Valve-sparing aortic root repair in acute type A dissection: how many sinuses have to be repaired for curative surgery?†

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INTRODUCTION

The use of valved conduits consisting of a mechanical valve prosthesis and a vascular graft for the complete replacement of the aortic root, as described first by Bentall and De Bono in 1968 [1], has become a standard surgical technique for the repair of acute aortic dissection involving the root [2]. However, there is an increasing tendency to spare the native valve, especially in young patients without leaflet pathology [3]. Adhesion of the aortic wall layers within the dissected sinuses of Valsalva with a biological glue and subsequent supracoronary aortic replacement offers a simple and efficient method of preserving the native valve and eliminating the aortic insufficiency when it is caused by the distortion of the root anatomy [4]. However, this technique is still a matter of debate because the non-curative root repair can result in the development of several pathologies necessitating re-do surgery that is even more challenging after previous use of the glue. Our modified remodelling of the aortic root with replacement of selected sinuses of Valsalva, which has been used exclusively for years at our centre for valve-sparing root repair, offers, even if limited only to pathological sinuses, a curative surgery of the dissected aortic root with all its advantages [5]. The aim of the study was to evaluate operative and long-term results after using this technique for valve-sparing aortic root surgery in acute dissection.
the latter patients, in whom the goal of surgery was a valve-sparing root repair with replacement of all dissected and pathologically changed sinuses of Valsalva. Aortic diagnostics were based for all patients on computed tomography (CT) angiography, which was completed by coronary artery visualization through heart catheterization or cardiac CT in 17 patients. During surgery, transoesophageal echocardiography was performed to assess the function of the aortic valve and to recognize its pathology. In all but 2 patients, there was an aortic insufficiency of at least grade 1+, and 4 patients had a bicuspid aortic valve. The detailed patient characteristics are given in Table 1.

### Surgical technique

Aortic root repair using the original single patch technique has been described previously [5, 6]. In short, the proper aortic graft size was chosen by measuring the aortic annulus with a valve sizer and defined as the same size as the biggest sizer that could pass through the aortic valve. Because this passing is not possible in bicuspid valves or in pronounced septal hypertrophy, the sizer was only placed on the valve, and the appropriate size was judged visually. The tube with the same diameter as the aortic annulus or slightly bigger (1–2 mm) was chosen. The pathological sinuses of Valsalva, especially those with a dissected aortic wall, were excised, leaving a minimal rim of aortic wall attached to the aortic valve. Depending on the number of sinuses that had to be replaced, one to three patches were excised from the vascular graft and trimmed to teardrop shapes matching the size of the respective valve cusps. Even if the sizing is based on visual judgement, the determination of the proper size of neo-sinuses is much easier when they are cut out from the chosen vascular graft, keeping in mind that the sum of the sinuses’ widths had to be equal to the circumference of the tube. Until 2006, we used a standard straight woven polyester graft (‘InterGard’) for the root repair, and thereafter, a special graft with an uncrimped proximal part (‘InterGard Woven Aortic Thoracic Graft; InterVascular, MAQUET Cardiovascular, La Ciotat, France) because cutting the patches from the uncrimped tube facilitates the determination of their proper size and shape and improves the tightness of the suture line by eliminating leaks between the folds of Dacron [6, 7]. In 1 case with dissection of all the 3 sinuses, the re-implantation technique was performed with this graft for demonstration [6]. Because the primary goal of the study was to determine how many sinuses have to be replaced for curative valve-sparing root repair in acute dissection, we included this patient into evaluation. The patches were sewn to the rim of the aortic wall with a 5-0 polypropylene running suture passing through the aortic annulus and, in cases in which the coronary sinuses were replaced, coronary buttons were re-implanted. Because curative resection of all dissected tissue was always performed, no glue was used for any reinforcement of the aortic wall nor for reinforcement of the suture lines.

In 7 patients additional procedures on the cusps such as free margin plication, cusp patch plasty or others completed the aortic root repair, if necessary. Warfarin was not given postoperatively with the exception of patients with atrial fibrillation or other specific indications.

