WRAPPING OF THE MODERATELY DILATED ASCENDING AORTA BY FRESH AUTOLOGOUS PERICARDIUM

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Abstract

Background and aim of the study. Wrapping of the ascending aorta (AA), isolated or associated with aortoplasty, has never been completely accepted. Some complications, as folding of the aortic wall, compression of the vasa vasorum and changes in the flow pattern, with consequent dilatation of the proximal arch, have been described. We used fresh autologous pericardium (FAP), so far never reported, to wrap the AA, with the aim to stabilize its size when moderately dilated, maintaining the preoperative dimension or limiting the reduction to a few mm. **Material and Methods.** From 2015 to 2019, 10 patients, who were operated on for valve or coronary surgery or both, underwent wrapping of the AA with FAP. Mean age was 69±7 years and ESII 3.5±1.7. Four patients had moderately impaired ejection fraction (35-49%). **Results**. There was no early or late mortality. One patient was reoperated on after 48 months for severe mitral regurgitation. At a follow up of 53±14 months, a transthoracic echocardiogram showed that the AA size reduced slightly but significantly, from 45.2±2.0 to 42.5±4.1 mm, p=0.03. The diameter of the proximal arch remained unchanged, from 37.1±1.6 to 36.3±2.9 mm, p=0.20. **Conclusions**. In presence of moderately dilated AA wrapping can be a reasonable option. The use of FAP stabilizes the size of the aorta after a follow up of 53 months. Maintaining a size similar to the preoperative one avoids the complications related to the procedure.

INTRODUCTION

In the early period of cardiac surgery pump time and ischemic time were strictly correlated to perioperative mortality. The consequence was that all the efforts were targeted to reduce the duration of these procedural parts. The ascending aorta (AA) aneurysms were treated by wall plication, or aortoplasty, or wrapping or a mixture of them[1-6]. This experience was maintained over time, even if the analysis of the long-term results sometimes led to some concerns. Among these techniques, external wrapping was used first to support the ascending aorta after reduction aortoplasty, but later it became more popular as the only tool to reduce the AA size, as it does not need extracorporeal circulation. The concept of wrapping as a support without aortoplasty has been recently revisited by Golesworthy et al[7], who introduced the personalized external aortic root support, developed as an alternative method to prevent dilatation of the aortic root in patients with Marfan's syndrome. However, this device is based on computer-aided design and 3D printing of the individual's AA on which the supporting mesh (microporous polyethylene terephthalate) is manufactured. It is a pre-emptive operations, addressed in general to patients with aortopathies with a AA size from 40 mm to not more than 60 mm[8].

The material used for conventional wrapping of the ascending aorta (WAA) is a microporous polyethylene terephthalate (dacron) tubular graft, which is rigid and changes the ascending aorta in a tubular pipe. We decided to use the fresh autologous pericardium (FAP) not to reduce the AA diameter, but to stabilize its dimension to more or less the same at the baseline. The rationale was that FAP had some elasticity, that allowed the AA to adapt to changes in hemodynamic stresses, does not calcify or retract, as it is not inside the bloodstream, and it is able to adapt to the AA shape. We herein report the early and late results of our experience.

MATERIAL AND METHODS

From 2015 to 2019 FAP was used for wrapping of the AA in 10 patients. In all of them the AA dimensions were below 50 mm. As none of them had bicuspid aortic valve or Marfan's syndrome, current guidelines did not advise AA replacement[9]. Preoperative clinical transthoracic echocardiographic data, with particular regards to aortic root at Valsalva sinuses level, sinotubular junction (STJ), AA and proximal arch dimensions, were collected in all patients using the parasternal long axis projection. Retrospective analysis of our database was approved by the Local Institutional Review Board, which waived patient consent.

Surgical technique . The pericardium was carefully dissected toward both pleuras. A piece large in general 16 cm and as long as the AA, from the origin of the brachiocephalic trunk to the STJ, was harvested. The pericardium was trimmed to fit the concavity and the convexity of the AA and was then kept in a bowl with saline. At the end of the procedure, after protamine, the AA was dissected for its whole length and surrounded by the pericardium. It was then sutured proximally and distally to the STJ and to the aorta close to the proximal arch with 4/0 Prolene, trying not to go through the full thickness of the aorta. The pericardium was then sutured around the aorta with 4/0 Prolene and the excess of tissue cut (fig. 1A). Another suture (4/0 Prolene) is then passed parallel to the previous one, from the proximal to the distal AA (fig. 1B). This suture, after pressure reduction, either pharmacological or by means of intermittent closure of inferior vena cava, is put in tension to allow the pericardium to fit properly to the AA (fig. 1C). The final result is an AA with a size more or less similar to the preoperative one, but wrapped completely with pericardium from the STJ junction to the proximal arch (fig. 1D). In all patients who underwent myocardial revascularization, we used anaortic grafting, using as blood source the left, the right or both internal thoracic arteries.

