ORIGINAL RESEARCH

Outcomes of Reoperation After Acute Type A Aortic Dissection: Implications for Index Repair Strategy

Hanghang Wang, MD, PhD; Matthew Wagner, BS; Ehsan Benrashid, MD; Jeffrey Keenan, MD; Alice Wang, MD; David Ranney, MD; Babatunde Yerokun, MD; Jeffrey G. Gaca, MD; Richard L. McCann, MD; G. Chad Hughes, MD

***Background*—**The optimal surgical approach for management of acute type A aortic dissection remains controversial. This study aimed to assess outcomes of reoperation after acute type A dissection repair to help guide decision making around index operative strategy.

***Methods and Results*—**All aortic reoperations (n=129) at a single referral institution from August 2005 to April 2016 after prior acute type A dissection repair were reviewed. The primary outcome was 30-day or in-hospital mortality. Secondary outcomes included organ-specific morbidity and 1- and 5-year outcomes as estimated using the Kaplan–Meier method. The majority of initial reoperations were proximal aortic (aortic valve, aortic root, or ascending) or aortic arch procedures (62.5%, n=55); most initial reoperations were performed in the elective setting (83.1%, n=74). Additional nonstaged second or more reoperations were required in 21 patients (23.6%) after the initial reoperation, during a median follow-up of 2.5 years after the initial reoperation. Thirty-day or in-hospital mortality for all reoperations was 7.0% (elective: 6.3%; nonelective: 11.1%) with acceptable rates of organ-specific morbidity, given the procedural complexity. One- and 5-year overall survival after initial reoperation was 85.9% and 64.9%, respectively, with aorta-specific survival of 88% at 5 years.

***Conclusions*—**Reoperation after acute type A aortic dissection repair is associated with low rates of mortality and morbidity. These data support more limited index repair for acute type A dissection, especially for patients undergoing index repair in lower volume centers without expertise in extensive repair, because reoperations, if needed, can be performed safely in referral aortic centers. **(*J Am Heart Assoc*. 2017;6:e006376. DOI: 10.1161/JAHA.117.006376.)**

Key Words: aortic dissection • aortic surgery

The optimal surgical approach for management of acute type A aortic dissection remains controversial. Specifically, there is no consensus regarding whether to perform limited repair (eg, ascending aortic and hemiarch replacement), followed by late reoperation if needed, or extensive repair (eg, total arch replacement with conventional or frozen elephant trunk) for the index (first) operation. Arguments in favor of limited index repair primarily include lower surgical risk compared with extensive repair[1]—the "live to fight another day" philosophy.[2] In addition, some studies have suggested that limited repair has late outcomes similar to extensive repair, including the development of late aortic dilatation, need for reoperation, and overall survival.[3–5] Arguments in favor of extensive index repair focus primarily on the potentially decreased need for late aortic reoperation, operations that are frequently viewed as complex and with much higher risks. Currently, however, data detailing the results of reoperations after acute type A dissection repair are lacking.[6] As such, this study aimed to assess outcomes of reoperation after acute type A dissection repair to provide further evidence around decision making for an index operative strategy.

Methods

This retrospective cohort study included all aortic reoperations (129 procedures, 89 patients) at Duke University Medical Center from August 2005 to April 2016 after prior acute type A dissection repair. The study was approved by the institutional review board of Duke University Medical Center, and the need for individual patient consent was waived. Patient demographics, procedure characteristics, and clinical

From the Division of Cardiovascular and Thoracic Surgery, Department of Surgery, Duke University Medical Center, Durham, NC.

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Correspondence to: G. Chad Hughes, MD, Box 3051 DUMC, Durham, NC. E-mail: gchad.hughes@duke.edu

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Clinical Perspective

What Is New?