Operative data including the extent of surgery are given in Table 2.

All operative data were collected prospectively and an intention-to-treat analysis was performed. For the purpose of the study, the follow-up duration of at least 1 year was the goal for survivors. The patients were followed up by echocardiography performed in our outpatient clinic or by their cardiologist, from whom written documents and echocardiographic images, if available, were requested and reviewed. All data were analysed according to reporting guidelines [8].

### Statistical analysis

The statistical analysis was performed with the SPSS software (SPSS, Inc., Chicago, IL, USA). Values in the tables and text are expressed as mean ± standard deviation (SD) unless otherwise indicated. The overall survival was estimated by the Kaplan–Meier method.

### Results

#### Operative data and early mortality and morbidity

The average diameter of the patients’ aortic annulus was 25.1 ± 2.7 mm, for which an average aortic vascular prosthesis size of 26.0 ± 3.5 was used. Curative aortic root repair by the replacement of all dissected sinuses of Valsalva without the use of any glue was performed in all patients. Replacement of 1, 2 or 3 sinuses of Valsalva was performed in 29, 12 and 5 patients, respectively. The operative data are shown in detail in Table 2.

Re-thoracotomy due to bleeding or delayed chest closure were necessary in 8 patients (17.4%) and 4 patients needed temporary dialysis after surgery.

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**Table 1: Preoperative patient characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No (%) or mean ± SD (range)</th>
</tr>
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<tbody>
<tr>
<td>Sex male</td>
<td>28 (60)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>62 ± 14 (29–88)</td>
</tr>
<tr>
<td>Aortic valve insufficiency</td>
<td>41 (89.1)</td>
</tr>
<tr>
<td>Mixed aortic valve defect</td>
<td>3 (6.8)</td>
</tr>
<tr>
<td>Insufficiency grade</td>
<td></td>
</tr>
<tr>
<td>1+</td>
<td>14 (30.4)</td>
</tr>
<tr>
<td>2+</td>
<td>17 (37.0)</td>
</tr>
<tr>
<td>3+</td>
<td>12 (26.1)</td>
</tr>
<tr>
<td>4+</td>
<td>1 (2.2)</td>
</tr>
<tr>
<td>Concomitant disease</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>35 (76.1)</td>
</tr>
<tr>
<td>Coronary heart disease&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6 (13.0)</td>
</tr>
<tr>
<td>COPD</td>
<td>4 (8.7)</td>
</tr>
<tr>
<td>Marfan syndrome</td>
<td>3 (6.5)</td>
</tr>
<tr>
<td>Unconscious/intubated</td>
<td>3 (6.5)</td>
</tr>
<tr>
<td>Cerebral malperfusion&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2 (4.3)</td>
</tr>
<tr>
<td>Other malperusions&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7 (15.2)</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>3 (6.5)</td>
</tr>
</tbody>
</table>

<sup>a</sup>With surgically relevant stenoses (among 17 patients in whom coronary artery visualization through heart catheterization or cardiac CT was performed).

<sup>b</sup>With clinical symptoms confirmed by angiography.

COPD: chronic obstructive pulmonary disease (requiring long-term therapy in anamnesis).
Permanent neurological deficit or temporary dysfunction such as confusion, delirium or agitation lasting >48 h but without any focal deficit occurred in 2 (4.3%) and 6 (13.0%) patients, respectively. Among the stroke patients, 1 suffered multiple embolism caused by heparin-induced thrombocytopenia and died on the 26th postoperative day due to multi-organ failure. She was the only patient who died during the 90-day postoperative period resulting in a 30-day as well as a 90-day mortality of 2.2%.

Another patient presenting with cerebral malperfusion before surgery suffered a stroke without motoric deficit but needed neurological rehabilitation after discharge from the clinic.

The most frequent postoperative complication, which occurred in 11 patients, was respiratory insufficiency necessitating prolonged ventilation or re-intubation. Eight of these patients required tracheotomy.

