Operative and Long-Term Outcomes After Curative Repair of Acute Dissection Involving the Proximal Aorta

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Background. **The aim of the study was to evaluate operative and long-term results after acute type A aorta dissection (AAAD) operation, in which complete resection of all dissected aortic segments (curative repair) was achieved.**

Methods. **Among 205 consecutive patients operated on between 2002 and 2014 because of AAAD were 88 patients (42.9%), in whom the dissection did not extend into the downstream aorta. The distal extension of the dissection ended before the origin of the innominate artery in 50 patients of the study cohort (56.8%) or extended throughout the arch, necessitating a total/subtotal arch replacement to achieve a curative distal repair in 38 remaining patients (43.2%). The aortic root was involved in 52 patients (59.1%) and was repaired using valve-sparing repair (31) or replacement with a valve composite graft (21). Combination of root and open arch surgery was reported in 46 patients (52.3%).**

Results. **Thirty-day and in-hospital mortalities were 3.4% and 5.7%, respectively. Survival was estimated starting with the operation and was 81.9% ± 4.5% and 56.6% ± 8.7% at 5 and 10 years, respectively. No patient required reoperation on the aortic root and/or distal thoracoabdominal aorta; however 2 cardiac reoperations were unrelated to the primary surgical procedure. Moreover, the freedom of aortic and/or sudden/unknown death was 100%.**

Conclusions. **Curative aortic repair can be achieved in a relevant share of AAAD patients and is mostly limited by the distal extension of dissection. This kind of repair is advisable, whenever possible, because it can provide very low risk of aortic complications and/or reoperations over time.**

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Leaving a dissected aortic wall after repair of acute type A aortic dissection (AAAD) is considered to be a risk factor for late aortic events and surgical reinterventions [1, 2]. On the other hand a replacement of all dissected aortic wall, if at all possible, is often associated with the need for proximal (root) and/or distal (arch) repair extension, which by prolongation of cardiopulmonary bypass and surgery times can impact operative outcomes and is therefore frequently avoided for fear of increased surgical risk [3]. Admittedly, approximation of the aortic wall layers within the dissected sinuses of Valsalva and/or aortic arch with a biologic glue and subsequent supracoronary ascending aorta replacement offers a simple and fast, although not always efficient, method of aortic repair. A noncurative aortic repair can result in operative bleeding from suture lines performed with dissected aortic wall and late development of several pathologies, which, especially after the use of glue, necessitates challenging redo operations. The aim of this study was to evaluate operative and long-term results after AAAD operations, in which resection of all dissected aortic wall (curative repair) was achieved.

Patients and Methods

Between 2002 and 2014, 205 consecutive patients underwent operations for AAAD at the Cardiovascular Clinic Bad Neustadt. A proximal complete resection of all dissected aortic root wall is technically almost always possible and is our surgical preference [4], but the extension of the dissection beyond the left subclavian artery limits the possibilities of a distal curative repair.

The examined cohort consisted of those patients (88, 42.9%) in whom a complete replacement of all dissected aortic wall was achieved. In 9 patients (10.2%) the extension involved only the ascending aorta (including the root in 7) and ended well before the origin of the innominate artery, enabling aortic cross-clamping with distal repair without circulatory arrest. In all remaining patients an open aortic repair was performed including a