- The current study provides new data regarding outcomes for late reoperation after index acute type A dissection repair. These data may help guide decision making around the extent of an index operation, given the current controversy regarding limited versus extensive index repair for this surgical emergency.
- The study demonstrates that the vast majority of reoperations after index acute type A dissection repair are elective (83%), with low rates of mortality (6.3% elective mortality) and major morbidity and excellent long-term aorta-specific survival (88% at 5 years).

What Are the Clinical Implications?

- Because the overwhelming majority of reoperations after acute type A aortic dissection repair are elective, these patients may be routed to referent aortic centers of excellence when necessary, with the current study demonstrating excellent results with this paradigm.
- The results provide support for limited index repair for acute type A dissection, especially for patients undergoing repair in lower volume centers without expertise in extensive repair; this point is especially relevant in the current era in North America, where regionalization of care for acute type A dissection does not exist and most patients undergo repair in low volume centers.

outcomes data were obtained from the prospectively maintained institutional aortic surgery database.

The index type A dissection repair was performed at Duke University Medical Center for 21 patients (23.6%), and the remainder were performed at outside institutions. Index repair procedures included proximal (ascending with or without valve or root) aortic with or without transverse arch and with or without frozen elephant trunk.

Primary indications for reoperation included (1) residual chronic dissection resulting in proximal aortic (aortic root and/or ascending aortic), aortic arch, or distal aortic (descending thoracic or thoracoabdominal) aneurysms; (2) progressive aortic insufficiency; (3) anastomotic pseudoaneurysm; (4) infective endocarditis; and (5) other (valve dehiscence, n=2; left ventricular outflow tract mass, n=1). Reoperation procedures included redo-sternotomy–based proximal repairs (aortic valve/root, proximal aortic or aortic arch) and left thoracotomy or endovascular-based distal repairs (descending thoracic or thoracoabdominal). Procedure selection was based on the extent of aortic pathology and comorbidity profiles. For selected patients with "mega-aorta" with concomitant transverse arch and distal aneurysms, a planned 2-stage procedure was performed with total arch replacement during the first stage and either endovascular completion using the Dacron elephant trunk graft as the proximal landing zone for a second-stage endovascular repair during a single hospital stay[7] or delayed second-stage open thoracoabdominal repair for patients with distal aneurysms not amenable to endovascular second-stage repair. Selected patients who had thoracoabdominal aneurysms and were deemed unfit for conventional open repair also underwent 2-stage procedures with complete visceral debranching followed by endovascular aneurysm exclusion[7,8] during a single hospital stay. Planned 2-stage reoperations were counted as a single reintervention for statistical analysis.

The primary outcome examined was 30-day or in-hospital mortality. Secondary outcomes included organ-specific morbidity, using the Society of Thoracic Surgeons definitions, as well as 1- and 5-year overall survival and freedom from aortic reintervention, as estimated using the Kaplan–Meier method. Aorta-specific mortality was defined as death from any aorta-related cause, including aortic rupture, malperfusion, and anastomotic or endovascular complications. Any 30-day or in-hospital mortality associated with initial or additional reoperations was also included as aorta-specific mortality. Using this definition, aorta-specific survival was estimated using the Kaplan–Meier method. Statistical analyses were conducted using R software, version 3.3.1 (R Foundation for Statistical Computing).

Results

Patient demographics, comorbidities, and index repair procedures are listed in Table 1. The median age was 58 years (interquartile range: 47–65 years), and 74.2% of the cohort was male. Hypertension was present in the majority of patients (93.3%) at baseline, as were cardiovascular comorbidities typical of this patient population. Notably, a significantly high number of patients (21.3%) had a history of prior stroke. Connective tissue disorders (Marfan syndrome, Loeys-Dietz syndrome, and unspecified) were present in 20 patients (22.5%). For index repair, >50% of patients underwent isolated ascending aortic replacement with aortic valve resuspension. Concomitant aortic root or valve replacement was performed in 19 patients (21.3%), and hemiarch replacement was performed in 21 patients (23.6%). Concomitant index total arch replacement or frozen elephant trunk were rare.