Follow up . All patients were clinically followed at our outpatient clinic. The follow up ended on November 2021 and was 100% complete. All the patients had an intermediate echocardiography after a mean of 16±4 months. The final postoperative echocardiogram was performed between June and October 2021. Mean clinical and echocardiographic follow up was 53±14 months.

Statistical analysis . Categorical variables are expressed as counts and percentages. Distribution of continuous variables was assessed using the Shapiro-Wilk test. Continuous variables are expressed as mean +- standard deviation if normally distributed, as median with the 25th and 75^{th} percentiles if not normally distributed. Pre- and postoperative data of each group were compared by paired t-test for normally distributed. variables, or Wilkinson test for non-normally distributed variables. The ANOVA test for repeated measures was applied for repeated echocardiographic data. If not otherwise indicated definition of the variables follows the definition reported in the EuroSCORE II model[10]. For all tests, a P-value <0.05 was considered statistically significant. The SPSS software (SPSS Inc, Chicago, IL) was used.

RESULTS

Table 1 shows some preoperative and perioperative data of the patients. Eight patients had chronic renal failure, mainly moderate (n=7). Ejection fraction was good in most of the patients (n=6). Nine patients had anaortic CABG, isolated (n=4) or associated with aortic valve replacement (AVR, n=5), whereas one patient had isolated AVR. Wrapping was successfully performed in all the patients.

There was no early or late mortality and no complications, either during the postoperative period or during the follow up. One patient was reoperated on after 48 months because of severe mitral valve disease and underwent uneventful mitral replacement.

Echocardiographic outcome . Table 2 shows the results of the median and last echocardiography compared with baseline. The ANOVA for repeated measurements showed that the aortic root at the level of the Valsalva sinuses reduced slightly but significantly as well as the AA diameter (p=0.03). The STJ and proximal arch showed a mild reduction, but not significant. Comparison between the median and the last follow up showed that all the results remained stable over time.

DISCUSSION

Wrapping of the AA was first described by Bahnson and Nelson in 1956[1], who performed aortic AA reduction using a side clamp and wrapping in 2 patients. Both suddenly died 4 and 5 months after surgery. Wrapping in the early period was associated with oval excision of the AA (aortoplasty) and was only an external support and not a tool to reduce the size of the aorta[11]. Results of aortoplasty and wrapping were satisfying[12,13], but a meta-analysis of Plonek et al[14] with 722 cases concluded that isolated aortic wrapping had better results than wrapping and aortoplasty or wrapping and aortic plication. However, even if wrapping of the AA is technically simple, the report of complications intrinsic to the technique with/out aortoplasty prevented a wide application of this strategy[15-21]. In contrast, replacement of the AA is a well-studied procedure, reproduceable and easy to perform, with uniformly good results. Wrapping of the AA involves the use of a conventional vascular prosthesis of a preselected size, smaller than that of the AA, with the aim to avoid further dilatation of the aorta and the related complications. A problem is the formation of folds[22]. The size of a vascular graft is, at maximum, 36 mm. Then the reduction is at least 10 mm or more. The presence of folds, due to a severe mismatch between the graft and the size of the AA, changes the flow patterns and can lead to compression and erosion of the aortic wall. Neri et al[15], in 2 patients who underwent a reoperation, found that the reinforced aorta was significantly thinner, with a sclerotic microstructure in which layers were no longer present. Also, the atrophied aortic wall showed cellular and neovascular infiltration and common in a foreign-body reaction. On the contrary, the samples retrieved from the non-reinforced aorta showed a basically normal histologic structure. At the basis of these changes there are the compromise of the vasa vasorum that nourish the middle layer of the aorta, chronic inflammatory response to the foreign material, and sustained compression of the aortic wall between the pressure of blood and of the external prosthesis. As a consequence of these changes, the aorta becomes a passive conduit with biomechanical characteristics similar to those of a synthetic vascular prosthesis. These changes seem to be less evident when the AA is reinforced with a dacron (macro-porous) mesh instead of a vascular conduit[23], probably due to its greater elasticity.