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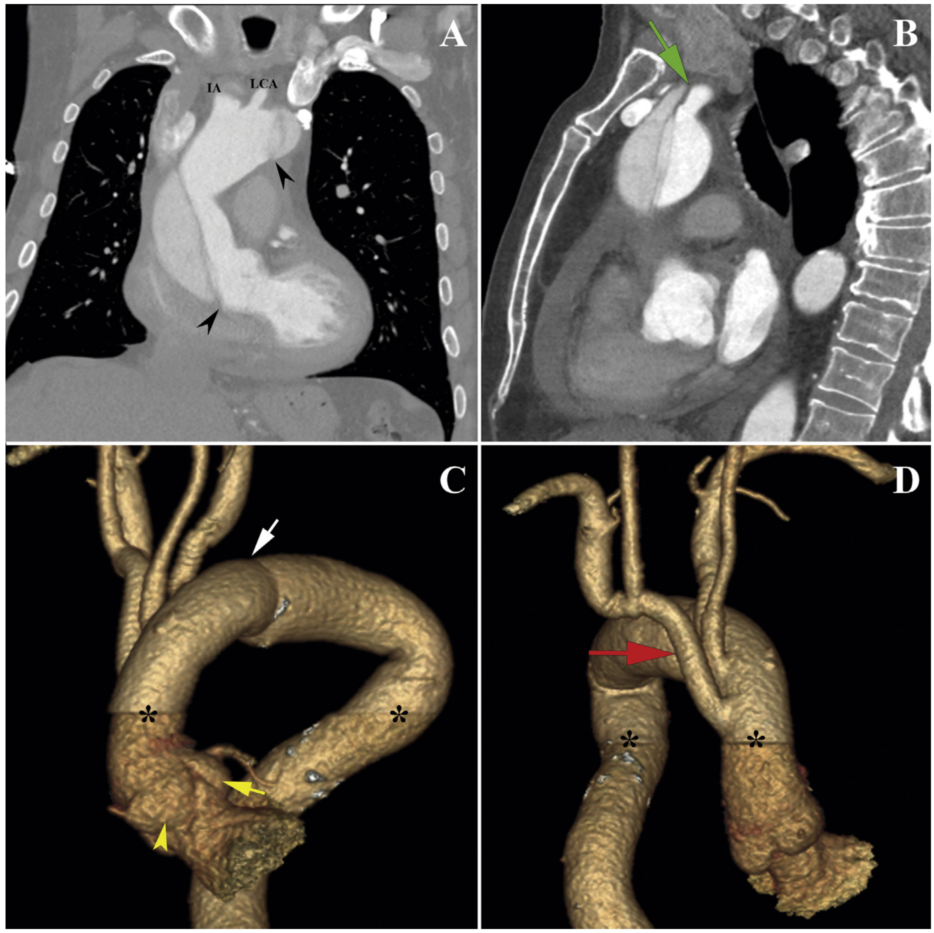

Fig 1. (A, B) Multiplanar reconstructions of preoperative computed tomography angiography scan showing acute aortic dissection in an 82-year-old man. The dissection membrane (marked with black arrowheads) extends from the aortic root throughout the entire aortic involving the innominate artery (IA; green arrow) and ends at the level of the aortic isthmus. (C, D) Volume rendering reconstructions of postoperative computed tomography angiography demonstrating a curative aortic repair that was achieved by complete arch replacement (distal anastomosis is marked with a white arrow), including replacement of the innominate artery (marked with a red arrow) and selective replacement of 2 dissected sinuses of Valsalva. Notice that after use of our sinus repair technique, there is no difference between the size and shape of the native sinuses (marked with a yellow arrow) and the artificial one (marked with a yellow arrowhead). Step artifacts due to electrocardiogram-triggered incremental image acquisition are marked with asterisks. (LCA = left carotid artery.)

total/subtotal arch repair in 42 patients (47.7%). Among them were all 38 patients with dissection extending throughout the arch who needed the arch repair for the achievement of the complete distal resection of all dissected aortic wall (distal anastomosis performed with nondissected aortic wall) and 4 patients with a dissection limited to the ascending aorta but with concomitant arch pathology (dilatation, severe atherosclerosis).

Altogether, the aortic root was involved in 52 patients (59.1%) and was repaired using valve-sparing root repair (31) or complete root replacement using composite valve graft (21). A combination of root and open arch surgery was reported in 46 patients (52.3%) (Fig 1). The choice between root repair and replacement was made at the surgeon's discretion, considering such aspects as aortic valve (leaflet) pathology, clinical condition, and surgical experience [4].

Aortic diagnostics were based on computed tomography angiography and/or conventional angiography in patients with dissection induced by heart catheterization. During operation transesophageal echocardiography was performed to assess the function of the aortic valve and to recognize its pathology. The detailed patient characteristics are given in Table 1, whereas the extent of dissection and site of intimal tears are presented in Table 2.