The median interval between index type A repair and initial reoperation was 5.0 years (interquartile range: 1.6–27.3 years). The majority of reoperations (83.1%, n=74) were performed in the elective setting. Main indications for reoperation (Table 2) included distal aortic (n=61), aortic arch (n=40), and proximal aortic (n=23) aneurysms, progressive aortic insufficiency (grade 3 or 4, n=24), anastomotic

Table 1. Patient Demographic Information, Comorbidities, and Index Type A Dissection Repair Procedures

Variable	Total (n=89)
Demographic information	
Age, y	58 (47–65)
Male	66 (74.2)
White race	54 (60.7)
Body mass index	26.7 (23.3–31.7)
Comorbidities	
Hypertension	83 (93.3)
Hyperlipidemia	52 (58.4)
Diabetes mellitus	8 (9)
Coronary artery disease	24 (27)
Chronic obstructive pulmonary disease	17 (19.1)
History of stroke*	19 (21.3)
Peripheral vascular disease	5 (5.6)
Connective tissue disorder	20 (22.5)
Marfan syndrome, n	13
Loeys–Dietz syndrome, n	4
Undefined, n	3
Index type A repair procedure	
Isolated ascending aortic replacement	47 (52.8)
Concomitant aortic root or valve replacement	19 (21.3)
Aortic valve replacement (Wheat procedure)	5 (5.6)
Aortic root replacement	14 (15.7)
Concomitant hemiarch replacement	21 (23.6)
Concomitant total arch replacement	2 (2.2)
Concomitant frozen elephant trunk	1 (1.1)

Data are shown as median (interquartile range) or count (percentage).
*History of stroke: In 8 patients, strokes were related to the original dissection event and were diagnosed with computed tomography and/or magnetic resonance imaging at the time of initial type A dissection or postoperatively after index repair; the remaining 11 strokes were unrelated to the prior dissection. Eight patients had residual visual, motor, or memory deficits at the time of reoperation.

Table 2. Procedural Characteristics for Initial Reoperation After Prior Type A Aortic Dissection Repair

Variable	Total (n=89)
Procedure status	
Elective	74 (83.1)
Urgent	13 (14.6)
Emergent	2 (2.2)
Indications*	
Distal (descending, thoracoabdominal) aortic aneurysm	61 (68.5)
Aortic arch aneurysm	40 (44.9)
Proximal aortic (root, ascending) aneurysm	23 (25.8)
Progressive aortic insufficiency	24 (27.0)
Anastomotic pseudoaneurysm	8 (9)
Other†	3 (3.4)
Infection (endocarditis)	2 (2.2)
Proximal repair (redo sternotomy based)	55 (62.5)
Proximal aortic repair (aortic valve, root, ascending)	42 (47.7)
Proximal plus arch repair	32 (36.4)
Hybrid arch repair	12 (13.6)
Distal repair (left thoracotomy or endovascular based)	35 (39.8)
Descending thoracic repair	22 (25)
Open	10
Endovascular‡	12
Thoracoabdominal aneurysm repair	13 (14.8)
Open	10
Hybrid	3
Other§	1 (1.1)

Data are shown as median (interquartile range) or count (percentage).
*Some patients had >1 indication for reoperation (percentages add up to >100%).
†Valve dehiscence (n=2), left ventricular outflow tract mass (papillary fibroelastoma, n=1).
‡Includes 2 hybrid arch repairs.
§Left ventricular outflow tract mass resection.

pseudoaneurysms (n=8), and infective endocarditis of the aortic valve or valved conduit (n=2). The median aneurysm size for those patients undergoing reoperation for an aneurysm indication was 6.2 cm (interquartile range: 5.7–7.1 cm). Most patients presented with a combination of proximal (aortic root or ascending) and arch aneurysms or arch and distal aneurysms; isolated proximal or descending aneurysm was present in 11.2% (n=10) and 27.0% (n=24) of patients, respectively. Reoperation procedures (Table 2) included proximal aortic repair using a redo-sternotomy–based approach (n=55, 62.5%), and distal aortic repair using a left thoracotomy or endovascular-based approach (n=35, 39.8%). Sixteen patients with mega-aorta underwent 2-stage repair including total arch replacement with elephant trunk followed by endovascular completion.

