Mortality and reoperations in survivors operated on for acute type A aortic dissection and implications for catheter-based or hybrid interventions

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Objective: **This study investigated late outcomes (mortality, reoperations) and their associated predictors after operations for acute type A aortic dissection. The role catheter-based and hybrid interventions is discussed.**

Methods: **All hospital survivors operated on for acute type A aortic dissection from 1990 through 2009 were reviewed, with cross-sectional follow-up. Mortality (overall and aortic) and freedom from reoperations (proximal and distal) were estimated using actuarial methods. Preoperative, intraoperative, and postoperative variables (n = 44) associated with late outcomes were analyzed with univariable and multivariable (Cox) statistical methods.**

Results: **Of 360 operated-on patients, 291 hospital survivors (81%) were monitored for a median of 5.5 years (1864 patient-years). Total late mortality was 30% (n = 86), with estimated (standard error) survival of 82% (3%), 64% (4%), and 48% (6%) at 5, 10, and 15 years, respectively. Aortic events accounted for at least 27% (up to 42% including unknown causes) of late deaths. In Cox analysis, variables independently related (hazard ratios [95% confidence limits]) to late mortality were increased age (1.6 per 10 years [1.3, 2.0]), earlier operation (<2005; 2.3 [1.2, 4.6]), permanent neurologic damage (2.6 [1.6, 4.2]), and respiratory insufficiency (3.4 [1.8, 6.4]). Thirty-four patients underwent 46 reoperations, 21 on the proximal and 25 on the distal aorta, up to 19 years after the primary operation; respective in-hospital reoperative mortality was 14% and 12%. Estimated freedom (standard error) from aortic reoperation was 95% (2%), 87% (4%), and 61% (5%) at 5, 10, and 15 years, respectively. In multivariable Cox analysis (hazard ratios [95% confidence limits]), use of surgical adhesive at the primary operation (4.2 [1.6, 11]) and temporary neurologic damage (3.2l [1.2, 8.9]) were independently related to proximal reoperation, and DeBakey type I dissection (10.5 [1.4, 80]) was related to late distal reoperation. Catheter-based (endovascular, percutaneous) or hybrid procedures were not used in any patients but could have been used in up to 74% of reoperations, including in four of six of those that resulted in in-hospital death and putatively in 10 of 17 patients who sustained lethal aortic events without reoperation.**

Conclusions: **Despite close follow-up, aortic-related death after a successful operation for acute type A aortic dissection is prevalent, and overall mortality remains substantial. Reoperations are not uncommon, may be indicated very late as well as repeatedly in the same patient, and are associated with a significant mortality. Increased use of applicable but seemingly under-used catheter-based or hybrid treatment approaches could benefit this growing patient population by offering repeat intervention to more patients and as substitute for reoperative open surgery in selected cases. (J Vasc Surg 2013;58:333-9.)**

Study and analysis of long-term results in operated-on acute type A aortic dissection survivors are important because (1) the long-term mortality rate is higher than that of the normal population[1,2]; (2) despite close follow-up, aortic events (rupture, repeat dissection) cause a substantial proportion of late deaths[1,3,4]; (3) mortality of reoperative aortic surgery is considerable, approaching 30%, depending on location[5]; (4) and the outcomes serve as a benchmark for—and help establish the role of—catheter-based (percutaneous, endovascular) and hybrid treatment modalities currently applicable to essentially all aortic segments.

Therefore, it also remains important to identify predictors of late death and late aortic reoperation as well as causes of late death, eventually to reduce as far as possible the occurrence of adverse outcomes. In this study, long-term survival, cause of death, and reoperations in a large, contemporary cohort of patients surviving surgery of acute type A aortic dissection were analyzed, emphasizing their implications for catheter-based or hybrid interventions.

METHODS

This study was approved by the regional Research Ethics Committee (Ref No. 2008/1771-31), which waived the need for individual informed consent.

Patients. From January 1, 1990, through December 31, 2009, 360 consecutive patients were operated on for acute type A aortic dissection. In-hospital mortality was

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The study was financially supported by a donation from the Mats Kleberg Foundation.

Author conflict of interest: none.

Additional material for this article may be found online at www.jvascsurg.org.

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The editors and reviewers of this article have no relevant financial relationships to disclose per the JVS policy that requires reviewers to decline review of any manuscript for which they may have a conflict of interest.