An external support that reinforces the vessel without interfering with the pattern of flow is very attractive, but not free of drawbacks. The aorta is a very strong structure. Aortic rupture does not occur if the intraluminal pressure ranges from 790 to 2070 mm Hg[24]. Robertson and Smith, injecting water into the media of 42 fresh human aortas, found that the lowest pressure required to exceed the cohesive strength of the media was 273 mm Hg and the highest was 975 mm Hg, with a mean of 566 mm Hg[25]. Therefore, the aorta is highly resistant to rupture or dissection. Recently, an appealing theory on the genesis of intramural hematoma and aortic dissection was reproposed[26,27]. Vasa vasorum dysfunction is the link between these entities, which are seen as progression of one into the other. Rupture and bleeding of the vasa vasorum into the media are the causes of intramural hematoma. It can remain limited to the thickness of the aorta or cause an intimal tear, which is at the basis of classic aortic dissection. The vasa vasorum fill during diastole as in the coronary circulation. Thus, an increase in arterial diastolic pressure results in reduced perfusion[28], which can cause vessel wall hypoxia and neoangiogenesis, with the neovessels more fragile and prone to bleed. Hypertension also can reduce blood flow by distortion or compression of the vasa, generating changes in the walls of the vasa vasorum with critical ischemia and necrosis of the media. Other factors (eg, inflammation) can induce aberrant and adverse remodelling of the aortic wall, including smooth muscle cell loss in the media and extracellular matrix degradation in the media and the adventitia. The consequence is chronic dilation of the aorta, but an acute aortic syndrome can superimpose at any moment. Increased tension or chronic inflammation due to wrapping can cause localized hematoma or necrosis, weakening the aortic wall. The benefit of reducing wall stress reducing the diameter has to be compared with the interference with the nourishment of the aortic wall.

Wrapping also modifies the biomechanical characteristics of the blood flow in the entire arterial system[29].

The synthetic materials used to externally reinforce the aorta are much less elastic than a healthy or diseased native aorta, which alters the pressure of the entire arterial system. This fact has been associated with a higher risk of cardiovascular events in hypertensive patients[30]. On the other hand, the compliance mismatch between the native and the reinforced aorta leads to hemodynamic changes that increase the circumferential wall stress in the aortic segments at the interface of supported and unsupported aorta[29], shifting distally the area of greatest expansion[31]. This particular aspect was emphasized in a recent paper from Kim et al[32], where the Authors compared the long term outcome of wrapping compared to conventional replacement of the AA in propensity matched patients. After a median follow up of 7.1 years, the proximal arch dilated in the wrapping group (0.343 mm/year), but not in the replacement group. In the wrapping group preoperative AA size was a risk factor for proximal arch dilatation, with a cut off value of 47.15 mm. Total adverse aortic event (reoperation of ascending or arch aorta, dissection or rupture, redilatation of the aortic arch) were higher in the wrapping group (24.3% vs 14.3%, p=0.010) during the follow up. Then, graft migration because of proximally or distally incomplete fixation of the prosthesis can cause proximal and distal redilatation, but proximal arch dilatation can be due to mechanisms intrinsic to the concept of wrapping even if presence of a correct surgical technique.

We decided, in presence of a moderately dilated AA, to change the strategy of wrapping. The size of the AA remained unchanged or reduced only of a few mm (fig. 1E), to avoid all the previously described possible complications, in particular folds and vasa vasorum compression. The use of FAP allowed us to follow the natural curvature of the vessel and to adapt proportionally to all the different portions of the aorta (fig. 1D). Moreover, it was observed that FAP is able to stretch in its two axes[33] and that the systolic deformation of the epicardial surface is characterized by a longitudinal shortening of 10%[34]. This property can act as shock absorber during the changes of the intra-aortic pressure, avoiding the aorta to become a static and passive conduit.

As our target is to stabilize the ascending aorta, the aorta does not fold internally and the hemodynamic stress at the distal portion of the AA remains unchanged. The concept we applied is similar to that one reported by Robicseck et al[35] who described the use of a tubular dacron prosthesis, if necessary enlarged by a dacron oval patch, to reinforce the aortic wall, procedure that the Authors called "external grafting". The targets were patients with a moderately dilated AA, "too big to leave in and too small to take out", as the population by us treated.