Survival

Clinical follow-up data were available for all patients. The mean follow-up was 54 ± 37, range 0.9–132 months totalling 207 patient-years. A total of 6 patients (median age 76, range 63–81 years) died, on average, 10 months after surgery (range 0.9–44), resulting in an overall survival rate of 87%. The linearized death rate was 2.9%/year and the actuarial survival rate at 8 years was 85.5 ± 5.6% (Fig. 1). No death was related to the aortic valve or aortic root. There were two cardiac deaths: 1 male patient died of congestive heart failure 44 months after surgery at the age of 79 years. Another patient (male, 64 years) suffering from coronary heart disease, died 11 months after surgery because of acute myocardial infarction despite catheter intervention.

Valve-related morbidity and reoperations

There were no valve-related events with the exception of 1 female patient (81 years) who, despite the competent aortic valve, suffered from stroke during numerous episodes of atrial fibrillation. No patient required reoperation on the proximal aorta and/or aortic valve during the entire follow-up time. However, 1 Marfan patient, who received aortic root repair and complete arch replacement primarily, underwent conventional replacement of the thoraco-abdominal aorta 8 years later and is still alive with a competent aortic valve at the overall follow-up of 120 months. In 2 further Marfan patients their aortic valves were also competent at the follow-up of 75 and 50 months, respectively. Even if in all 3 patients only 2 sinuses were replaced, we would not like to overestimate this aspect. First, we do not consider the Marfan patients as a good example for the efficacy of valve-sparing root surgery at all, because there is an enormous diversity of pathologies in these patients with leaflet pathology as the most limiting factor of repair. If a valve-sparing root repair is suitable, we generally replace all the 3 sinuses in elective Marfan patients; however, our results may indicate that in an emergency, even limited root repair can be considered in very selected patients having, apart from dissection, an unchanged root anatomo-physiology [7].

Functional data

The echocardiography performed during the hospital stay showed excellent valve function with no (37) or slight (9) insufficiency. The mean gradient across the aortic valve was 4.7 ± 2.0 mmHg. At the last echocardiography performed on average 47.8 ± 35.6 months after surgery, 33 patients showed no and 13 patients slight aortic insufficiency. No pathological alterations of...
the aortic root were noticed in any patient, and there was no relevant change of the transvalvular gradient.

DISCUSSION

The pathomechanism of aortic insufficiency can be explained by any abnormality of the anatomo-physiological balance between the size and shape of the sinuses of Valsalva and the size and shape of the aortic cusps [7]. In acute aortic dissection, the circulation of blood in the false lumen leads to a distortion of the aortic root and to a change of this relationship even if the shape and size of the sinuses before the event of dissection was normal. Therefore, the elimination of the false lumen by adhesion of the dissected aortic wall layers within the sinuses and restoration of the sinotubular junction leads to the elimination of aortic insufficiency, that is, if it was not preceded by additional sinus and/or cusp pathologies. Adhesion of the aortic wall using biological glues is the simplest and therefore most attractive method for root repair; however, a clear majority of reports, especially from recognized aortic reference centres, have revealed a definite influence of non-curative aortic repair on the recurrence of aortic root and valve pathologies necessitating repeated proximal aortic surgery [4, 9-13]. In turn, valve-sparing surgery with curative replacement of the dissected aortic root leads to favourable functional results comparable with those after elective surgery of chronic aortic aneurysm [14]. The re-implantation technique, which is preferred in such cases by many surgeons, is connected, however, with the necessity of replacing an entire root and implanting both coronary arteries, regardless of the number of dissected sinuses. For this reason, even centres with extensive experience in the re-implantation technique do not recommend this method in risky or elderly patients [15].