Surgical Technique

The curative aortic repair was achieved in all patients. In 52 patients with root involvement either a valve-sparing root repair (31) or complete root replacement with valved conduit (21) was performed. For root repair our modified remodeling technique with selective sinus replacement described elsewhere in detail was used exclusively [4, 5]. One sinus, two sinuses, and three sinuses were replaced in 22, 7, and 2 patients, respectively. In short the proper aortic graft size was chosen by measuring the aortic annulus with transoesophageal echocardiography and a valve sizer. The tube with a slightly larger (2 to 4 mm) diameter than the aortic annulus was chosen. 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. Bulged neosinuses were built from the patches and sewn to the aortic annulus rather than the remnants of the dissected aortic wall with a 5-0 polypropylene running suture as demonstrated in intraoperative videos

Table 1. Preoperative Patient Characteristics

Characteristics	Value
Sex, male	55 (62.5)
Age, years, mean ± SD (range)	64.5 ± 15.7 (23.4–90.4)
Hypertension	67 (76.1)
COPD	10 (11.4)
Diabetes	7 (8.0)
Previous cardiac surgery	7 (8.0)
Aortic valve defect	
Insufficiency	52 (59.1)
Mixed/stenosis	4 (4.5)
Artificial valve	2 (2.3)
Bicuspid valve	12 (13.6)
Unconscious/intubated	5 (5.7)
Malperfusion	9 (10.2)
Myocardial	6 (6.8)
Cerebral	3 (3.4)

Values are n (%) unless otherwise defined.

COPD = chronic obstructive pulmonary disease (requiring long-term therapy in anamnesis).

published elsewhere [5]. In 8 of 31 patients additional procedures on the cusps such as free margin plication, cusp patch plasty, or others completed the aortic root repair, if necessary.

A complete valve and root replacement was performed with a modified self-assembled composite graft consisting of mechanical or biologic aortic valve prosthesis. The assembly of modified composite grafts has been described previously [4, 6]. A mechanical (15) or biologic valve prosthesis (6) was used for assembling the conduit in accordance with the clinical situation or patient and surgeon preferences. The valve prosthesis was placed inside the collagen-coated woven polyester vascular prosthesis and attached approximately 5 mm above the proximal end of the tube with a continuous 4-0 polypropylene mattress suture. As demonstrated in an intraoperative video published elsewhere [6], the conduit was anastomosed to the annulus with interrupted pledgeted mattress sutures, passing them through the aortic annulus from the ventricular side and through the rim of the tube graft rather than through the sewing cuff of the prosthetic valve. Coronary buttons were implanted in the usual manner [4, 7].

Table 2. Aortic Pathology

Variables	Value
Extent of dissection	
D-a[a]	50 (56.8)
D-b	1 (1.1)
D-ab	36 (40.9)
D-abc[b]	1 (1.1)
Involvement of supraaortic arteries	13 (14.8)
Involvement of aortic root	52 (59.1)
Concomitant involvement of aortic root and arch	46 (52.3)
Site of intimal tears	
E-a	65 (78.4)
E-ab	9 (10.2)
E-b	10 (11.4)

[a] Corresponding with De Bakey type II aortic dissection. [b] Distal extension of dissection ended a few centimeters distal to the origin of the left subclavian artery, and therefore curative repair via median sternotomy was possible (computed tomography angiography images of this patient are demonstrated in [2]).

Values are n (%).

a = ascending aorta; b = aortic arch; c = descending aorta; D = extent of dissection; E = entry localization.

Table 3. Surgical Strategy

Variables	Value
Cannulation site	
Aorta	8 (9.1)
FA	9 (10.2)
CCA left	14 (15.9)
CCA right	49 (55.7)
IA	1 (1.1)
CAA left + FA[a]	5 (5.7)
CAA right + FA[a]	2 (2.3)
Cerebral protection	
UCP	69 (78.4)
BCP[b]	1 (1.1)
Straight CA	9 (10.2)
No arch repair	9 (10.2)

[a] Double cannulation was preferably used in dissections involving supraaortic arteries. [b] Left common carotid artery (CCA) originated from innominate artery (IA; bicarotid trunk) resulting in bilateral cerebral perfusion after clamping the IA.

