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## Personalized external aortic root support

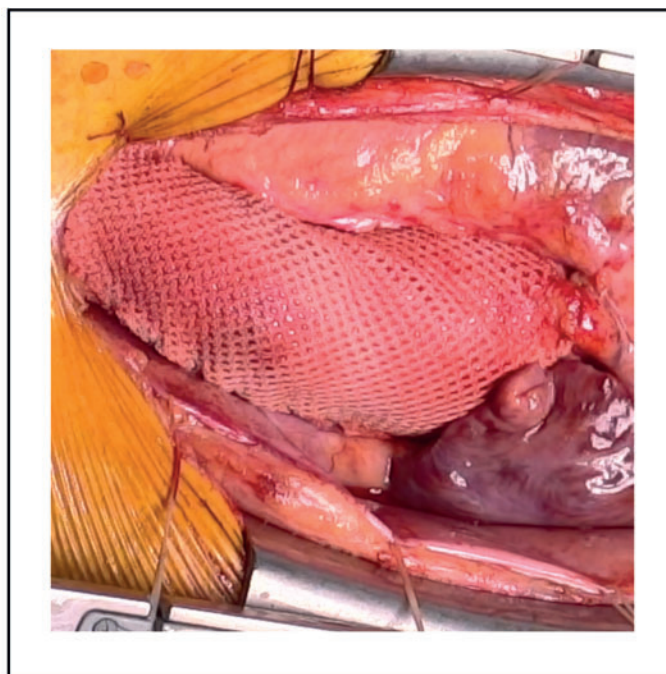
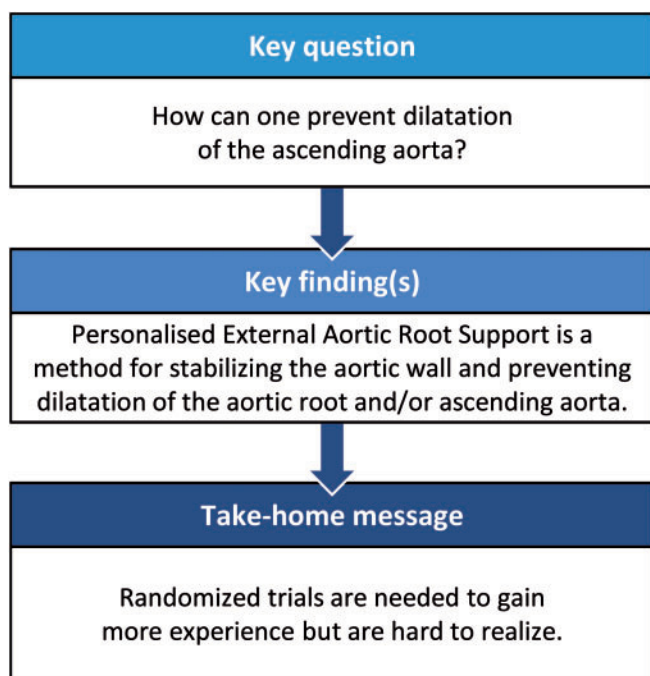
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### Abstract

**OBJECTIVES:** Implantation of a personalized external aortic root support (PEARS) can prevent dilatation of the aortic root and ascending aorta in patients with aortopathy of various aetiologies. Because PEARS is an emerging technology, all aspects concerning indications, surgical technique and safety should be elucidated. Our goal was to summarize all of these aspects so that physicians and patients would have sufficient information to evaluate this alternative approach.

**METHODS:** Between April 2004 and March 2020, 317 patients underwent PEARS operations at 25 surgical centres in 9 countries.

**RESULTS:** The most common indication was Marfan syndrome (57%). The single perioperative death represented a mortality of 0.3%. The long-term experience comprises 871 patient/years with 1 patient living for 15 years and 19 patients living for more than 10 years.