Root remodelling not only offers a curative surgery but also allows the limitation of the repair to only dissected sinuses. However, in the original method it is almost impossible to sew the tongue-shaped ends of the tube (especially when there are >1) to the aortic annulus so exactly that each stitch passes the annulus rather than the aortic wall remnants, and this can be a reason for the disappointing functional results that have been reported [16]. We consider this technical aspect very important and therefore developed a modification consisting of a patient-tailored repair of the isolated sinuses with single patches [5, 7]. This technique enables very precise sewing, passing the stitches exactly through the annulus rather than the aortic wall remnants, a characteristic that, in our opinion, is decisive for haemostatic tightness and lasting durability. Additionally, the technique allows any correction of the size and shape of the neo-sinuses, which is not possible when a tube is used and trimmed to the final crown-shaped form. Furthermore, it enables an individual, case-based matching of the neo-sinuses to the corresponding cusps, and it ensures the creation of a lasting neo-sinotubular junction within the suture line between the repaired root and the tube. Finally, it is advantageous when additional cusps repair is necessary because it facilitates the reconstruction of the cusps that are not located deep inside the tube. Hence, after repairing isolated sinuses in our series, neither was there a recurrent aortic insufficiency observed nor did an adverse change of the aortic root size and/or form occur, regardless of the number of sinuses repaired. The lack of randomization can be considered a limitation of the study; however, we are convinced that the variety of the aortic root and valve pathologies as well as the clinical parameters demand individual surgery, which is essential for an optimal outcome. Hence, it was an observational study with an intention-to-treat analysis of all relevant perioperative parameters collected prospectively. Among 72 patients with acute aortic dissection involving the root, there were 36 complete root replacements with valve composite grafts. Eight patients with a bicuspid valve and 10 patients with a tricuspid valve presented with leaflet changes, which made the valve repair unsuitable. Another 4 patients had an artificial aortic valve. In the remaining 13 patients with a tricuspid valve, the composite graft was used for several reasons, mostly clinical; however, the influence of the experience in reconstructive surgery and extent of the dissection within all sinuses (in 6 patients) on the choice of the operative technique cannot be ruled out.

The majority of patients with acute aortic dissection involving the root exhibit type II aortic insufficiency as provided in our classification (isolated changes of the sinuses of Valsalva), which, in our opinion, is very suitable for valve-sparing surgery [7]. This type of surgery was performed in 56% of the patients in our series who had acute aortic dissection involving the aortic root. In all of them, a curative repair was achieved, even though replacement of all the 3 sinuses was necessary in only 5 of 46 patients (11%). This curative but limited aortic root surgery with preservation of the valve leads not only to excellent operative results but also to a favourable long-term functional and clinical outcome. The repair of selected sinuses is a simple and effective method of valve-sparing root repair in acute aortic dissection and can be recommended.

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REFERENCES

APPENDIX. CONFERENCE DISCUSSION

Dr T. Fischlein (Nuremberg, Germany): In this study, you and your colleagues evaluated operative and long-term results of valve-sparing aortic root surgery in 46 patients with acute type A aortic dissection. You proposed a modified remodelling of the aortic root with replacement of selected sinuses of Valsalva using the original single-patch technique. Additionally, you concluded that curative repair with replacement of all dissected and pathological sinuses with aortic valve-sparing shows excellent operative and long-term results.

One of the major concerns in surgery for acute type A aortic dissection involves management of the aortic valve when the aortic root is involved in the dissection. Also, an aggressive approach with total root replacement has been shown to improve long-term results in connective tissue disorder or in annular aortic ectasia. Management of the aortic valve in the diseased but not dilated aortic root remains the subject of debate. I have three questions.

You had some patients with Marfan syndrome and bicuspid valves in your group. How do you treat those patients, do you resect all sinuses? What is the long-term evolution of the sinuses of Valsalva which are not replaced, do you have any echo follow-up in those cases?

Dr Urbanski: Yes, we have follow-up. We have a database of all patients who underwent an aortic valve repair. There are 800 at the moment. We strive to follow-up our patients once a year, especially patients after acute aortic dissection. In our Marfan patients we didn’t see any alterations of repaired aortic root. However, it may be a problem in this group of patients because it’s not possible to compare one Marfan patient to another. Their pathologies are very complex and the limitations of repair in this group lie in the quality of leaflets. If the leaflets are good, the chance to repair the valve is very good also. You can perform aortic root repair with a method you like and expect a favourable result if the surgery is performed properly.