Our results have been good in all patients, without any early or late aortic complication. The AA size remained stable with time. However, the main limitation of this report is the small number of patients, only 10, even if with a reasonable follow up. Moreover, the follow up was performed with echocardiographic parameters, as many of the patients had no preoperative CT scan and an echocardiogram was easy to perform.

In conclusion, we think that wrapping of the AA (from the STJ till the beginning of the proximal arch) can have still a place when the AA is moderately dilated. The use of FAP allows to avoid further dilatation, maintaining more or less the same diameter at the moment of wrapping, without interfering with the nourishment of the aortic wall and with the hemodynamic patterns. The rationale of wrapping has to be changed, from reduction to values more or less normal (by 10 or more mm) to pure stabilization of the actual diameter to avoid any further dilatation.

LEGEND

Figure 1 – A, after being sutured distally (at the level of the sino-tubular junction) and proximally (between the distal ascending aorta and the proximal arch), the fresh autologous pericardium is wrapped around the aorta. B, another suture is then passed parallel to the previous one (white arrows and dashed lines), from the proximal to the distal ascending aorta (fig. 1B). C, this suture is put in tension to allow the pericardium to fit properly to the ascending aorta. D, the final aspect is an ascending aorta with the same shape and size than before surgery, but completely wrapped with fresh autologous pericardium, that, at the follow up, becomes completely adherent to the aorta (E).

Table 1 – Preoperative and perioperative data (n=10)

Age (y) 69+-7

Female gender 2

Hypertension 7

Diabetes 0

COPD 0

Creatinine 1+-0.2

Creatinine clearance (ml/min) 78+-28

CRF moderate 7

Severe 1

Peripheral vascular disease 1

Previous CVA 0

Redo 0

NYHA Class I-II 7

III 3

ESII 3.5+-1.7

EF (%) [?]50 6

35-49 4

AVR 1

AVR+CABG 5

CABG (off-pump) 4

ECC (min, n=6) 132+-26

Xclamping (min, n=6) 88+-19

Table 2 – Echocardiographic aortic measurements before surgery, at intermediate and at last follow up.

baseline intermediate last p1 p2 p3 ANOVA

16+-4 mos 53+-14 mos

Valsalva sinuses (mm) 37.4+-1.9 36.5+-2.6 36.2+-2.7 0.04 0.03 0.08 0.03

Sinotubular junction (mm) 38.5+-2.3 37.7+-3.0 37.7+-2.9 0.07 0.07 0.34 0.07

Ascending aorta (mm) 45.2+-2.0 42.7+-4.2 42.5+-4.1 0.04 0.03 0.33 0.03

Proximal arch (mm) 37.1+-1.6 36.6+-2.5 36.3+-2.9 0.32 0.20 0.08 0.20

p1: baseline vs median 1: p2: baseline vs last; p3: median vs last

Legend: mos, months.

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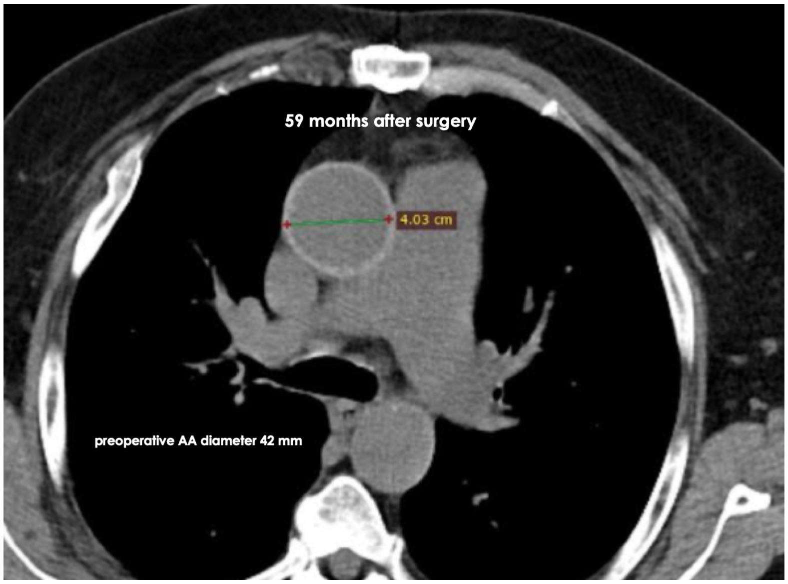
59 months after surgery
4.03 cm
preoperative AA diameter 42 mm