0741-5214/$36.00

http://dx.doi.org/10.1016/j.jvs.2012.12.078

69 of 360 (19%), resulting in 291 surgical survivors available for long-term follow-up. Clinical characteristics of the hospital survivors and nonsurvivors are summarized in Table I. Cross-sectional follow-up was performed in October 2010, with additional data on reoperative procedures procured in May 2011.

Procedures. Surgical procedures, anesthesia, and perfusion techniques have been described in detail previously.[6] Briefly, prosthetic replacement of the ascending aorta was performed, combined proximally with aortic valve preservation (valve untouched, resuspended, or reimplanted) or replacement (separate prosthetic valve or as a composite graft with coronary artery reimplantation). Distally, procedures were performed during aortic cross-clamping or with open distal anastomosis requiring hypothermic circulatory arrest. Hemiarch or total arch replacement was performed selectively. For augmented cerebral protection, retrograde antegrade cerebral perfusion was used selectively.

Outcomes. Variables, including 19 preoperative, 17 intraoperative, and eight postoperative variables, and definitions used for statistical univariate and multivariable analysis are detailed in the Appendix (online only). The specific outcomes studied were overall mortality, aortic-related mortality, and proximal or distal aortic reoperation (definitions detailed in the Appendix, online only). Follow-up included in-house regular (annual and biannual) computed tomography scans of the entire aorta and clinical visits as motivated in the majority of patients.

Statistical analysis. Categoric variables are presented as numbers and percentages. Continuous variables are presented as means with 95% confidence limits (CLs). Group comparisons were performed using the Student *t*-test for continuous variables and the two-sided χ^2 test or Fisher exact test for categoric variables. Survival estimates were calculated with 95% CLs using actuarial (Kaplan-Meier) methods. Survival estimates were group-wise compared using the log-rank test. Variables associated with survival in univariate analysis (log-rank $P < .10$) were included in multivariable Cox regression analysis to identify variables independently related to outcome ($P < .05$) using a backward stepwise approach to variable selection. Results of Cox regression are presented as hazard ratio (HR) with 95% CL. Statistical analysis was performed using STATA 11.1 software (StataCorp LP, College Station, Tex).

Table I. Preoperative, intraoperative, and postoperative variables in surgical hospital survivors and nonsurvivors

	Hospital	
Variable[a]	*Survivors (n = 291)*	*Nonsurvivors (n = 69)*
Preoperative		
Sex		
Male	215 (74)	50 (72)
Female	76 (26)	19 (28)
Age, years	59 (58, 60)	61 (59, 65)
Marfan syndrome	7 (2.4)	1 (1.4)
Family history	14 (4.8)	4 (5.8)
COPD	14 (4.8)	5 (7.2)
Diabetes	2 (0.69)	1 (1.4)
Hypertension	198 (68)	45 (65)
Smoking	72 (25)	8 (12)
Obesity	22 (7.6)	9 (13)
CVI history	7 (2.4)	3 (4.3)
Redo operation	9 (3.1)	3 (4.3)
DeBakey type I	165 (57)	47 (68)
Early era (<2004)	176 (60)	52 (75)
Aortic regurgitation	155 (53)	34 (49)
Tamponade	95 (33)	31 (45)
Penn class		
Aa	189 (65)	30 (43)
Ab	39 (13)	12 (17)
Ac	8 (16)	15 (22)
Abc	15 (5.2)	12 (17)
Intraoperative		
Supracoronary graft	201 (69)	43 (73)
Valve + graft	4 (1.4)	2 (2.9)
Composite graft	86 (30)	23 (33)
Aortic valve resuspension	76 (26)	9 (13)
HCA	249 (86)	64 (93)
Hemiarch replacement	48 (16)	10 (14)
Total arch replacement	11 (3.8)	7 (10)
Coronary artery bypass	24 (8.2)	18 (26)
Surgical adhesive (GRF)	92 (32)	23 (33)
Cerebral perfusion	186 (64)	43 (62)
Postoperative		
Reoperation for bleeding	49 (17)	15 (22)
Reoperation for infection	6 (2.1)	0 (0)
Renal failure	17 (5.8)	8 (12)
Respiratory failure	21 (7.2)	7 (10)
Neurologic damage		
Temporary	29 (10)	2 (2.9)
Permanent	38 (13)	26 (38)

CL, Confidence limit; *COPD,* chronic obstructive pulmonary disease; *CVI,* cerebrovascular insult; *GRF,* gelatin-resorcinol-formaldehyde; *HCA,* hypothermic circulatory arrest.
[a]Categoric variables are shown as number (%) and continuous variables as mean (95% CLs).