During a median follow-up of 2.5 years after first reoperation, additional nonstaged reoperations (n=24) were required in 21 patients (23.6%) after the initial reoperation (Table 3). Connective tissue disorders were common (42.9%) in this subgroup: 5 patients had Marfan syndrome, 3 had Loeys–Dietz syndrome, and 1 had an undefined connective tissue disorder. Patients with connective tissue disorders were more likely to require additional reoperations than those without (45.0% versus 17.4%, χ^2 test P=0.01) and underwent a total of 51 operations (mean: 2.6 operations per patient) including the index repair. Patients with connective tissue disorders did not tend to have extended repair at their initial acute type A

Table 3. Procedural Characteristics for Additional Reoperations (Nonstaged) After Prior Type A Aortic Dissection Repair

Variable	Total (n=24)
Procedure status	
Elective	20 (83.3)
Urgent	3 (12.5)
Emergent	1 (4.2)
Indications*	
Distal (descending, thoracoabdominal) aortic aneurysm	15 (62.5)
Aortic arch aneurysm	9 (37.5)
Proximal aortic (root, ascending) aneurysm	6 (25)
Anastomotic pseudoaneurym	1 (4.2)
Other†	4 (16.7)
Proximal repair (redo sternotomy based)	8 (33.3)
Proximal aortic repair (aortic valve, root, ascending)	4 (16.7)
Proximal plus arch repair	3 (12.5)
Hybrid arch repair	4 (16.7)
Distal repair (left thoracotomy or endovascular based)	15 (62.5)
Descending thoracic repair	7 (29.2)
Open	0
Endovascular	7 (29.2)
Thoracoabdominal aneurysm repair	8 (33.3)
Open	6 (25)
Hybrid	2 (8.3)
Other‡	1 (4.2)

Data are shown as count (percentage).
*Some patients had >1 indication for reoperation (percentages add up to >100%).
†Endoleak (n=3), stent graft collapse (n=1).
‡Amplatzer plug occlusion ascending aortic pseudoaneurysm.

dissection operation: Only 2 of 20 underwent hemi- or total arch replacement. The majority (81%) of these index repairs in patients with connective tissue disorders were performed at outside institutions. Indications for additional reoperations were distal aortic aneurysm (73.1%), aortic arch aneurysm (50.0%), and proximal aneurysm (26.9%). Additional reoperation procedures (Table 3) included proximal aortic repair (16.7%), hybrid repair (16.7%), descending thoracic repair (29.2%), and thoracoabdominal aortic aneurysm repair (33.3%).

Perioperative outcomes for all procedures (initial and additional reoperations) are presented in Table 4. Thirty-day mortality was 7.0% (proximal repair: 8.5%; distal repair: 6.0%), with a higher mortality rate for nonelective procedures (11.1%) compared with elective procedures (6.3%). Organ-specific morbidity was acceptable, given the complexity of these procedures: Incidence of stroke was 5.4% (proximal repair: 6.4%; distal repair: 4.8%), acute kidney injury (increase in serum creatinine of >100%) was 6.2% (proximal repair: 6.4%; distal repair: 6.0%), prolonged ventilation for >24 hours was 12.4% (proximal repair: 17.0%; distal repair: 9.6%), and reoperation for bleeding was 3.1% (proximal repair: 8.5%; distal repair: 0%). The median length of stay was 6 days (interquartile range: 5–10 days), and most patients (97.7%) were discharged to home. Kaplan–Meier estimates of unadjusted overall survival are shown in Figure 1. Overall survival for the entire cohort at 1 and 5 years after initial reoperation was 85.9% and 64.9%, respectively. The most common causes of late death were secondary to underlying patient comorbidities and included sepsis (20%, secondary to pneumonia or urinary tract infection unrelated to reoperations), congestive heart failure or myocardial infarction (10%), and malignancy (5%). In addition, there were 3 late aorta-specific deaths (15%) in patients who died within 30 days after additional reoperations. Freedom from aortic reintervention after initial reoperation was 86% at 1 year and 60% at 5 years (Figure 2), with aorta-specific survival after initial reoperation of 91% at 1 year and 88% at 5 years (Figure 1).