Values are n (%).

BCP = bilateral cerebral perfusion; CA = circulatory arrest; FA = femoral artery; UCP = unilateral cerebral perfusion.

In 9 patients with open aortic arch repair operated on at the beginning of the study period brain protection was performed using straight circulatory arrest under deep hypothermia. Starting in 2004 unilateral cerebral perfusion through the cannulated common carotid artery under mild-to-moderate hypothermia was used for brain protection in all remaining patients with open aortic arch repair as described elsewhere in detail [8].

In no patient was glue used for the reinforcement of the proximal or distal aortic sutures.

Surgical strategies and operative data are shown in Tables 3 and 4, respectively.

Statistical Analysis

The perioperative data of all acute dissection patients operated on in the Cardiovascular Clinic Bad Neustadt were collected prospectively and evaluated retrospectively for those patients who received a curative aortic repair. Informed consent was obtained from all patients; however institutional review board approval was waived for this study because of the retrospective and completely anonymous character of the analysis.

Table 4. Operative Data

Variables	Value
Total/subtotal arch repair	42 (47.7)
Open/hemiarch repair	37 (42.0)
Root repair	31 (35.2)
Root replacement	21 (23.9)
CABG	14 (15.9)
CAIG	5 (5.7)
CPB duration, minutes	169.7 ± 56.1 (56–303)
Aortic clamp time, minutes[a]	104 ± 40 (22–192)
CA time, minutes	32 ± 19 (3–100)
CP, minutes	36 ± 21 (10–100)

[a] Including circulatory arrest.

Values are n (%) or mean ± SD (range).

CA = circulatory arrest; CABG = coronary artery bypass grafting; CAIG = coronary artery interposition graft (because of ostial pathology); CPB = cardiac pulmonary bypass; CP = cerebral perfusion.

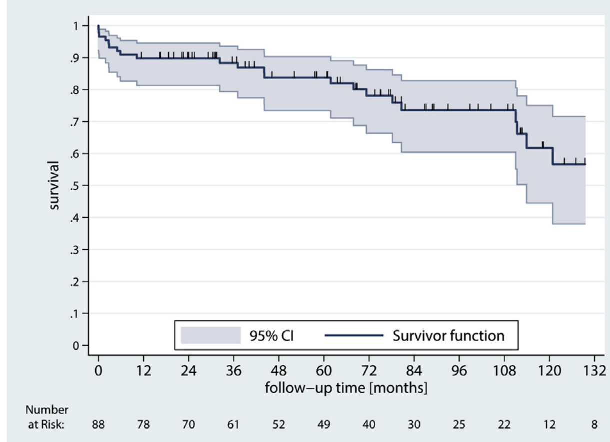

Fig 2. Survival curve after curative aortic repair in acute type A aortic dissection of the proximal aorta. Survival was calculated using Kaplan-Meier method starting with the procedure. (CI = confidence interval.)

Mortality and morbidity causes were defined and analysed according to reporting guidelines [9]. Early mortality was considered for the postoperative time of 30 days and for in-hospital stay. Categorical variables were expressed in the tables and text as frequency (percentage) and continuous variables as mean ± SD (range).

No patient was lost from follow-up. The patients were followed up by echocardiography and, if necessary, by computed tomography angiography performed in our outpatient clinic or by their cardiologist, from whom written documents and images, if available, were requested and reviewed. Overall survival was estimated by the Kaplan-Meier method. The statistical analysis was performed with the IBM SPSS software (version 24.0; IBM Corp, Armonk, NY).

Results

Early Mortality and Morbidity

Three patients died during the 30-day postoperative period, and 2 further patients died beyond this period but still during the hospital stay. Consequently, the 30-day and the in-hospital mortality rates were 3.4% and 5.7%, respectively.

The causes of early deaths were cardiac in 2 patients (caused by preoperative myocardial infarction due to coronary artery dissection and right ventricular failure related to systemic inflammatory response syndrome, respectively) and sudden in 1 patient (83-year-old man with cardiac arrest a few days after extubation). In both patients (ages 84 years and 85 years) who died in hospital but beyond the 30-day time range the cause of death was a respiratory insufficiency and pneumonia. One of the latter patients presented a neurologic deficit after the operation.