Dr Fischlein: So you mean you do not resect all sinuses in those cases with Marfan or bicuspid valves?

Dr Urbanski: Even in some Marfan patients, resection of all sinuses is not necessary. I demonstrated here two Marfan patients who, 10 years after resection of only two sinuses, did not develop any changes of the root.

Dr Fischlein: In cases where you replace all sinuses with single patches, what is the advantage of your technique in comparison to the Yacoub technique? I mean, the Yacoub technique might involve a little bit less of suturing.

Dr Urbanski: I believe that it is not possible to perform very exact stitches between the annulus and the tongue-shaped ends of the tube. It is possible with the first tongue, but very difficult with the second, and almost impossible with the third, at least in my hands. And for this reason I developed a single-patch technique, because you can control every stitch from both sides, from inside and from outside. This is also a very important aspect for prevention of bleeding, which can be a problem in remodelling surgery.

Dr Fischlein: And my last question is about patient survival; I have to ask this because we have to learn from each other. Your operative mortality was zero and you say one patient died in your group with acute aortic dissection, 90-day mortality was 2.2%. In our International Registry for Acute Aortic Dissection (IRAD), there is a report of mortality of about 16.7% in stable patients and 31% in unstable patients. The German registry, GERAADA, which involves more than 2,000 patients, shows a 30-day mortality rate of 17%, and in patients over 80 years, of even 35%. So could you comment on your external mortality rate of 2.2% in this really difficult patient group?

Dr Urbanski: Yes, I have to admit that almost all patients demonstrated here were operated on by myself. As in other clinics, we also see a difference between the results of different surgeons. I believe that acute aortic dissection is a very important example of situations where only experienced surgeons should deal with this patient group to improve the results. As you said, there has been no general improvement of results for 20 or even 30 years. We can improve results only by very meticulous surgical strategy and surgery should be performed by experienced surgeons.

Dr Fischlein: So you didn’t select your patients for this group? Because I didn’t find any renal...

Dr Urbanski: I don’t select the patients. We select the surgeon.

Dr Fischlein: I didn’t find any renal insufficiency or any limb ischaemia in your preoperative data.

Dr Urbanski: As I said, we don’t select patients; they are consecutive patients. But we select the surgeon for the special surgery. If it is acute dissection or total arch replacement, very complex surgery, total aortic surgery will probably be performed only by two surgeons in our centre.

Dr A. Martens (Hannover, Germany): I have a question that is directed at the same thing. We also do David procedures in acute dissection patients, but we don’t do it in every patient. So my first question is: do you have age limits, or what do you do in a young patient with a malperfusion syndrome; would you take the time for the David or for the valve-sparing operation instead of performing a fast Bentall?

Dr Urbanski: Malperfusion is, of course, some limitation; but you can evaluate the problem during the surgery and during preparation of strategy. Even if you perform complete arch replacement in such patients, which was the case in half of our group, with the single-patch technique you save a lot of time you can invest in total arch replacement, for example. The global time is similar. If you need two hours to perform the David procedure, even if only one sinus of Valsalva is dissected, you don’t have a lot of time for other surgeries like the aortic arch. However, young patients can profit from the distal extension of surgery and you don’t have to abandon valve preservation.

Dr Martens: What about the age limit?

Dr Urbanski: In my eyes, there is no age limit for valve-sparing root repair. But this is very individual.

Dr M. Romano (Massy, France): Your surgical results are excellent, but there remains the problem of malperfusion. What is the mortality of the patients with peripheral malperfusion, splanchic malperfusion, renal, hepatic? Because the patients operated on for an aortic dissection do not necessarily die because of the surgical errors, bleeding or anything else, they die from other causes.

