td>N (% or IQR)</td>
<td>N (% or IQR)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>138 (69%)</td>
<td>57 (71.3%)</td>
<td>57 (71.3%)</td>
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<td>Age</td>
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<td>31.7 (21.5–42.5)</td>
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<td>48 (46–50)</td>
<td>48 (46–49)</td>
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<td>64 (80.0%)</td>
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<td>Reoperation for bleeding</td>
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<td>6 (7.5)</td>
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<tr>
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<td>1 (1.3%)</td>
<td>1 (1.3%)</td>
<td>1.00</td>
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<td>Death</td>
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<td>Length of stay (days)</td>
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<td>7 (6-9)</td>
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<td>AR grade 0/4 Post op</td>
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Data on the first 200 primary PEARs operations and a matched comparison of PEARs and VSSR. P values are for the two right hand columns.
References