**CONCLUSIONS:** PEARS seems to be a promising method of treatment of dilatation of the aortic root and/or ascending aorta. Multicentre observational studies are needed to gain more experience because this operation is still uncommon and the number of operations per surgeon/centre is low.

**Keywords:** Dilatation of aortic root • Dilatation of ascending aorta • Personalized external aortic root support

### ABBREVIATIONS

|       |   |
|-------|---|
| AA    | Ascending aorta                           |
| PEARS | Personalized external aortic root support |
| VSRR  | Valve-sparing root replacement            |

## INTRODUCTION

Dilatation of the aortic root or ascending aorta (AA) is a common condition, especially in patients with genetic disorders (e.g. Marfan syndrome, Loeys–Dietz syndrome) and bicuspid aortic valve disease. If the aortic dilatation exceeds a diameter of 60 mm, the risk of aortic dissection is high [1]. Therefore, according to international guidelines, surgical intervention is recommended as a preventive measure against aortic dissection if the dilatation of the aortic root reaches 45–55 mm (subject to differing clinical and genetic situations) [1]. Current prophylactic operations include replacement of the AA with a prosthesis. In patients with any kind of valve disease, either replacement of the aortic root and the AA with a composite valved conduit (Bentall operation), a Ross operation or a valve-sparing root replacement (VSRR) is advised. All these operations are performed with the aid of cardiopulmonary bypass and cardiac arrest. They have an early mortality risk of ~1% and also a risk of some complications, such as valve regurgitation or false aneurysms in the longer term [2].

Personalized external aortic root support (PEARS) is a technology that was used for the first time 15 years ago but which has only recently been used with increasing frequency [3]. It was developed as an alternative surgical method to aortic root replacement in patients with Marfan syndrome [4]. It is a result of a new way of dealing with the problem, very similar to ‘respect rather than resect’ in mitral valve repair.

It is a pre-emptive operation without the necessity of opening the AA. In this procedure, a 3-dimensional copy of the patient’s aorta is made according to a computed tomography scan. A soft polyester mesh sleeve of the same shape and size is individually formed on the copy for implantation around the patient’s aorta and becomes incorporated in the aortic wall. PEARS halts further expansion of the aortic root and/or AA and conserves the architecture of the wall. Because the aortic valve and the endothelium are preserved, the potential complications of the Bentall procedure or VSRR are avoided [5].

## INDICATIONS

The most recent clinical guidelines only recommend replacement of the aortic root/AA in cases of dilatation [1]. No other technique, including the different types of wrappings, is mentioned. Conventional wrapping of the dilated AA with a rigid Dacron graft was used as early as 1994 [6]. Usually it is used in patients with a bicuspid aortic valve and post-stenotic fusiform dilatation. The advantage of wrapping is that it can be used during an emergency operation as an intraoperative option without prior planning [7]. This technique may lead to deformation and plication of

the aortic wall. Accumulation of fluid between the aorta and the stiff support has been seen [8]. Wrapping is not recommended in patients with Marfan syndrome or other connective tissue diseases [9]. Histological studies suggest that the stiff, low-porosity vascular grafts used were poorly incorporated into the adventitia and caused buckling at the transition between the wrapped and the unwrapped aorta. Conversely, the macroporous mesh (PEARS) is fully incorporated, resulting in a composite mesh/biological aortic wall [10].

The original indication for PEARS was asymptomatic patients with Marfan syndrome with aortic root dilatation. After initial favourable results, the indication criteria were slowly extended to all adult patients with dilatation of the AA or aortic root above 40 mm or to those patients with an aortic diameter whose size increased by  $\geq 3$  mm/year. Individual cases were reviewed by the PEARS Steering Group with a progressively wider range of aortopathies being included. The upper limit of the aortic diameter for PEARS use is not yet clear, but if the diameter exceeds 60 mm, PEARS should be used with caution. In children with genetic disorders affecting the aorta, implantation of PEARS is recommended if the diameter of the aortic root or AA has reached normal adult size (i.e. at least 35 mm) [11]. No upper age limit is advised (personal communication, J.P.).

