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David Procedure in Patients With Acute Type A Dissection: from Controversy to Excellent Results

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Abstract

Background

Aortic valve (AV) reimplantation (David procedure) has demonstrated very good long-term results when performed in the elective setting. Limited use of the technique in patients suffering from the acute type A aortic dissection (ATAAD) due to its technical complexity is still debated. We present long-term results of 84 patients operated on using David procedure as part of surgical treatment of ATAAD.

Methods

Between January 1996 and January 2025 a total of 84 patients with ATAAD were operated on at two institutions in Frankfurt, Germany and Brno, Czech Republic using David procedure for aortic root reconstruction. The primary end-point was defined as AV performance: freedom from the AV regurgitation (AR) ≥ moderate and freedom from the aortic valve and/or root related reoperation in the follow-up. The secondary end-points we defined as perioperative outcomes and late survival. The data were evaluated retrospectively, using medical records and a register.

Results

The mean age was 45 years and male sex was represented in 83%. Operative risk according to the GERAADA Score was 9.5% and moderate AR or more was present in more than a half (52.4%) of patients. The 30-days mortality was 7.1%. Median follow-up time was 6.96 years (IQR 3.3-6.1). Freedom from the AR ≥ moderate at 5, 10 and 20 years was: 90% (95% CI 83.1%-97.3%), 82.4% (95% CI 72.4%-93.7%) and 73.7% (95% CI 60.3%-90.1%), respectively. Freedom from AV and/or aortic root reoperation at 5, 10 and 20 years was: 92.3% (95% CI 86.0%-99.1%), 86.1% (95% CI 77.5%-95.8%) and 86.1% (95% CI 77.5%-95.8%) respectively. The survival after 5, 10 and 20 years was 90.1% (95% CI 83.7%-96.9%), 72.2% (95% CI 61.3%-85.0%) and 51.2% (95% CI 33.0%-79.4%).

Conclusions

David procedure performed in patients suffering from acute type A dissection can be performed safely, with low short-term mortality and especially with excellent long-term AV performance (low incidence of reccurent AR requiring redo surgery).

Keywords: acute type A aortic dissection; David procedure; aortic valve reimplantation; valve-sparing aortic root replacement

Background

Acute type A aortic dissection (ATAAD) is a life treating emergency with 25% mortality in the firts 24 hours an 50% in one month remaining without surgical intervention. When aortic root is involved or dilated, an aortic (AV) and root replacement using mechanical valved conduit (Bentall-de Bono operation) became a gold standard in young patients. Nevertheless the rate of bleeding complications of 16% after 10 years, 61% after 20 years and thrombo-embolic complications 10% and 24% after 10 and 20 years respectively are not negligible.[1] Some systematic reviews showed that AV reimplantation (David procedure) is superior to the Bentall-de Bono technique in terms of in-hospital mortality, mid-term survival, the rate of early postoperative stroke and thrombo-embolic events during follow-up, although some of these differences are undoubtedly due to selection bias.[2] At present only 6.2% of ATAAD patients undergo valve preservation using the reimplantation technique.[3] There are very few aortic centres routinely performing this technique in such critically ill group of patients, which is certainly caused by – among other reasons – demanding and complex surgery performed on the aortic root under emergent conditions. In some cases, combined with time-consuming surgery on the aortic arch. Nonetheless, it has been shown that David procedure does not compromise early and mid-term survival in ATAAD in experienced centers.[4]

The aim of this study was to examine whether long-term AV performance, characterized by freedom from AV and/or root reoperation and freedom from recurrent AV regurgitation (AR), is affected by AV reimplantation among patients with ATAAD.

Methods

Study design and patients' selection

Between January 1996 and January 2025 a total of 84 patients with ATAAD were operated on at two institutions in Frankfurt/Main, Germany and Brno, Czech Republic. In all patients the David procedure was the treatment of choice for valve-sparing aortic root reconstruction. The main indication for the operation was type A dissection requesting aortic root surgery either due to (AR) and/or aortic root dilatation. The decision on the surgical technique was entirely upon the surgeon. All patients who underwent the above mentioned operation were included in this study, including patients receiving concomitant procedures at the aortic arch and other valves surgery. Patients initially planed for the AV reimplantation but operated finally with other

technique were excluded from this study. Early postoperative data was obtained from the hospital information system. The follow-up was performed in 100% of the patients with the median follow-up of 7 years (IQR 3.3.-6.1), counting 2,352 patient-years. The follow-up data - including transthoracic echocardiography - have been obtained at the hospital outpatient department or from the referring cardiologist. The primary end-point was defined as AV performance: freedom from AV and/or root related reoperation and freedom from AR ≥moderate during the follow-up. The secondary end-points were defined as the early postoperative outcomes and late survival.

