Graft dilation after redo surgery for aneurysm formation following patch angioplasty for aortic coarctation

Jan Bogaert,*, Steven Dymarkowski, Werner Budts, Marc Gewillig, Willem Daenen

*Department of Radiology, University of Leuven, Gasthuisberg University Hospital, Herestraat 49, B-3000 Leuven, Belgium
Department of Cardiology, Gasthuisberg University Hospital, Leuven, Belgium
Department of Pediatric Cardiology, Gasthuisberg University Hospital, Leuven, Belgium
Department of Cardiac Surgery, Gasthuisberg University Hospital, Leuven, Belgium

Received 27 July 2000; received in revised form 24 November 2000; accepted 8 January 2001

Abstract

Objectives: Aneurysm formation after patch angioplasty for aortic coarctation is a frequent and potentially lethal complication, necessitating surgical reintervention. Although several mechanisms have been postulated, flow disturbance in a concomitant hypoplastic transverse aortic arch most likely contributes to the aneurysm formation. The outcome of the grafts after redo surgery, however, is unknown. The purpose of this study was to evaluate the outcome of the inserted graft in patients with surgery for aneurysm formation following patch angioplasty for coarctation of the aorta. Methods: In 16 patients redo surgery was performed for aneurysm formation (diameter: 47.1 ± 11.9 mm) (mean ± SD), 12.7 ± 2.1 years after the initial patch angioplasty. All patients had a concomitant arch hypoplasia. They were treated by insertion of a Dacron Gelseal graft (16–30 mm), but the associated hypoplastic arch segment was left untouched. To evaluate the evolution of the new graft, patients were followed by means of magnetic resonance (MR) imaging. Results: The immediate postoperative outcome was uneventful in 12 patients. Four patients, however, suffered from a recurrent nerve paralysis and one of them of a spinal cord transection. The mean follow-up time was 54.1 ± 17.9 months during which 59 magnetic resonance studies were performed. The number of MR studies per patient ranged from two to seven. The graft diameter increased significantly with 56 ± 18%, range 20–82 (P, 0.0001). This widening was most pronounced within the first year after surgery (43 ± 16%, range 5–67) (P < 0.0001). Conclusions: Flow acceleration caused by an even mild hypoplastic transverse arch can put excessive strain on the distal part of the aortic arch. This can lead not only to aneurysm formation after patch angioplasty but also to excessive dilation of the Dacron Gelseal graft. At intermediate long-term follow-up, however, a stabilization of the graft dilation is observed. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Aortic coarctation; Aneurysm; Aortic surgery; Magnetic resonance

1. Introduction

Current state-of-the-art treatment of surgical coarctation of the aorta is aimed at relieving the stenosis, preferably by resection and end-to-end anastomosis, and may in rare surgical cases require the use of prosthetic material. The latter procedure, however, was favored in the late seventies and early eighties. Patch grafts angioplasties aimed to enlarge the narrowed aorta by means of insertion of synthetic material (Dacron, polytetrafluoroethylene (Gore-tex, Teflon, Impra)). However, despite the excellent early clinical results, an increasing number of patients showed late aneurysm formation at the repair site [1–5]. To prevent complications such as rupture of the aneurysm, long-term follow-up is strictly required, and surgical reintervention may be necessary. A reintervention consists in an insertion of a synthetic graft in the aneurysm. Since the outcome of the newly inserted graft is unknown, the present study was designed to prospectively evaluate those patients by means of magnetic resonance (MR) imaging on a regular time base. This non-invasive imaging modality has proven to accurately assess both the morphologic and functional abnormalities in patients with surgical repair for coarctation of the aorta [4,6–9].

2. Material and methods

2.1. Patient population

Between 1978 and 1985, 85 patients (63 male, 22 female) (age at surgery: 6.9 ± 4.5 years, range 0.2–27 years) with coarctation of the aorta were treated with synthetic (Dacron)
patch angioplasty. After two patients suddenly died of a ruptured aneurysm at the repair site late after surgery, all remaining patients were screened to exclude new aneurysm formation. Screening was performed regularly, and consisted in a clinical examination, blood pressure measurements in both the upper and lower limbs, chest X-ray, echocardiography and since 1990, also MR imaging. We used similar criteria to those in the literature to diagnose an aneurysm [3,10,11]. A ratio of the diameter at the repair site to the diameter of the aorta at the diaphragm equal or larger than 1.5 was defined as an aneurysmal dilation. However, not all patients with a ratio \( \geq 1.5 \), underwent surgical reintervention. The decision to surgical reintervention was based not only on the ratio, but also the growth rate of the aneurysm obtained on the follow-up studies. Similar to the literature, concomitant hypoplasia of the transverse aortic arch was defined as a ratio of transverse aortic arch to distal descending aorta \( < 0.9 \) [3,12]. All patients who underwent reoperation for aneurysm formation, according to the above-mentioned criteria, presented with a transverse arch hypoplasia at the first operation. All studies conformed to the guidelines of the Ethical Commission of our hospital. Informed consent was obtained from all patients.