RESULTS

Long-term survival. Survival status follow-up was 99% complete. Cumulative follow-up was 1864 patient-years, and median (95% CL) survival was 5.5 years (4.8, 6.2; range, 10 days-20.5 years). Fig 1 delineates the overall long-term outcomes for mortality and reoperations. During the entire follow-up, late death occurred in 86 of 291 (30%), corresponding to a linearized attrition rate of 5% per patient-year. Estimated Kaplan-Meier survival (standard error) at 1, 5, 10, and 15 years was 94% (1%), 82% (2%), 64% (4%), and 48 (6%), respectively (Fig 2).

Causes of late death. As summarized in Table II, aortic and cardiac events were the dominating causes of late death. Specifically, univariate analysis showed family history ($P = .022$) and lower age (≤39 years; $P = .0069$) were risk factors for aortic cause of late death. In multivariable analysis, lower age remained independently related to increased risk of aortic late death; the HR (95% CL) for each decade of increased age >39 years was 0.60 (0.39, 0.90; $P = .011$). Seventeen patients died from an aortic cause without a direct relation to an aortic reoperation.

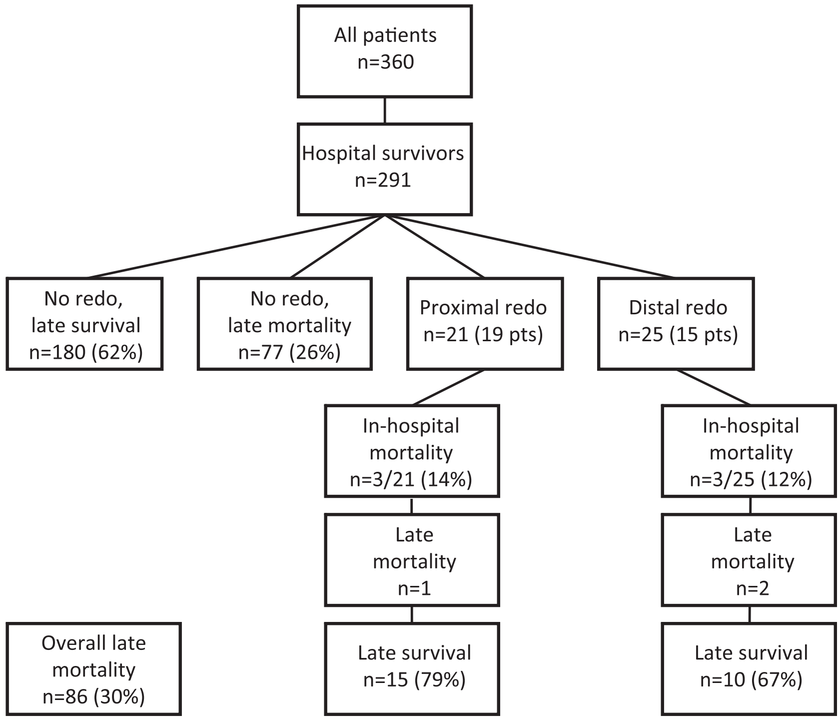

Fig 1. Flow chart shows overall patient population and follow-up status regarding reoperation and survival of 291 operative survivors after surgery for acute type A aortic dissection.

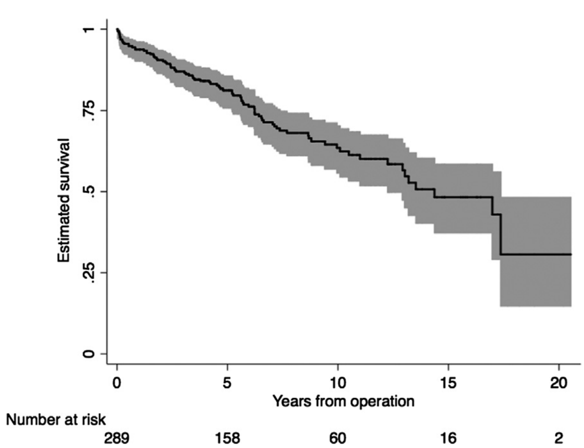

Fig 2. Kaplan-Meier analysis shows estimate (*solid line*) of actuarial long-term survival for all patients with the with 95% confidence limits (CLs) (*grey shaded area*).