Patients' selection had two stages: pre-operative and intra-operative. Pre-operative selection depended on the clinical status of the patient. The main condition taken to the account was hemodynamic stability. The signs of malperfusion and advanced age were only relative contraindications for this complex surgery, although surgeons tended to select patients under 50 years of age (see Table 1). Intraoperative assessment of the valve and root morphology based on CT-scan and transoesophageal echocardiography (TEE) combined with direct inspection of the root confirmed the reparability of the aortic valve. The ability to restore the normal geometry and function of the aortic root and valve was crucial for the final decision. Attention was paid also to the surgeon´s experience, expertise in aortic valve reimplantation in elective setting and flexibility of the team to convert on Bentall procedure.

Surgical technique

The surgical technique has been previously published.[5] The standard technique (David I) using a straight Dacron Graft was used until 2018, afterwards only bulged Cardioroot Woven Vascular Graft® (Getinge, Gothenburg, Sweden**)** was used. Aorta was transected approx. 1 cm above the sino-tubular junction. The commissural posts are fixed with 3 Teflon pledgeted 4–0 polypropylene U-sutures and aortic root preparation is performed down to the basal virtual ring. Once the aortic root is mobilized, the coronary ostia are dissected as buttons and the sinuses of Valsalva are resected leaving a sufficient rim of abot 4-5 mm. The straight graft sizing was performed according to the formula (leaflet height in mm x 1.5) + 2 mm and as described by El-Khoury et al. in bulged graft.[6] Consecutively, up to 9 pledgeted Teflon braided U-sutures are circumferentially distributed along the basal virtual ring (from inside to outside) and placed accordingly to the basal Dacron graft ring and are tied down. Then, the 3 commissural posts are pinned and fixed to the Dacron graft and the

remnants of aortic sinuses are reattached with 3 polypropylene 5-0 running sutures within the prosthesis. The coronary neo-ostia are cut out of the graft and the coronary buttons are reattached by 5–0 polypropylene running sutures. Finally, the distal end of the Dacron graft is anastomosed to the distal aorta or vascular prosthesis with a 4–0 polypropylene running suture. In some patients the surgery was limited on the aortic root and ascending aorta. No selective cerebral perfusion was performed in that case.

Ethics statement

The study was performed in accordance with the Declaration of Helsinki (revised 2024) and approved by the local Ethic Committee of University Hospital Frankfurt (No. No. 20-782 from 23.6.2020). The article will be published in accordance with the STROBE reporting checklist.

Statistical analysis

Data are presented as mean values ± standard deviation (SD). For data not normally distributed the median and range were used. Categorial and ordinal variables were expressed by number and percentage of observations. Continuous and discrete variables were compared using a 2-sample t-test or Mann-Whitney test, where appropriate. Normal distribution of metric variables was first evaluated by using the Shapiro-Wilk test. If the variable showed a normal distribution, the Levene test was employed to test for the equality of variances. For the characterisation of our data sets, descriptive statistics with calculation of mean, median and range of values in the data sets were obtained. Kaplan-Meier curves, along with mortality tables and Kaplan-Meier survival estimators were acquired to analyse data and visualise the primary and secondary endpoints. In addition, we analysed pre-, intra-, and postoperative parameters using univariate and multivariate Cox regression risk analysis to identify predictors for reoperation and relevant AR ≥moderate. Statistical analysis was performed using the IBM® SPSS® Statistics software program (version 28 for MS Windows, IBM Corporation, Armonk, NY, USA).

Results

The preoperative patient characteristics are given in the Table 1. The mean age was 45±12 (22-80) years, 17% were females. Expected mortality estimated according to the GERAADA score was 9.5% with range 4.1-46.9

and median EuroSCORE II of 5.7% with the range of 1.1 – 85.25. More than a half of the patients presented with relevant AR (≥moderate). A substantial part of the patient set (26.2%) already suffered from any form of a peripheral malperfusion (non-coronary, non-cerebral). Five patients (6%) have had signs of myocardial ischemia on admission.