The requirement for other concomitant procedures (e.g. mitral valve repair, atrial septal defect closure, MAZE procedure) does not preclude PEARS implantation [3, 12].

Experimental studies with reinforcement of the pulmonary artery with the PEARS microporous mesh in the arterial system revealed limited dilatation but also thinning of the vessel wall due to atrophy of the smooth muscle cells [13, 14]. Based on this experience, PEARS can be one of the preventive measures for the support of the pulmonary autograft in the systemic position (free-standing root replacement) (Ross-PEARS) [15].

## SURGICAL TECHNIQUE

The technique of implantation has already been described in detail [16]. In short, dissection and mobilization of the AA from the aortoventricular junction to the origin of the brachiocephalic trunk is necessary. It includes dissection proximal to the origin of both coronary arteries. A certain degree of controlled hypotension facilitates dissection of the aorta, particularly around and below the coronary arteries and at the aortoventricular junction. Optical magnification during dissection is essential. The preferred technique is implantation without the use of cardiopulmonary bypass. The latter is recommended primarily for patients with poor access to the aortoventricular junction due to a severely dilated aortic root or for patients with a thin wall and/or haemodynamic instability during the surgical dissection. Four to 6 stitches are recommended for proximal fixation at the level of the aortic annulus to the aortic wall, ideally 1 in each commissure and 1 in the nadir of each AV sinus. In the case of a bicuspid valve, the stitches should be placed symmetrically around the aortic annulus.

Openings for the coronary arteries into the external mesh are made with the implant still on the former, usually in the shape of an asterisk. The longitudinal/axial seam is opened. The mesh is

incised from the axial seam to the ostia of each coronary orifice. The lower tongue of mesh is placed under each coronary ostium with the aid of sterile gel. Then the lower margin of the mesh is secured with the previously inserted sutures. The incision of the mesh extending to the coronary orifices is sutured and the axial seam is then sutured. The distal end of the graft should be secured just beneath the brachiocephalic trunk.

There are several advantages of PEARS implantation in comparison to the traditional Bentall operation or VSRR. Ischaemic myocardial arrest, with its potentially detrimental effect on myocardial cells, is avoided. Disconnection of the coronary arteries and their reimplantation, which increases the risk of surgical complications, is also avoided. Opening the aorta, which introduces the risk of air or particulate embolization, is likewise avoided during PEARS implantation [17].

It is presumed that the PEARS implant does not present any obstacle to future surgical procedures. In fact, for those patients with compromised vasculature, e.g. Marfan syndrome, the incorporated mesh implant should make reoperation significantly safer because the reinforced vascular tissues are more robust. This situation was observed in the patient who died (of an unrelated cause) 4.5 years after his PEARS operation. His unsupported aortic arch had the histological features of connective tissue disintegration, typical of Marfan syndrome, whereas the histological makeup of the supported portion of the aorta was normal [18]. It shows that the aortic wall may have a tendency to heal when spared repetitive stress injury [19].

## SIZE OF THE PERSONALIZED EXTERNAL AORTIC ROOT SUPPORT

The diametrical size of the PEARS used is based on an individual assessment by the surgeon who performs the implant. The general recommendation from the manufacturer is 100% and 95% of the original aortic diameter. It should be noted that this diameter is based on the blood/contrast agent/lumen size. Even a 100% sized device is therefore slightly smaller than the outer diameter of the aortic wall.

## COST-EFFECTIVENESS

PEARS implantation is likely to save money because of the reduced hospital stay. The low risk of complications would also favour cost-effectiveness. However, the pre-emptive nature of this operation leads to more operations, even in patients who would never go on to have dissection later in life. But the well-timed operation could save lives [20]. The PEARS operation certainly improves the quality of life because patients can live satisfying and uneventful lives instead of being constantly in fear of a catastrophic event during the period of watchful monitoring until their aorta reaches the current size threshold recommended in the guidelines for aortic root replacement [5].