Ten (59%) were considered too old, deconditioned, or both, to be candidates for reoperation. None of these patients were offered a reoperation. Six (35%) sustained an aortic rupture and died before coming to surgical treatment, all of these occurring in a part of the aorta distal to the operated-on segment. Finally, the circumstances were unknown in one patient (6%). Overall, the cause of death in 10 patients (59%) was confirmed by autopsy or they died in-hospital; in the remainder, the death certificate was used. The median largest aortic diameter at latest radiologic follow-up (data from 12 patients) was 6.0 cm (range, 4.8-10.0 cm). Fifteen (88%) had a DeBakey type I dissection.

Predictors of late death. In univariate analysis by log-rank test, several variables were significantly related to late all-cause mortality: male sex ($P = .0022$), increased age ($P < .0005$), operation before 2005 ($P = .015$), hemiarch replacement ($P = .0021$), hypothermic circulatory arrest ($P = .033$), respiratory failure ($P < .0005$), and permanent neurologic damage ($P < .0005$). Several of these remained independently related to late all-cause mortality in the multivariable Cox regression analysis (Table III).

Late reoperation. Thirty-four patients underwent 46 reoperations, comprising 21 on the proximal aorta and 25 on the distal aorta (excluding reoperations unrelated to the aorta, its side branches, or the initial operation). Reoperation was performed after a median of 2.4 years (range 17 days-19 years). Indications for the 21 proximal reoperations included 11 (52%) for pseudoaneurysm, anastomotic insufficiency in proximal, or distal suture line, or a combination of these; eight (38%) for aortic root dilatation, with or without concomitant aortic regurgitation (one with concomitant mitral valve regurgitation); one (4.8%) for right common carotid artery bypass due to dynamic obstruction, and one for fungal prosthetic valve endocarditis. No patients reoperated on for aortic root dilatation or aortic regurgitation had a documented bicuspid aortic valve.

Table II. Cause of late mortality

Variable	*No. (%)*
Aortic	23 (27)[a]
Cardiac	21 (24)
Malignancy	9 (10)
Infection	8 (9.3)
Cerebrovascular	7 (8.1)
Pulmonary	2 (2.3)
Other	3 (3.5)
Unknown/missing	13 (15)
Total	86 (100)

[a]Including two intraoperative deaths due to bleeding at late reoperation.

Table III. Multivariable Cox analysis of variables related to long-term all-cause mortality

Variable	*HR (95% CL)*	P
Age, 10-year increment	1.63 (1.34, 1.97)	<.0005
Operation before 2005	2.32 (1.16, 4.64)	.017
Permanent neurologic damage	2.58 (1.57, 4.25)	<.0005
Respiratory failure	3.43 (1.84, 6.39)	<.0005

CL, Confidence limits; *HR,* hazard ratio.

Of 21 proximal reoperations, 15 (71%) had a previous supracoronary graft, five (24%) had a composite graft, and one (5%) had a separate valve and supracoronary graft. Overall, 15 of 201 (8%) with a supracoronary graft replacement underwent a proximal reoperation compared with five of 86 (6%) with composite graft and one of four (25%) with valve and graft ($P = .34$). The indication for the 25 distal reoperations was aortic dilatation engaging the descending aorta in 12 (48%), the aortic arch in nine (36%; in six managed with a concomitant elephant trunk), the thoracoabdominal aorta in two (8%) and the infrarenal aorta in one (4%). The distal reoperation was more common in DeBakey type I than in type II dissection (9% vs 0.8%; $P = .0024$).

Twelve patients (35% of those reoperated-on) underwent multiple reoperations, as detailed in Table IV. The primary operation in eight was a simple supracoronary graft repair with open distal anastomosis not including the arch. For those undergoing distal reoperations, an elective, staged approach, including total arch replacement (with or without elephant trunk extension), followed by descending aortic repair, was carried out in six of ten. Overall, the Kaplan-Meier estimated (SE) freedom from aortic reoperation at 1, 5, 10, and 15 years was, respectively, 99 (1%), 95% (2%), 87% (4%), and 61% (5%). The 30-day mortality for reoperations was six of 46 (13%). Three patients died late during follow-up, and median survival after any reoperation was 3.2 years. Reoperation-related in-hospital mortality is detailed in Table V.