2.2. Surgical reintervention

A left thoracotomy was used as approach for the surgical reintervention. The thoracic aorta was clamped proximal of the left subclavian artery and distal of the aneurysm. Next, the aneurysm was opened and a tubular Dacron Gelseal graft was inserted proximally at the confluence of the transverse aortic arch and left subclavian artery, distally at the distal endoluminal neck of the aneurysm. All the aneurysms were true aneurysms: all the suture lines were intact; the native aortic tissue was stretched at the opposite site of the Dacron patch. The diameter of the graft was adjusted to the aortic diameter of the descending thoracic aorta. Surgical reintervention was often impeded by fibrotic adhesions in the pleural space and at the repair site following patch angioplasty. Moreover, surgery was often impeded by the size of the aneurysms, which made not only clamping of the thoracic aorta often very difficult but also, special care had to be taken not to dissect the vagal, phrenic or recurrent nerves.

2.3. MR imaging protocol and image analysis

The thoracic aorta was studied by means of an ECG triggered T1-weighted spin-echo (SE) MR sequence in the axial plane and parasagittal through the thoracic aorta. Additionally, a three-dimensional contrast-enhanced ultrafast MR angiography was performed of the thoracic aorta. Postprocessing of the MR angiography data includes multiplanar reconstruction (MPR) in the axial and parasagittal plane and maximum intensity projection (MIP) of the thoracic aorta. The maximum diameter of the thoracic aorta at the repair site is measured taking into account the regional curvature and eventual kinking of the postoperative aorta. For the evaluation of the changes in diameter of the inserted graft, we used normalized rather than absolute diameters, which were obtained by dividing the measured diameter by the diameter of the inserted graft [3,11].

2.4. Statistical analysis

All results are expressed as mean \( \pm \) SD. For the evaluation of the graft dilation a paired \( t \)-test was used comparing the absolute diameters of the graft at insertion with the measured diameter of the aorta at the repair site on the follow-up MR studies. A \( P \)-value of less than 0.05 was considered as being statistically significant.

3. Results

3.1. Patient group

Sixteen of the 85 patients (14 male, two female) with patch angioplasty for aortic coarctation underwent surgical reintervention for aneurysm formation at the repair site. Despite the above-mentioned surgical difficulties, the immediate postoperative outcome was uneventful in 12 patients. Four patients, however, suffered from a recurrent nerve paralysis and one of them of a spinal cord transaction. Mean age at redo surgery of the 16 patients was 23 \( \pm \) 5 years, range 17–37. The time between patch angioplasty and redo surgery was 13 \( \pm \) 2 years, range 8–17. The diameter of the aortic aneurysm at the preoperative MR study was 47.1 \( \pm \) 11.9 mm, range 29.0–73.8 (ratio 2.21 \( \pm \) 0.51) and corresponded closely with the surgical findings. At surgery, the wall of the aortic aneurysm was extremely thin in all patients. Moreover, all patients presented with a transverse aortic arch hypoplasia (15.8 \( \pm \) 2.8 mm (range 10.2–19.4; ratio 0.75 \( \pm \) 0.1)). A tubular Dacron Gelseal graft was inserted at the aneurysm. Depending on the caliber of the thoracic aorta, the diameter of the inserted tubular Dacron Gelseal graft varied between 16 and 30 mm (16 mm \( n = 4 \); 20 mm \( n = 7 \); 22 mm \( n = 3 \); 28 mm \( n = 1 \); 30 mm \( n = 1 \)). The concomitant hypoplastic transverse aortic arch was left untouched.

3.2. MR studies

A total of 59 follow-up MR studies were performed after the reintervention in these 16 patients (seven MR studies: \( n = 1 \); six MR studies: \( n = 1 \); five MR studies: \( n = 1 \); four MR studies: \( n = 6 \); three MR studies: \( n = 3 \); two MR studies: \( n = 4 \)). The mean follow-up time was 54 \( \pm \) 18 months (range 19–85). In 12 patients, a first MR study was performed during the first year after redo surgery.

3.3. Outcome of the inserted tubular graft

The changes in graft diameter, normalized to the original diameter, are shown in Fig. 1. After a mean follow-up time
of 54 ± 18 months, there was a graft dilation of 56 ± 18%, range 20–82. Most of this dilation occurred in the first year following surgical intervention (43 ± 16%, range 5–67) obtained in 12 of the 16 patients. Only a slight to moderate dilation was demonstrated on the latter MR studies (15 ± 14%, range 0–42) (Fig. 2). No other complications such as graft dehiscence or restenosis were demonstrated. In one patient, a small outpouching was detected at the level of distal suture, most likely caused by a small pseudoaneurysm (Fig. 3). The latter patient was closely monitored by means of MR imaging to follow the changes in size of this outpouching. At the last MR study, 85 months post-reintervention, no increase of the small outpouching was detected.