Table 4. Outcomes for Initial and Additional Reoperations After Prior Type A Aortic Dissection Repair

Outcomes	Total (n=129)	Elective (n=111)	Nonelective (n=18)
30-d or in-hospital mortality	9 (7.0)	7 (6.3)	2 (11.1)
Stroke	7 (5.4)	4 (3.6)	3 (16.7)
Acute kidney injury (increase in serum creatinine of >100%)	8 (6.2)	7 (6.3)	1 (5.6)
New-onset dialysis	2 (1.6)	2 (1.8)	0
Prolonged ventilation (>24 h)	16 (12.4)	11 (9.9)	5 (27.8)
Reoperation for bleeding	4 (3.1)	4 (3.6)	0
Length of stay, d	6 (5–10)	6 (5–9)	9 (7–14)
Discharge to location other than home	3 (2.3)	3 (2.7)	0

Data are shown as median (interquartile range) or count (percentage).

Discussion

The optimal management strategy for acute type A aortic dissection remains controversial. In this study, we examined 129 reoperations (in 89 patients) performed at a single referral aortic center after index repair for acute type A dissection. The results suggest that reoperation after acute

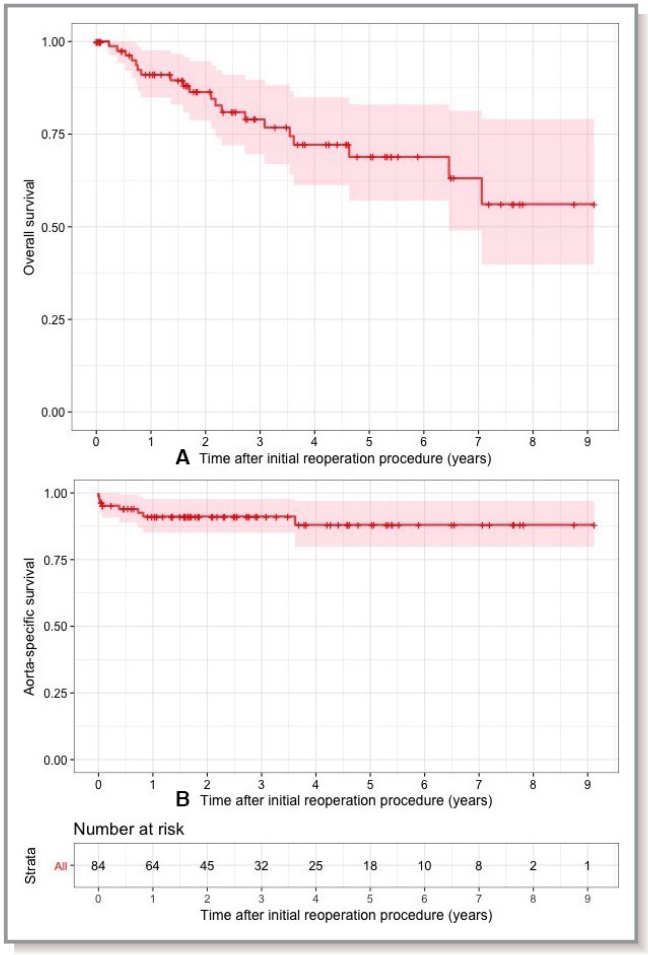

Figure 1. Kaplan–Meier estimates of overall survival (top) and aorta-specific survival (bottom) after initial reoperation following index type A dissection repair.