Predictors of late reoperation. In univariate analysis by log-rank test, use of gelatin-resorcinol-formaldehyde (GRF) glue ($P = .0018$) and temporary neurologic damage ($P = .020$) were related to the risk of proximal reoperation. These variables remained significant in multivariable Cox regression analysis (Table VI). GRF glue was used in 12 of 21 patients (57%) later undergoing proximal reoperation and in seven of 11 patients (64%) reoperated on due to pseudoaneurysm formation. Overall, 14 of 92 patients (15%) operated on with the aid of GRF underwent subsequent proximal reoperation. Being an iatrogenic cause of reoperation, proximal reoperation was also analyzed after excluding patients in whom GRF glue was used. In the remaining 200 patients, Penn class Abc emerged as the only independent predictor, with a HR (95% CL) of 10.2 (1.9, 56). Excluding GRF-treated patients did not alter the findings of multivariable analysis for overall mortality, aortic mortality, or distal reoperation.

For distal reoperation, De Bakey type I dissection ($P = .0071$), reoperation for infection ($P = .0332$), and male sex ($P = .049$) were significant in univariate analysis. DeBakey type I dissection remained significant in multivariable Cox regression (Table VI). The only patient without DeBakey type I dissection requiring distal reoperation underwent a total arch replacement as a remedy for distal suture line insufficiency causing an arch pseudoaneurysm. Of the 16 patients undergoing distal aortic reoperation, 15 were men and none had prior hemiarch or total arch replacement ($P = .08$).

Marfan syndrome. Eight patients had Marfan syndrome. Six (75%) presented with DeBakey type I dissection. Seven (88%) underwent aortic root replacement using a mechanical composite graft; one redo patient already had a composite graft implanted. In none was a hemiarch or total arch replacement performed. One (13%) early and one late death occurred, in both instances as a result of aortic events. Of the remaining six patients, three (50%) underwent late reoperation—all with DeBakey type I dissection, all on the descending aorta—after an interval of 7 to 19 years and without operative mortality. Two of these eventually underwent a second redo with replacement of the remaining thoracoabdominal aorta, also without operative death (Table IV).

DISCUSSION

Emanating from our previously reported[6] cohort of 360 consecutive patients operated on for acute type A dissection, this is one of the most extensive follow-up studies to date, including 291 operative survivors monitored for a median of 5.5 years, totaling 1864 patient-years, and including 132 events (late deaths and reoperations; Fig 1). The long-term survival in this study, estimated at 64% after 10 years and 48% after 15 years (Fig 2), was comparable to that of other studies[5,7-10] and re-emphasizes the impaired survival outlook compared with a healthy population.[1,2]

Variables independently related to late all-cause mortality, including age, permanent neurologic damage, respiratory insufficiency, and operation during an earlier period (<2005), are consistent with previous reports.[7-12] Increased age was a predictor of overall mortality, whereas younger age was a predictor of aortic-related mortality.

Table IV. Patient characteristics and procedures in cases of multiple late reoperations

Pt No.	*Sex*	*Age,[a] years*	*Primary operation*	*Time elapsed*	*First reoperation*	*Time elapsed*	*Second reoperation*	*Survival[b]*
13	M	68	SCG, ODA	1.9 years	TAR	2.5 months	DTA	10.4 years; alive
46	M	52	Comp, AXC	5.6 years	TAR+ET	4.5 years	DTA	5.8 years; alive
63	M	61	Comp, ODA	2.8 years	TAR+ET	3 months	DTA	1.9 years; alive
67	M	60	SCG, ODA	3.6 years	TAR+ET	10 months	DTA	4 months; alive
69	M	59	SCG, ODA	2.5 years	TAR+ET	3 months	DTA	1.8 years; alive
80	M	54	SCG, ODA	17 days	RCCA bypass	6.5 years	DTA	3 months; alive
86	M	50	SCG, ODA	2.4 years	Comp	5 years	Pseudo	1.5 years; alive
98	M	43	Comp, ODA	8.4 years	DTA	1.1 years	TAAA	1.1 years; alive
99	F	34	Comp, ODA	19 years	DTA	3 months	TAAA	1 months; alive
104	M	40	SCG, ODA	6.4 years	TAR+ET	3 months	DTA	1.7 years; alive
188	M	58	SCG, ODA	1.7 years	Comp	3.5 years	TAR	0; dead
355	F	59	SCG, ODA	1.4 years	Comp	2.3 years	Pseudo	4.9 years; dead

AXC, Aortic cross-clamp; *Comp,* composite graft; *DTA,* descending thoracic aortic repair; *ET,* elephant trunk; *F,* female; *M,* male; *ODA,* open distal anastomosis; *Pseudo,* pseudoaneurysm; *Pt,* patient; *RCCA,* right common carotid artery; *SCG,* supracoronary graft; *TAAA,* thoracoabdominal aortic aneurysm repair; *TAR,* total arch replacement.