Altogether a new permanent neurologic deficit occurred in 2 patients (2.3%) and was embolic in both cases. In particular no patient with involvement of the supraaortic arteries experienced a neurologic deficit. Transient neurologic dysfunctions like agitation, confusion, or delirium without evidence in computed tomography or magnetic resonance imaging were observed in 9 patients (10.2%).

Six patients (6.8%) required a rethoracotomy because of bleeding; however there were 2 cases (2.3%) of delayed chest closure because of severe coagulopathy. Respiratory insufficiency necessitating prolonged ventilation or reintubation occurred in 13 patients (14.8%). Tracheotomy and temporary dialysis were necessary in 6 patients each (6.8%). The most frequent postoperative complication, which occurred in 41 patients (46.5%), was temporary atrial fibrillation.

Survival

Clinical follow-up data were available for all patients. The mean follow-up time was 70.3 ± 46.9 months (range, 0 to 168) for all patients. Survival was estimated starting with the operation and was 81.9% ± 4.5% and 56.6% ± 8.7% at 5 and 10 years, respectively (Fig 2).

Further 17 late (6 cardiac and 11 noncardiac) deaths occurred, on average, 58.5 ± 40.8 months after operation (range, 3 to 121) at a median patient age of 79 years (range, 56 to 92). No death was related to the aortic valve or aortic root. Moreover, the freedom of aortic and/or sudden/unknown death was 100%.

Valve-Related and Aortic Morbidity and Reoperations

No patient required reoperation on the aortic root and/or distal thoracoabdominal aorta; however 2 cardiac reoperations (mitral valve) were not connected with the primary surgical procedure. Two patients suffered a neurologic event during the follow-up period. One patient (44 years old) with supracoronary ascending and complete aortic arch replacement (with no root and/or valve involvement) suffered a minor stroke 5 weeks after the operation without any further events during the follow-up duration of 87 months. Another patient

suffered a lethal stroke at age 83. She had a native and well-functioning aortic valve (mild insufficiency, no stenosis) after aortic root and valve repair (decalcification) and complete arch replacement almost 80 months before.

No structural or nonstructural dysfunctions were noted in any patients with artificial aortic valves. Also no relevant aortic defects were observed in patients who had had valve-sparing root and valve operations.

Comment

In this retrospective evaluation we investigated the early and long-term outcomes after AAAD operations following a curative aortic approach, which comprised complete resection of all dissected aortic tissue and which left no residual dissection or false lumen, neither in the proximal nor in the distal parts of the aorta. Our data show excellent early and long-term results, particularly for the freedom of reintervention and mortality related to aortic disease.

Surgery for AAAD has evolved substantially over the past decades. In this process a multitude of strategies for cannulation, cerebral protection, and surgical aortic repair has been developed. One particular issue of interest is the proper extent of aortic resection. Following the so-called tear-oriented surgical approach the aortic segment containing the primary intimal tear is to be resected, whereas the remaining dissected aortic wall is secured or stabilized at the level of the anastomoses by means of Teflon felt strips and/or tissue glue or use of elephant trunk techniques. Although this approach has some merit in terms of limiting the extent of operation and thereby possibly shortening the duration of cardiopulmonary bypass and hypothermic circulatory arrest, numerous studies have shown that on follow-up the false lumen, if present in the downstream aorta, remained patent in the vast majority of such cases with a noncurative distal repair, even if there are no reentries beyond the distal aortic anastomosis (Fig 3). Moreover the patent false lumen in the distal aorta leads to an increase of the aortic diameter and, consequently, to an increase of the reintervention rate in the dissected distal aorta [10–14]. Our study demonstrates, however, that such a process can be avoided when a complete resection of all dissected aorta is performed. Even though Rylski and coworkers [15] reported a significant occurrence of aortic re-nterventions after curative distal aortic repair in dissections limited to DeBakey type II, our study