Dr Urbanski: Yes, malperfusion is a very important aspect in this special group. Our approach is that every patient suffering aortic dissection gets CT angiography. On the basis of CT angiography, we prepare the strategy. We use two lines if necessary. We put one line in the carotid artery to perfuse the brain and the second line in the femoral artery to perfuse the lower body. This strategy is very important to deal with malperfusion, and to improve the global results.

Dr J. Bachet (Abu Dhabi, United Arab Emirates): Just a few comments. We have all seen a lot of dissections in our lives. Don’t let me believe that you don’t have these kind of problems. For instance, you say all the patients get a CT scan before surgery. Don’t you ever have patients arriving under cardio-pulmonary resuscitation, rushed immediately into the operating theatre, how can you do a CT scan in such a patient? In this patient you can do the most beautiful operation in the world and the patient is dead the next morning because of a malperfusion of the bowel or the brain or whatever. In acute dissection, surgery is very important, but there are other things that are just as important in determining the outcome of the patients.

Dr Urbanski: I absolutely do not agree. To date we have never lost a patient because of CT angiography which takes only a few minutes. And even then I think it is better to lose 1 patient per 200 because of the delay for angiography, than to lose 20% of patients because you don’t have a proper strategy.
Currently, aortic valve-preserving root replacement is gaining popularity in selected younger patients with the tricuspid valve to avoid the requirement for lifelong anticoagulation. Different types of procedures (aortic root remodelling according to M. Yacoub and reimplantation technique according to T. David) have been described and increasingly used in the elective setting. Resuspension of the commissures of the aortic valve and graft replacement of the supracoronary aorta represent the most commonly performed procedures for patients presenting with acute dissection type A. When doing them, the surgeon needs to be confident that the valve repair will be durable and the sinuses of Valsalva will not dilate excessively over time. The presence of advanced valve pathology (leaflet calcifications, commissural fusion or large fenestrations close to the commissures) is usually an indication for valve replacement.

Urbanski et al. [1] report a series of 46 patients treated because of acute aortic dissection type A in whom one-, two- or a three-sinus repair was performed in order to selectively repair the dissected part of the aortic root and to avoid the use of any type of glue. The authors have to be congratulated for the excellent early and long-term results obtained in a difficult group of patients.

Aortic root remodelling using a selective sinus repair was reported by Stephen Westaby as early as 2002, where he described this successful approach in 29 patients suffering from atherosclerotic aneurysm of the aortic root and who were operated on between 1995 and 2001 (Fig. 1) [2]. In this paper, Westaby et al. suggested that root dilatation begins in the non-coronary, then in the right coronary sinus. The left coronary sinus usually retains normal dimensions until a very advanced stage. Rather than employing aortic root replacement or the David procedure, Westaby et al. elected to replace the ascending aorta and remodel the sinotubular junction and the involved sinuses. The long-term follow-up of these patients revealed that aortic valve and root repair provided a durable repair and allowed the avoidance of a more radical aortic root replacement with prosthesis-related complications.

Although the approach described by Urbanski et al. is an attractive one, some critical points have to be emphasized:

(i) It might be questionable to include very old patients for a valve-sparing technique since aortic valve replacement with a bioprosthesis (or complete root replacement with a biological composite graft) might be the more straightforward and secure treatment.

(ii) It is difficult to confirm an important advantage with single or double sinus repair with separate patches in Marfan patients, because the latter suffer generally from a pathology of the whole aortic root and should receive the most complete root repair or replacement. With this in mind, it is surprising that a ‘partial’ repair did not lead to any re-intervention on the aortic root.

(iii) Whether a classical David reimplantation procedure, or a root repair with three separate patches is the better option for those patients with a circumferentially dissected aortic root seems clear to me: the David procedure with a Valsalva tube graft secured below the aortic annulus ensures the best stability of the aortic annulus on its whole circumference and should therefore be the preferred surgical technique.

(iv) Finally, the surgical treatment of acute aortic dissection type A should remain the simplest possible, shortening the time spent on cardiopulmonary bypass as well as the myocardial-protected ischaemic time as much as possible. I personally found a clamp time of 106 min to be rather long for two aortic anastomoses and a selective sinus repair.