Table 1: Study population	
Age mean±SD (range)	45±12 (22-80)
Male sex	70 (83%)
BMI mean±SD (range)	27.7±5 (18-45)
EF <30%	5(6%)
GERAADA Score (%) median (range)	9.5 (4.1-46.9)
AR ≥moderate	44 (52.4%)
Marfan syndrome	7 (8.3%)
Preoperative Stroke	6 (7.1%)
Malperfusion (peripheral)	22 (26.2%)

SD – standard deviation, BMI – body mass index, GERAADA – the score of German Registry for Acute Aortic Dissection Type A, AR – aortic valve regurgitation.

The perioperative data are shown in Table 2. Total aortic arch replacement in 23% was one of the factors causing longer mean cardio-pulmonary bypass time of 212 minutes (range 124- 363) minutes and mean aortic cross-clamp of 155 minutes (range 83 – 267). Concomitant aortocoronary bypass was performed in tree patients (3.6%). Five patients (6%) were operated minimally invasive fashion, through the upper partial sternotomy.

Table 2: Operative data	
Total bypass time (min) mean±SD	212±60
Aortic cross-clamp time (min) mean±SD	155±34
Selective antegrade cerebral perfusion time (min) mean±SD	27.6±14
Surgery of another valve	1 (1.2%)
Total aortic arch replacement (debranching of the arch arteries)	19 (22.6%)
Bicuspid aortic valve	7 (8.3%)

SD – standard deviation, min – minutes

The postoperative course with the most important complications is displayed in the Table 3. Five of the early deceased 6 patients died in hospital. The causes of their death were abdominal ischemia (2), major cerebral insult (2), complete AV-block (1) and myocardial infarct resulting in low-cardiac output syndrome (1).

Table 3: Early postoperative data	
Re-exploration for bleeding	18 (21%)
Ventilation time (min) median (range)	12.5 (3-696)
New postoperative stroke - minor - major	7 (8%)
30-day mortality	6 (7%)
AR ≥moderate (Either after CPB or at discharge)	7 (8%)
CVVHD	6 (7%)

Min – minutes, AR – aortic valve regurgitation, CVVHD – continuous veno-venous hemodialysis

The follow-up was complete in 100% patients with median of 7 years (IQR 3.3.-6.1), accounting 2,352 patient-years. Estimated Kaplan–Meier survival was approximately 90% (95% CI 84-97%) at 5 years, 72% (95% CI 62-85%) at 10 years, and 51% (95% CI 33-80%) at 20 years. (Figure 1). The most casulties happen between 7th and 11th postoperative year. The freedom from the AR ≥moderate at 5, 10 and 20 years was: 90 (95% CI 84-98%), 82 (95% CI 73-94%), and 74% (95% CI 60-90%), respectively (Figure 2). The estimated freedom from AV and/or root reoperation at 5, 10 and 20 years was 92 (95% CI 86-99%) , 86 (95% CI 78-96%) and

86%, (95% CI 78-96%) respectively (Figure 3). At 20 years there are only small risk sets, so the actual Greenwood CI ist most probably slightly wider.