Fig. 1E

Fig. 1D

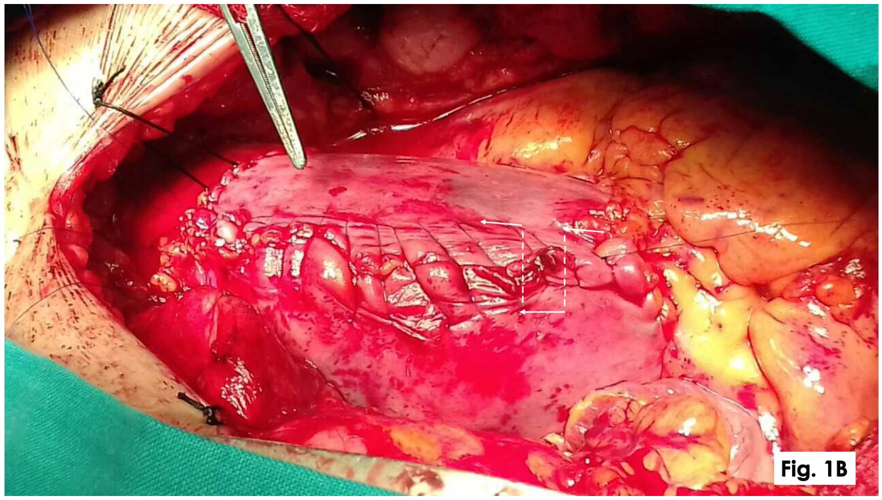

Fig. 1B

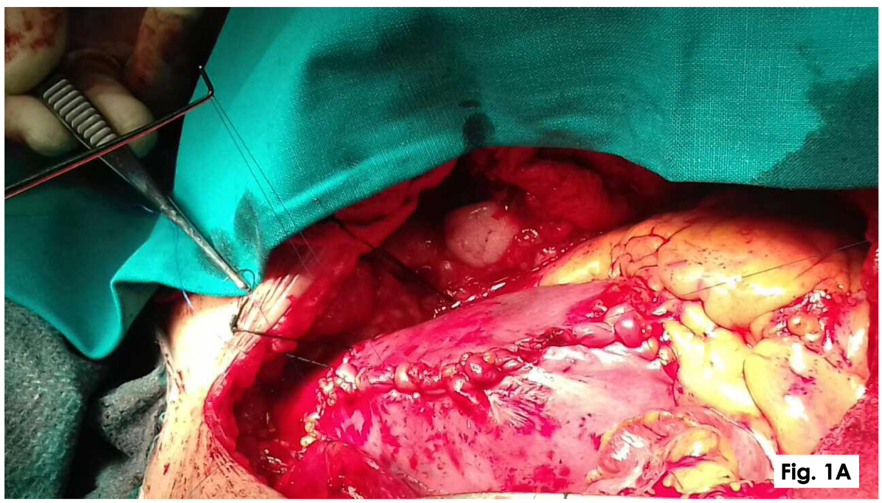

Fig. 1A

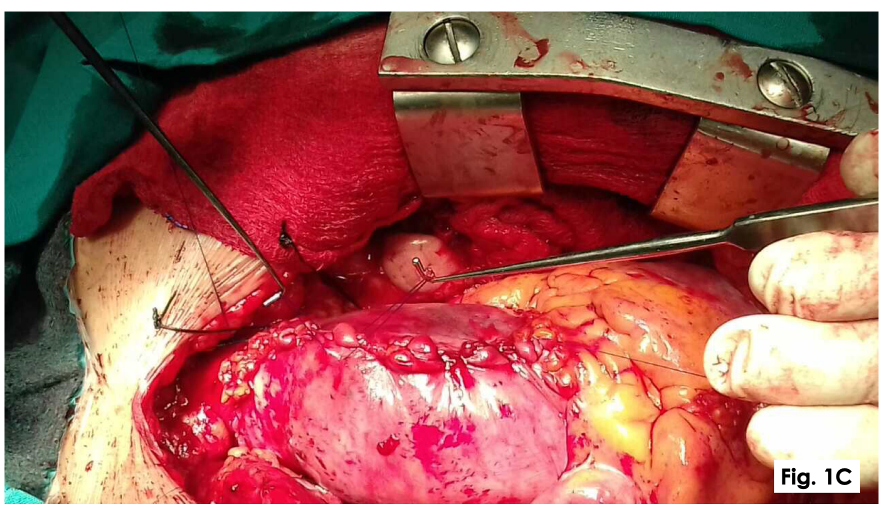

Fig. 1C