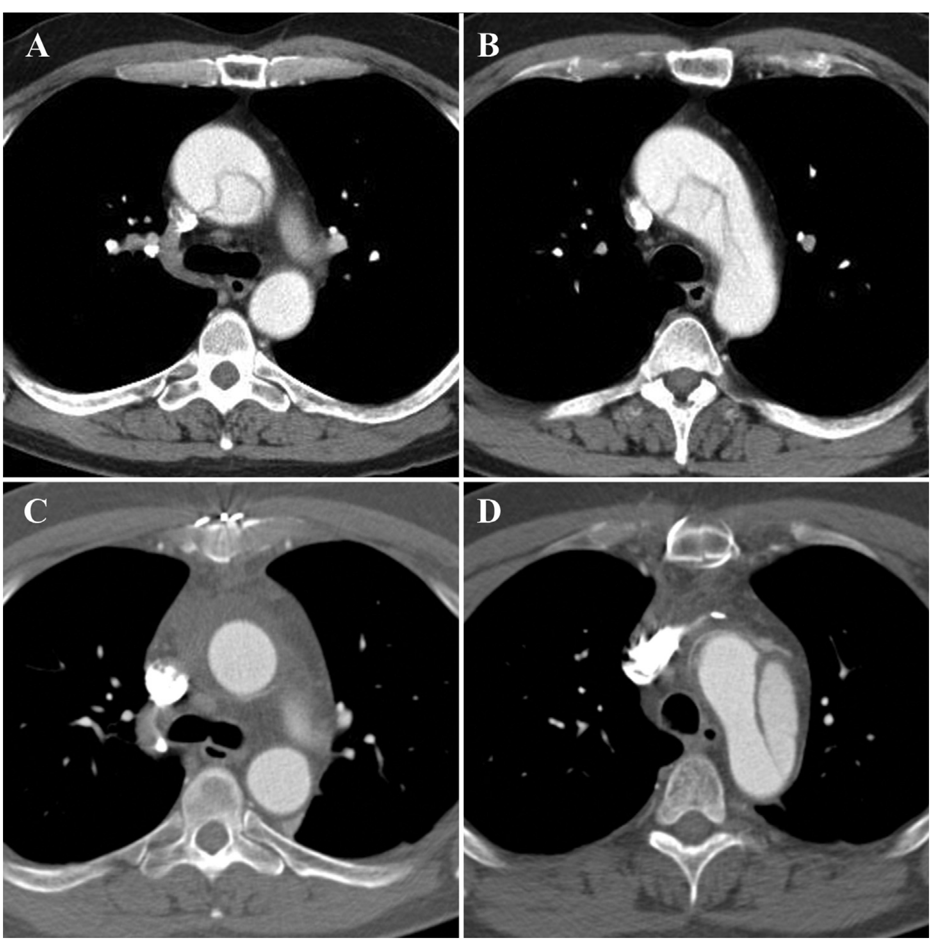

Fig 3. (A, B) Preoperative and (C, D) postoperative axial computed tomography angiography images demonstrating ascending aorta and arch dissection extending to the level of the aortic isthmus. (C) After replacement of the ascending aorta, (D) there is still a patent false lumen in the aortic arch.

demonstrates just the contrary, and this is also supported by other observations [15, 16].

In an attempt to achieve a distal remodeling of the dissected aorta, a frozen elephant trunk technique has increasingly been used in AAAD repair to eliminate all entries, at least along the level of the stent graft segment within the descending aorta. In our opinion its use in patients in whom a curative distal repair is technically possible (the distal end of the dissection is at the isthmus level or shortly below) is not necessary. Nevertheless it can be a matter of future investigations if the frozen elephant trunk technique (increased costs, complex and time-consuming distal anastomosis, risk of distal leak) would surpass a conventional total aortic arch replacement (challenging distal anastomosis deep within the chest, risk of recurrent nerve injury) in cases in which a curative replacement of all dissected aortic tissue is surgically possible.