4. Discussion

Aneurysm formation is a well-known, potentially fatal complication after patch angioplasty for coarctation of the aorta. In our patient group with Dacron patch aortoplasty, two patients died of a ruptured aneurysm, while 16 other patients presented an aneurysm necessitating reintervention. Some of them were very large (up to 74 mm). Although the underlying physiopathological mechanisms are unclear (e.g. aortic wall weakness, compliance mismatch between graft and native wall) [13–16], we recently reported on the relation between the occurrence of an aneurysm at the repair site and a concomitant hypoplastic transverse aortic arch [11]. This report describes a historical series. In those days a repair of the transverse aortic arch was not advocated. Abnormal flow patterns, i.e. flow acceleration and turbulence, originating in this hypoplastic aortic arch very likely contribute to the occurrence of aneurysms in the distal aorta char-

Fig. 1. Graft dilation. The changes in graft diameter in the 16 patients during follow-up are expressed as the percent diameter change.

Fig. 2. Follow-up MR study, preoperatively (a, b), and at 7 months (c), 46 months (d) and 68 months (e) post-operation. This 23-year-old male (patient 3) presented 10 years after patch angioplasty with a huge aneurysm at the repair site (71 mm diameter) as shown on the axial (a) and parasagittal view (b). A 30-mm Dacron Gelseal graft was inserted. A significant widening is already noticed at the first follow-up study 7 months after the redo surgery (c). The third (at 46 months) (d) and fifth (at 68 months) (e) follow-up study do not demonstrate an important further graft dilation.
acterized by changed wall properties. Depending on the size of the aneurysms, surgical reintervention is required and consists of an insertion of a tubular graft into the aneurysm, thus connecting the transverse aortic arch to the more distal descending thoracic aorta. At surgery, the necessity of reintervention became evident because most aneurysms presented with an extremely thin wall, prone to a sudden rupture. Because of the complexity of surgery and the much higher risk for complications, the concomitant hypoplastic transverse aortic arch was left untouched. Since the outcome of these newly inserted tubular grafts in this anatomic position is unknown, we prospectively evaluated the thoracic aorta in these patients by means of MR imaging and more recently also by means of MR angiography. They are not only excellent for non-invasive follow-up but allow one to measure the vessel diameter accurately. With the advent of three-dimensional ultrafast contrast-enhanced MR angiography sequences, the morphology of the postoperative thoracic aorta can be very well assessed [17].

In the present study, we were able to follow the patients after redo surgery during a mean period of 54 ± 18 months during which 59 MR studies were performed. Most patients received their first MR study soon after reintervention (i.e. within the first year), and in each patient repetitive studies were available. Most patients received a control MR study each year. Unexpectedly and in contrast with the use of these type of grafts in other parts of the body, all newly inserted grafts showed a marked dilation. While a minor degree of dilation of the graft can be expected, we found a significant dilation of more than 50%, ranging from 20 to 83%. More reassuring, however, are the findings from the repetitive follow-up studies. Most of the graft enlargement occurs during the first postoperative year, while only a small enlargement is noticed later on with a trend towards stabilization at intermediate to long-term follow-up.

At the moment, the mechanisms for this significant dilation are unclear. However, as we mentioned above, the hypoplastic transverse aortic arch was left untouched mainly for technical reasons. It might be hypothesized this pathologic segment acts as a trigger to induce the exaggerated dilation, as was previously found in patients with patch aortoplasty for coarctation of the aorta [11]. This might also explain why these excessive increases in graft diameter are found in this part of the aorta and not elsewhere. Next, some grafts are prone to a certain degree of stretch (i.e. knitted type), whereas others (i.e. woven type) will not show any dilation. In this study, the knitted type was used, and the follow-up caliber measurements suggest a stabilization of the stretch shortly after the insertion. Nunn et al. reported a 17.6% increase in diameter, while den Hoed and Veen only found a 5.9–8.9% increase in diameter of knitted Dacron aorto-ilio-femoral grafts [18,19]. One patient showed a small outpouching at the distal part of the graft, probably related to a small pseudoaneurysm. At the moment, no reintervention is planned, but the patient is being followed closely with an MR study each 6 months.

The results of this study show the relative high morbidity rate (one spinal cord transection, four recurrent nerve paralysis) after surgical reintervention procedures. Spinal cord transection can be prevented using a left heart bypass system, which is now routinely used for these surgical reinterventions. Therefore less-invasive procedures, such as placement of an intravascular endoprosthesis, will very likely become the preferred therapeutic choice in these patients. Finally, these findings are a strong argument in favor of correcting the transverse aortic arch at primary repair.

In conclusion, excessive graft dilation is found in patients with redo surgery for aneurysm formation after patch aortoplasty. However, at intermediate term this enlargement tends to stabilize. Longer follow-up studies are needed to confirm these findings.

Acknowledgements

This study has been supported in part by the Belgian Foundation for Research in Pediatric Cardiology.

References