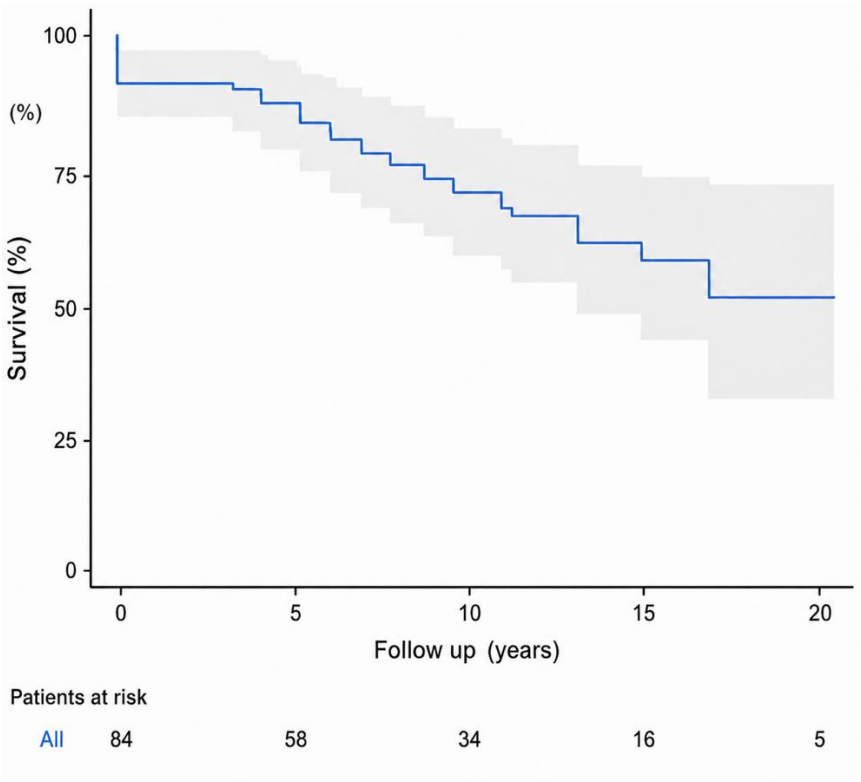


Figure 1: Kaplan-Meier curve showing the freedom from all-cause death

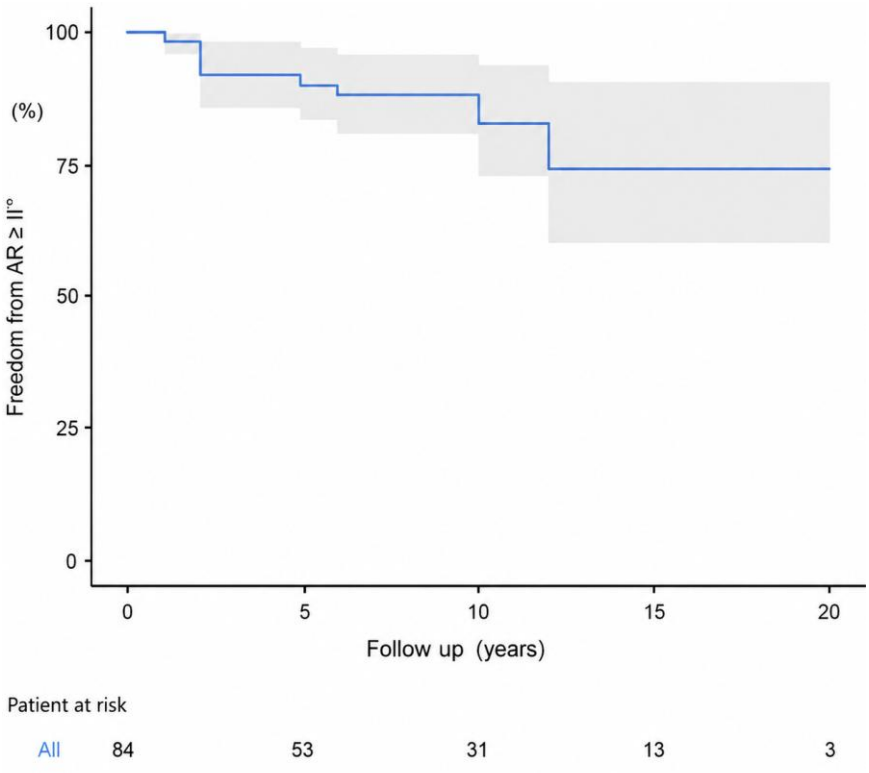


Figure 2: Kaplan-Meier curve showing the freedom from recurrent aortic regurgitation