This ampleness of evidence associating residual aortic dissection and patent false lumen with long-term aortic morbidity and mortality provided the conceptual foundation for the curative surgical approach that we followed in this study. Even if the curative repair is limited by the distal extension of the dissection beyond the aortic isthmus, it can be achieved in all cases with aortic dissections limited to the ascending aorta and aortic arch. The relatively high rate of such dissection extents in our cohort (42.9%) may result from the fact that we do not differentiate between subadventitial intramural hematoma and false lumen thrombosis and consider both forms a dissection necessitating surgical treatment [17]. The study cohort also included 9 patients with catheter-induced acute dissections, which mostly (8) were limited to the proximal aorta. Considering this fact the rate of dissections limited to the proximal aorta described here (ascending and/or arch of 42.9%) is in agreement with the 37% rate described by another author group [18]. In some reports the involvement of supraaortic arteries, especially the innominate artery, is higher than that in our report; however we regard the supraaortic arteries as dissected when the dissection extends throughout the main segments of these vessels. In contrast we do not consider a partial dissection at the origin as a true dissection because it does not implicate any vascular repair and mostly disappears after aortic replacement [19].

In 59% of the cohort patients, in whom the dissection was limited to the ascending aorta and aortic arch, the aortic root was also involved and curatively repaired with resection of all dissected aortic wall using either valve-sparing root repair or implantation of a valved conduit. The proximal replacement of all dissected aortic wall is technically almost always possible and therefore strongly recommended by us and other authors to avoid late aortic events and complications such as redissection, dilatation, pseudoaneurysm, or aortic insufficiency and to improve long-term survival [4, 18]. Admittedly a curative proximal and distal repair demands a combination of complex aortic root and aortic arch procedures, but as demonstrated in this series and other reports this kind of surgery, when performed by specialized and experienced teams in referral aortic centres, offers not only excellent outcomes but also provides a high rate of curative aortic repairs [18–23]. The authors therefore believe that the time may have come to challenge the traditional motto “the goal is to bring the patient alive from the operating room” and move toward “the goal is to provide the patient with the best possible short- and long-term outcomes modern surgery can offer.”

Study Limitations

The lack of randomization and patient selection, which may have introduced a selection bias, can be considered a limitation of the study. However almost all patients were operated on following the curative approach, and this in turn does not allow any compilation of a matched control group because only an irrelevant number of patients underwent a noncurative repair if a curative repair was technically possible [4, 22].

Conclusion

Complete resection of the dissected aorta in AAAD can be achieved in a relevant number of patients, especially in those whose dissection does not extend below the level of the aortic isthmus. Based on current data this curative approach to both proximal and distal aortic repair is advisable, whenever surgically feasible, because it apparently leads to favorable operative and long-term outcomes with a very low risk of aortic complications and/or reoperations.

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ABTS Announcement for Maintenance of Certification

The American Board of Thoracic Surgery's Maintenance of Certification (MOC) program was adopted 11 years ago. Since that time, the Board has continuously evaluated the overall process, based upon internal discussions and input from our Diplomates.

The input resulted in our decision to migrate from a purely knowledge-based, multiple-choice exam using a Pearson Testing Center to a mastery learning process using a SESATS format. Diplomates enrolled in the 10-year MOC process will now fulfill their Part III requirement by following the instructions on the ABTS website and conveniently completing the exam at their home or office.

The MOC exam is composed of 100 questions that are based on SESATS. Diplomates choose their exam module (Adult Cardiac, General Thoracic, Cardiothoracic, or Congenital) by indicating their preference within the 10-year application. The exam is tailored to one's practice—for example, if your practice is 100% adult cardiac, you may choose the Adult Cardiac exam, which will only have adult cardiac and some critical care questions on your exam.

Diplomates with approved applications will be able to take the 100-question MOC exam anytime during the months of September and October 2019. For those Diplomates who have used SESATS in the past, the process of working through the questions is the same. For those who are not familiar with SESATS, it may be beneficial to purchase and download SESATS and work through the specialty-specific module. This preparation will enable you to become familiar with the process. While SESATS is a helpful resource, it is not required. The Board and MOC Committee believe that reading the critique provided after each question is key to the learning process.

The goal of this exam is to provide a learning opportunity using judgment, knowledge, and decision-making skills. The Board sincerely hopes that this new MOC exam format is viewed favorably by our Diplomates.

The ABTS staff thank you for embracing the primary principle of MOC—life-long learning, which is consistent with our obligation to the public trust.