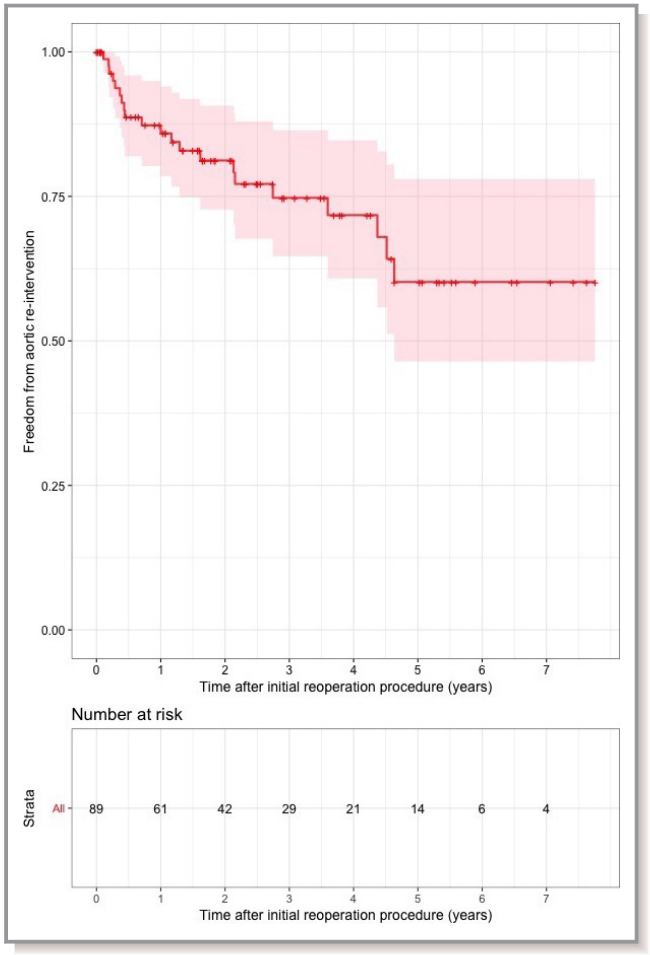

Figure 2. Kaplan–Meier estimates of freedom from aortic intervention after initial reoperation following index type A dissection repair.

type A dissection repair can be performed with low rates of mortality and organ-specific morbidity. Furthermore, the vast majority (83.1%) of reoperations are performed in the elective setting, which allows time for careful case planning and likely accounts for the particularly good outcomes in this cohort. Long-term survival after reoperation was acceptable, especially considering the comorbidity profile of the patient population, including prior stroke in >20%. Aorta-specific survival, which is the goal of reoperation, was excellent.

Few previous studies have examined the safety of reoperation after type A dissection repair. An early study by Estrera et al[9] reported 63 patients (58 elective, 5 emergent) who underwent reoperation after previous type A dissection repair between 1991 and 2006, including ascending aortic replacement (94%), aortic root replacement (27%), total arch replacement (62%), elephant trunk (56%), aortic valve replacement (38%), and coronary artery bypass grafting (8%). Thirty-day mortality was 11%, and incidence of stroke, acute renal failure, respiratory failure, and postoperative bleeding was 0%, 6%, 23%, and 6%, respectively. In a more recent study by Rylski et al[1] of 153 patients who underwent index repair for type A aortic dissection, reoperation was required in 8% of patients at a median follow-up of 1 year. Elective reoperation (hybrid arch repair, total arch replacement, and distal repair) was associated with 0% in-hospital mortality. Outcomes of distal aortic interventions were also examined by Roselli et al[10] in 305 patients who underwent reoperation after index type A dissection repair. The authors reported hospital mortality of 6.1% and overall survival of 84% and 73% at 1 and 5 years, respectively. Our study is among the largest to date to investigate both proximal and distal aortic reoperations following index type A dissection repair, and the results provide further evidence that reoperation after type A dissection repair can be performed safely in a mainly elective setting with low risk of mortality or major morbidity and excellent late aorta-specific survival.