[a]Age at primary operation.

[b]Survival from latest reoperation until, and status at, time of cross-sectional follow-up.

Table V. In-hospital mortality associated with aortic reoperation and possibility of catheter-based or hybrid intervention

Pt No.	*Sex*	*Age, years*	*Indication*	*Surgical procedure*	*Outcome*	*Possible alternative intervention*
166	F	66	Aortic root dilatation + aortic regurgitation	Composite graft	IOD	None
185	M	70	Arch and descending aortic dilatation	TAR + ET	Death POD 13	Hybrid arch repair
188	M	63	Distal anastomotic pseudoaneurysm	TAR	IOD	Hybrid arch repair; percutaneous device closure
231	M	72	Arch and descending aortic dilatation	DTA	IOD	Hybrid arch repair; TEVAR
242	M	75	Distal anastomotic pseudoaneurysm	Aneurysm repair	Death POD 19	Hybrid repair; percutaneous device closure
303	M	48	Fungal prosthetic valve endocarditis	Composite graft	Death POD 7	None

DTA, Descending thoracic aortic repair; *ET,* elephant trunk; *F,* female; *IOD,* intraoperative death; *M,* male; *POD,* postoperative day; *Pt,* patient; *TAR,* total arch replacement; *TEVAR,* thoracic endovascular aortic repair.

Table VI. Multivariable Cox analysis of variables related to proximal and distal reoperation

Variable	*HR (95% CL)*	P
Proximal reoperation		
Use of surgical adhesive	4.17 (1.58, 11.0)	.004
Temporary neurological damage	3.24 (1.18. 8.93)	.023
Distal reoperation		
DeBakey type I dissection	10.5 (1.38, 80)	.023

CL, Confidence limits; *HR,* hazard ratio.

Paradoxical as it would seem, it is thought to reflect the natural effect of age on mortality on one hand, and on the other the fact that any condition causing death in young individuals would appear significant given their very low background mortality rate. The findings underscore the sobering fact that operative techniques and perioperatively modifiable variables do not perceivably influence late mortality—a strong incentive for developing novel treatment approaches. The cause of late death was aorta-related in at least 27, up to 42%, including those with unknown cause of death (Table II). Reducing late aortic complications, including reoperation-related mortality, would contribute to an improved long-term prognosis.

Overall, 46 late reoperations were undertaken in 34 patients (12%) up to 19 years after the primary procedure, and 12 underwent two reoperations. The estimated freedom from any reoperation was 87% at 10 years and 61% at 15 years, also equivalent to previous reports.[7-12] Reoperation rate is biased by institutional attitudes, given a substantial risk of mortality and morbidity; in this study, in-hospital mortality was 14% for proximal reoperations and 12% for distal reoperations (Fig 1), and was reported as high as 30% for distal reoperations.[5]

The use of GRF glue to adapt and reinforce aortic wall layers was associated with an increased risk of late proximal reoperation, and in 64% was related to suture-line pseudoaneurysm formation. This is a recurring, but not universal or undisputed, finding from other studies,[13,14] suggesting judicious patient selection and glue application, respectively. We have abandoned the use of GRF glue.

In statistical analysis, Marfan syndrome was not independently related to late reoperation, but the small patient number (n = 7) introduces the possibility of type II error, and in fact, 50% of long-term survivors with Marfan syndrome did undergo late (distal) reoperation. These patients also had a high prevalence of DeBakey type I dissection, self-evidently related to the risk of late distal reoperation (Table VI) given the extent of aortic wall damage.

Interestingly, yet again not statistically significant, hemiarch or total arch replacement at the primary operation entailed no late distal reoperations, corroborating recent findings.[15] The decision to perform more extensive surgery at the primary acute operation is certainly better justified if conveying a decreased risk of subsequent procedures on the aortic arch and downstream.