AR – aortic valve regurgitation

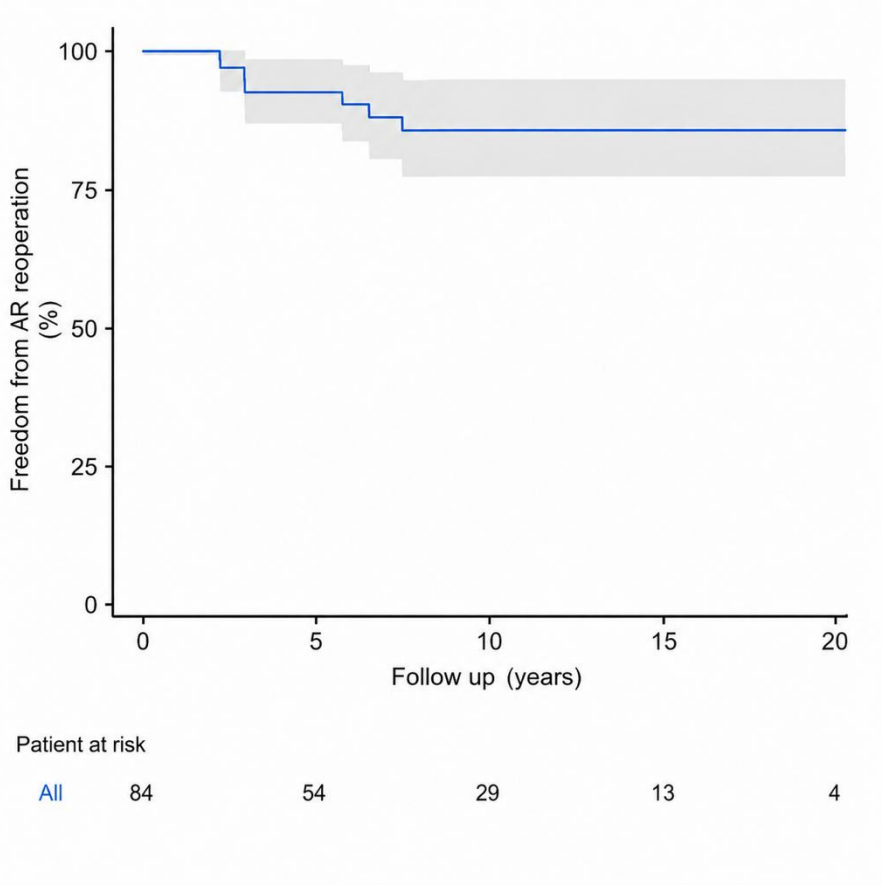


Figure 3: Kaplan-Meier curve showing the freedom from aortic valve and/or root reoperation

AR – aortic valve regurgitation

The multivariate risk analysis identified one risk factor for the mortality: ventilation time (p=0.48) and one risk factor for late reoperation of the AV an/or aortic root: early postoperative AR ≥moderate (p<0.001) at discharge. In the follow-up we observed AR ≥moderate in 12 cases (14%), 16% of the patients needed reoperation from any reason and 11% selectively at the aortic root. The mortality was 25%.

Discussion

The decision to perform valve-sparing aortic root replacement in the setting of ATAAD remains controversial. Previous studies have described the David procedure in ATAAD as overly time-consuming and technically demanding in the emergency setting, suggesting that it should be reserved for surgeons who are highly experienced with this technique in the elective setting.[7] Overall, it has been demonstrated that long-term outcomes of the David procedure performed in the emergency setting are not inferior to those achieved in elective surgery.[8]

Beckmann et al. reported a 30-day mortality rate of 12.8%, which was lower compared with both Bentall-de Bono group[7]. With a 30-day mortality rate of 7.1%, the results observed in our study are lower than those reported in previous studies. International Registry of Acute Aortic Dissection (IRAD)reported 30-day mortality ranged between 15% and 26%.[9] However, this finding must be interpreted in the context of the higher overall patient age - particularly in the biological Bentall-de Bono group - which was associated with a greater burden of comorbidities and postoperative complications.[7] Nevertheless, our study demonstrates that AV reimplantation (David procedure) represents a safe and feasible surgical option in the setting of ATAAD, providing very good short- and long-term outcomes despite a markedly high preoperative risk profile. The GERAADA score is considered an important risk stratification tool for preoperative estimation of 30-day mortality following cardiac surgery for ATAAD. In our cohort, the median GERAADA score was 9.5%, while the median EuroSCORE II was 5.7%.

Patients with ATAAD represent a distinct patient population with a particularly high perioperative risk; therefore, the predictive value of EuroSCORE II in this cohort is limited. In patients with ATAAD, EuroSCORE II may either underestimate or overestimate the actual perioperative risk. For this reason, the GERAADA Score was developed and established specifically for use in ATAAD patients and focuses on preoperative variables that play a central prognostic role in this condition. As a result, it enables a more accurate prediction of 30-day mortality in patients undergoing surgery for ATAAD.[9] During patient selection, particular emphasis was placed on younger patient age (<50 years), which - consistent with previous reports - is associated with a lower prevalence of comorbidities. However, detailed patient selection requires extensive preoperative screening and diagnostic work-up, which cannot be fully ensured in the emergency setting.[7]

More than half of our patients presented with preoperative AR greater than mild. Special attention must be paid to preoperative peripheral malperfusion, which was present in 26.2% of patients. Preoperative peripheral malperfusion is regarded as a major predictor of mortality and morbidity in ATAAD, as it is associated with increased early postoperative mortality.[10] Despite the associated high-risk profile, favorable outcomes were achieved with the David procedure in our cohort. The results demonstrated in our study support the use of the David procedure in the emergency setting, even in the presence of preoperative peripheral malperfusion, provided that hemodynamic stabilization can be achieved and no irreversible organ damage is present. Thus,

preoperative peripheral malperfusion as a high-risk factor per se does not represent a contraindication for the David procedure in surgical therapy of patients with ATAAD. Our findings suggest that prompt AV reconstruction with restoration of perfusion through the true lumen has a beneficial effect on malperfusion, without adversely affecting early postoperative mortality or long-term outcomes.