Existing studies comparing extensive and limited index repair for acute type A dissection have yielded conflicting results and recommendations, likely due to heterogeneous patient populations and diverse clinical profiles. Some studies

have shown comparable mortality rates between limited and extensive index repair,[4,5,11,12] whereas others have reported higher operative risk associated with extensive repair.[1,13] Specifically, the reported 30-day or in-hospital mortality of extensive repair ranges widely from 4.7% to 29%.[5,11,12,14–16] In general, studies reporting lower mortality rates had younger patients (mean ages of 45, 46, and 54 years for the lowest mortality rates of 4.7%, 5.7%, and 5.9%, respectively[4,12,14]), a known strong independent predictor of mortality.[5] Most studies[1,4,11–13,16] also had small numbers of patients who underwent extensive repair (range: 14–140), limiting the statistical power and generalizability of the results. A recent meta-analysis[17] examining 9 studies for a total of 1872 patients (in Germany, China, Korea, and Japan) showed that limited index repair is associated with lower early mortality (risk ratio: 0.69; 95% confidence interval, 0.54–0.90) compared with extensive repair, whereas long-term mortality was similar between the 2 approaches (hazard ratio: 1.02; 95% confidence interval, 0.51–2.06). In our study, the mortality rate of elective reoperation (6.3%) was lower than that of index extensive repair in most series (20–29%) with similar patient age and comorbidity profiles,[5,11,16] thus justifying the approach of limited index repair followed by reoperation if needed. This latter point is especially relevant in the current era in North America, where regionalization of care for acute type A dissection does not exist.[18] Considering that most patients undergo repair in low-volume centers,[19] lower risk, limited index operations would appear most appropriate. Because the overwhelming majority of reoperations are elective, however, these patients may subsequently be referred to aortic centers of excellence if necessary, with the current study demonstrating excellent results with this paradigm.

In the current study, 23.6% of patients required at least 1 additional reoperation after the initial reoperation. Connective tissue disease, a known risk factor for reintervention,[6] was common (42.9%) in these patients. Mortality and morbidity were low in this group, likely because patients with connective tissue disease tend to be younger with few comorbidities. This result is consistent with previous series in which patients with connective tissue disease had low mortality and morbidity following multiple reinterventions.[20,21] In the series of patients with Loeys-Dietz syndrome reported by Williams et al,[20] those who experienced acute type A dissection underwent multiple surgical interventions with a mean of 3.4 operations performed. Despite these multiple operations, there were no aortic-specific deaths in the cohort. Similar results were seen in a large series of patients undergoing thoracoabdominal aortic aneurysm repair in which mortality and adverse outcomes were significantly lower in patients with the Marfan syndrome as opposed to the remaining cohort with degenerative aortic disease.[21]

The current study has several limitations. First, the study was limited by the potential bias of a single-center, retrospective analysis. In addition, the study examined only patients needing reoperation after index repair of type A dissection, and thus the results cannot be used to implicate the rate of aortic reoperation or dilatation secondary to patent false lumen after index repair. The aim of this study was not to directly compare extensive versus limited repair as initial management strategies for type A dissection but rather to provide evidence of the safety of late reoperation to help guide decision making for an index operative strategy, especially for patients undergoing index repair in lower volume centers without expertise in extensive repair.

In conclusion, reoperation after acute type A dissection repair can be performed safely, usually in the elective setting, and with low mortality and morbidity. The results of this study provide support for limited index repair for acute type A dissection, especially for patients undergoing index repair in lower volume centers without expertise in extensive repair.

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Disclosures

None.[1,4,11–13,16]

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