A stagnating development of nonimproving surgical results unfolding during the recent decades[8,16] is paralleled by a significant and promising development of less invasive treatment modalities comprising percutaneous, endovascular, and hybrid interventions. There are implications for endovascular and related interventions to the growing cohort of patients surviving acute type A dissection surgery:

First, already at the primary operation, the development of the so-called frozen elephant trunk, using a composite stent graft/vascular graft device delivered antegradely through the opened aortic arch, shows very promising results, with very low (4.6%-4.7%) intraoperative mortality, almost abolished need for distal reintervention (0.5%-2.5%), and an accordingly high (92%-95%) false lumen obliteration at midterm follow-up.[17,18] If an indication for a distal reintervention does occur, the frozen elephant trunk paves the way for continued endovascular repair of the descending or thoracoabdominal aorta. Downstream from the aorta, in analogy, an endovascular or even open surgical repair of the descending aorta—recently shown not to carry unduly high risk related to the chronic dissection per se[19,20]—may transform a higher-risk thoracoabdominal aortic aneurysm type I or II into a lower-risk[21] type III or IV, at the same time accomplishing two desirable goals: reduced risk of paraplegia from staging the intervention (0% vs 15% in extensive single-stage procedures)[22] and, again, regularly creating a suitable proximal landing zone for further endovascular repair if indicated.

Second, importantly, the present and previous studies[4-5,12] report no use of late endovascular (re)interventions in these patients, suggesting underutilization of this important treatment modality and departing from the approach to treat primary type B dissection using endovascular techniques.[23] Patients arguably considered excluded from endovascular aortic repair include those with pathology of the aortic root or valve, or both, Marfan syndrome,[24] infected vascular prosthesis—although conceivable when surgical risk is deemed prohibitive.[25] In other situations, treating progressive or recurrent aortic pathology of the arch, descending, or thoracoabdominal aorta, as well as favorably localized postoperative pseudoaneurysms, catheter-based repair can be an attractive remedy to complex or high-risk problems.[21]

Applying such principles to the patient cohort in this study, 12 of 21 proximal and 22 of 25 distal reoperations (74% of all reoperations) could have been eligible for catheter-based or hybrid intervention: four of the six operations (66%) entailing surgical mortality were potentially amenable to catheter-based therapy (Table V). Patients suffering aortic-related death were often (59%) not considered for reoperation regardless of aortic diameter (in this group, median, 6.0 cm; max, 10.0 cm) or ruptured unexpectedly (32%) despite surveillance, always in the distal aorta.

Endovascular or hybrid treatment is often considered a suitable choice for old or fragile patients and should be contemplated in situations where an indication for intervention is reasonable but open reoperation is not. Most of these patients died before the introduction of catheter-based aortic repair, which helps to explain why no patient was offered such treatment in this series. The point, however, is that with the development of catheter-based aortic repair, more acute type A dissection survivors may be considered for reintervention.

Increased aortic diameter also confers worse surgical results in this patient population,[25] supporting the more liberal treatment indications (5.5-cm aortic diameter in the descending aorta) established in recent guidelines[26] and suggesting even more possible candidates for open or endovascular repair. For reasons stated above, chronic residual dissection present in patients after being operated on for acute DeBakey type I dissection will behave differently from the relatively benign course of uncomplicated type B (DeBakey type III) dissection, hitherto not shown to benefit from prophylactic endovascular treatment.[27]

This study has some limitations. In this retrospective follow-up study, with inherent study design weaknesses, treatment was not randomly assigned and varied over time. Several putatively important variables related to late mortality and reoperation were not studied, including exact localization of intimal tear(s), whether the tear(s) was completely resected, the precise extent of dissection apart from DeBakey type, coronary artery disease, left ventricular ejection fraction, and renal and respiratory failure of other degrees than those entailing dialysis and tracheostomy.

CONCLUSIONS

Reduction of late mortality rates, avoidance of unnecessary (primarily aorta-related) deaths, and timely detection of the often asymptomatic changes in the operated-on or residual aorta qualifying for reoperation or reintervention are still needed. Vigilant radiologic and clinical follow-up is necessary for as long as a patient can be considered a reasonable candidate for an open surgical reoperation or a catheter-based reintervention.[26] This is demonstrated by the indefinite attrition rate (linearized late mortality of 5% per patient-year), the proportion of late aorta-related deaths (27%-42%), and the need for late reoperation even very remote (up to 19 years) from the primary operation. Obvious in DeBakey type I dissection, we, as opposed to others,[15] would also argue for similar follow-up of patients with DeBakey type II dissection, not because of the risk of late distal disease but because of the apparent risk of late surgical failure manifested as anastomotic leakage and pseudoaneurysm formation, especially if GFR glue was used primarily. Novel approaches, including hybrid and catheter-based treatment, primarily or in combating late aortic sequelae, may contribute to improved early and late survival and expand treatment indications to patients previously considered at too high a surgical risk; here, some 59% of patients suffering aortic-related death.