The previously reported increased risk of reoperation due to structural failure of the AV reconstructed in the acute setting could not be confirmed by our data. Freedom from AR ≥moderate was 90%, 82.4%, and 73.7% at 5, 10, and 20 years, respectively. As well as the freedom from AV and/or root reoperation at 5, 10, and 20 years was 92.3%, 86.1%, and 86.1%, respectively. These results are comparable to those reported for cohorts undergoing the David procedure in the elective setting.[11,12] At 1-year follow-up, the highest freedom from reoperation was observed in the biological Bentall-de Bono group (100%), followed by the David group (95.2%).[7] These findings suggest that even in the emergency setting, safe reconstruction with restoration of normal aortic root geometry and sustained long-term AV function can be achieved, provided that the surgeon has sufficient experience and expertise acquired in the elective setting. To avoid early postoperative AR (≥moderate) , which was identified as the strongest predictor for late reoperation in our study, it is essential to correlate intraoperative direct inspection findings with echocardiographic assessment and to evaluate the success of valve-sparin procedure intraoperatively and further at an early stage.[7]

When these principles are applied, the David procedure offers a substantial advantage, particularly for younger patients under 50 years of age, who according to current standards would otherwise receive a mechanical Bentall-de Bono procedure. This advantage primarily relates to lower rates of bleeding and thromboembolic complications, as well as a reduced risk of endocarditis.[7,13,14] However, longer follow-up is required to fully assess these benefits.

As previously described by Beckmann et al., the David procedure - despite a slightly prolonged aortic cross-clamp time compared with the Bentall-de Bono procedure - does not negatively impact overall operative duration or cardio-pulmonary bypass times.[7] In our study, prolonged bypass and cross-clamp times were mainly attributable to the performance of total aortic arch replacement rather than to the complexity of the David procedure itself.

The primary objective of emergency surgery performed in the setting of an ATAAD is the safe surgical management of the aortic arch. After restoration of the corporal circulation, it may be feasible for a highly experienced surgeon to proceed with a valve-sparing aortic root replacement procedure, particularly during a prolonged warm-up period.

Nevertheless, early postoperative mortality remained low, and when combined with favorable long-term outcomes and low reoperation rates, the David procedure represents a valuable alternative even in a high-risk population of patients with ATAAD. This approach requires not only careful preoperative patient selection but also thorough intraoperative evaluation of aortic valve-sparing.[15] The latter, however, is subject to selection bias.

Limitations and strengths oft the study

The retrospective nature of this study is associated with many well known problems. The randomization in an acute to emergent clinical setting is ethically very problematic in the best interest of the patient. The decision for or against a specific surgical procedure must be individualized and tailored to the patient to ensure the best possible outcome. Not only individual skills of every participating surgeron but also the entire operative team are crucial. That is why our result are non-transferable in the wide professional public. On the other hand the international multicentric format of the study, involving in both centres more surgeons, compensates undoubted shortcomings of the retrospective study, such a selection bias.

Conclusions

In summary, AV reimplantation (David procedure) in a urgent or emergent setting for patients suffering from ATAAD is feasible with very good early postoperative and excelent long-term results. As the analyse has shown the lenght of ventilation and early moderate and worse AR are the only risk factors negatively influencing long-term survival and reoperation. Compared to the Bentall-de Bono operation, the long-term results are very promising. Future guidelines should take this fact – supported by further, larger randomised trials – in account.

Author Contributions Jan Hlavicka[1], Petr Nemec[2], Afsaneh Karimian-Tabrizi[1], Vladimir Horvath[2], Yasemin Ilgin[1], Jiri Nicovsky[2], Petr Fila[2], Tomas Holubec[1]

J.H., P.F. and T.H.: conception and design of the study, analysis, and paper writing. V.H., Y.I. and J.N.: data acquisition, A.K.T. data analysis and statistics. P.N., J.H. and T.H..: drafting of the paper and revising the manuscript. All authors have read and agreed to the published version of the manuscript.

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Clinical trial number: not applicable.

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Conflicts of Interest There is no conflict of interests.

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