## ADVERSE EVENTS

Present experience includes single cases of specific adverse events. One perioperative death occurred due to an injury to the left coronary artery in a patient with severe pectus excavatum. No mesh was ultimately implanted. The patient died 5 days after

the operation of cerebral bleeding [21]. Another patient suffered an injury to the right coronary artery. It was successfully resolved with coronary artery bypass grafting. These 2 cases should be taken as important reminders of the potential hazards of this procedure.

One patient died 4.5 years after PEARS implantation of an unrelated cause: the reason was probably malignant arrhythmia [18]. A second patient died 6.5 months after his PEARS operation of chronic heart failure. He had a history of alcoholic cardiomyopathy. Immediately after his PEARS implantation, he had acute heart failure due to occlusion of his circumflex artery. It was managed successfully by a reoperation, adjustment of the PEARS support and implantation of a stent in the circumflex artery.

One patient had to be reoperated on due to hypotension while in the intensive care unit. The axial suture line of the mesh implant was partially released. After 6 years, aortic valve regurgitation developed, and the patient had to be reoperated on to correct dilation of the non-coronary sinus. The mesh-reinforced aortic wall was identified and could be cut and sewn safely [21].

## FOLLOW-UP

Patients should be regularly followed up by their surgeon or cardiologist. The preferred method for repeated examination is magnetic resonance imaging [5]. Magnetic resonance imaging examinations are recommended at 6 months and 1 year after the procedure and then at 2-year intervals, provided there is no change in aortic dimensions/morphology. The objectives of this examination are to check the aortic root and/or AA within the PEARS implant and the aortic arch/descending aorta because dilatation can occur beyond the distal end of the implant. If (mild) AR is suspected, transthoracic echocardiography at the same intervals is recommended.

Antithrombotic therapy and prevention of infective endocarditis are not necessary.

Long-term follow-up has shown favourable results in comparison with the Bentall operation or VSRR [20]. Some doubts were expressed about the ability to fully stabilize the aortic annulus [22]. Izgi *et al.* [5] disproved this concern by showing in their cohort of 24 patients that the aortic annulus diameter stayed constant for 6.3 years after the initial operation. Moreover, 2 female patients from his series had uneventful pregnancies without any significant changes in aortic diameter.

## PATIENT INFORMATION

The overall experience with PEARS is limited. It comes only from anecdotal case reports or small series from single institutions [5, 16, 17, 20]. However, all patient data are collected prospectively and kept in a secure database. Furthermore, ExoVasc Ltd is the sole manufacturer of the PEARS implant. According to the 'Project Status' information, PEARS has been performed in more than 300 patients at 25 surgical centres in 9 countries. The most common indication was Marfan syndrome (57% of cases). A single perioperative death represents mortality of 0.3%. Long-term experience comprises 871 patient/years with 1 patient living for 15 years and 19 patients living for more than 10 years [3].

These data provide good evidence of the safety of this procedure. That said, all physicians should keep in mind that this procedure is still in an early clinical phase of use. All patients should

be fully informed about all the facts pertinent to this operation and also about possible alternative treatments [23, 24].

## CONCLUSIONS

PEARS appears to be a promising method of treatment of dilatation of the aortic root and/or AA. The number of patients receiving a PEARs implant is increasing. The durability of the material and procedure is proven and mid-term results are extremely promising. Nevertheless, this operation is still uncommon, and the number of operations per surgeon/centre is low. Randomized trials are needed to gain more experience and could help to provide further insights but are probably hard to realize.

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## Author contributions

**Petr Nemeč:** Conceptualization; Writing—original draft. **John Pepper:** Writing—review & editing. **Petr Fila:** Resources; Writing—review & editing.

## Reviewer information

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