The authors gratefully acknowledge the assistance of Camilla Lindell, RN, for data acquisition.

AUTHOR CONTRIBUTIONS

Conception and design: CO, JL, AF
Analysis and interpretation: CO, AF
Data collection: CO
Writing the article: CO, AF
Critical revision of the article: CO, CH, JL, UL, PE, AF
Final approval of the article: CO, CH, JL, UL, PE, AF
Statistical analysis: CO
Obtained funding: AF
Overall responsibility: CO

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Submitted Oct 9, 2012; accepted Dec 26, 2012.

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APPENDIX (online only)

List of variables and definitions used in univariable and multivariable statistical analysis

Sex (male/female)
Age (years): grouped by decade ≤39, 40-49, 50-59, 60-69, 70-79, ≥80 years
Family history (yes/no): known family history of aortic aneurysm or dissection, or both
Marfan syndrome (yes/no)
Obesity (yes/no): Body mass index ≥35 kg/m^2
Diabetes (yes/no): requiring medical treatment
Chronic obstructive pulmonary disease (yes/no): requiring medical treatment
Hypertension (yes/no): requiring medical treatment or diagnosed at admission
Smoking history (yes/no): current or past smoking
CVI history (yes/no): verified cerebrovascular incident with or without current sequelae
Redo operation (yes/no): Previous open heart surgery requiring median sternotomy
DeBakey type I dissection (yes/no)
Early era (yes/no): operation before 2005 vs 2005 through 2009
Bicuspid aortic valve (yes/no): known or diagnosed perio peratively
Aortic regurgitation (yes/no): known or diagnosed perio peratively
Grade of aortic regurgitation (I-IV): mild (grade I); moderate (grade II); severe (grade III-IV)
Shock (yes/no): any of hypotension <90 mm Hg, inotropic support, pulmonary edema, anuria or oliguria
Penn Class (Aa/Ab/Ac/Abc/non-Aa): Aa, no end-organ ischemia; Ab, localized ischemia (upper/lower extremity, central nervous system, renal, mesenteric); Ac, generalized ischemia or dissection-related coronary ischemia producing general ischemia, or both; Abc, localized and generalized ischemia; Non-Aa, any Penn class other than Aa
Tamponade (yes/no): as diagnosed perioperatively
Supracoronary graft (yes/no): tube graft with proximal suture line at the level of the sinotubular junction
Composite graft (yes/no): mechanical valved graft with reimplantation of coronary artery ostia
Separate valve + graft (yes/no): prosthetic valve replace ment with concomitant supracoronary graft
Hemiarch replacement (yes/no): open distal anastomosis including resection of the minor curvature
Total arch replacement (yes/no): arch replacement with cervical vessel reimplantation with or without elephant trunk
Aortic valve resuspension (yes/no): suture with or without glue used to resuspend or reattach the aortic valve
Gelatin-resorcinol-formaldehyde glue (yes/no): Glue used to adapt aortic wall layers
Coronary artery bypass grafting (yes/no)
Hypothermic circulatory arrest (yes/no)
Hypothermic circulatory arrest time (minutes)
Aortic cross-clamp time (minutes)
Cardiopulmonary bypass time (minutes)
Cerebral perfusion (yes/no): retrograde or antegrade vs no cerebral perfusion
Retrograde cerebral perfusion (yes/no)
Antegrade cerebral perfusion (yes/no)
Femoral artery cannulation (yes/no)
Axillary artery cannulation (yes/no)
Reexploration for bleeding (yes/no): requiring resternotomy
Reexploration for infection (yes/no): requiring resternotomy
Renal failure (yes/no): requiring hemofiltration or hemodialysis
Respiratory failure (yes/no): requiring tracheostomy
Temporary neurologic deficit (yes/no): symptom(s) resolving during hospitalization
Permanent neurologic deficit (yes/no): symptom(s) not resolving during hospitalization
Proximal reoperation: reoperation on previously operated part(s) of the aorta including the aortic valve and root
Distal reoperation: reoperation on not previously operated part(s) of the aorta distal to the initial operation
Late death: death occurring after hospital discharge
Cause of death

Aortic, due to aortic rupture, dissection, repeat dissection or aortic reoperation
Cardiac, due to myocardial infarction, heart failure, or arrhythmia
Pulmonary, due to respiratory insufficiency
Cerebrovascular, due to cerebrovascular insult (embolic or hemorrhagic)
Infectious
Malignancy
Other, due to other known condition
Unknown