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Outcomes of patients with acute type A aortic dissection and concomitant lower extremity malperfusion

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From the Midwestern Vascular Surgical Society

Outcomes of patients with acute type A aortic dissection and concomitant lower extremity malperfusion

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ABSTRACT

Objective: The occurrence of acute lower limb ischemia (ALLI) is a serious risk within the context of aortic dissection repair. The aim of the present study was to examine the outcomes of patients with acute type A aortic dissection (ATAD) and concomitant lower extremity malperfusion.

Methods: We performed a retrospective medical record review at our tertiary referral center of patients who underwent ATAD repair from January 2002 to June 2018. We used univariate and multivariate analyses to compare the outcomes of patients with and without lower extremity malperfusion. The primary outcomes were 30-day and 1-year mortality.

Results: A total of 378 patients underwent ATAD repair during the study period. Their mean age was 57 years, 68% were men, and 51% were White. A total of 62 patients (16%) presented with concomitant ALLI, including 35 (9%) who presented with isolated ALLI and 27 (7%) who presented with ALLI and concomitant malperfusion of at least one other organ. Of the 62 patients with ALLI, 46 underwent only proximal aortic repair. Of the 378 patients, 6 died within the first 24 hours, and their limb perfusion was not assessed. Among the 40 patients who underwent isolated proximal repair and survived >24 hours, 34 (85%) had resolution of their ALLI. Of the 16 patients who underwent concomitant lower extremity peripheral vascular procedures, 10 had bypass procedures and 1 died within 24 hours due to refractory coagulopathy and hypotension. All six patients with adequate follow-up imaging studies had asymptomatic occlusion of the bypass graft with recanalization of the occluded native arteries. Patients who presented with any organ malperfusion had increased 30-day (odds ratio, 1.8; $P = .04$) and 1-year (odds ratio, 1.8; $P = .04$) mortality and decreased overall survival ($P < .01$). For the patients with isolated ALLI, no significant differences were found in 30-day or 1-year mortality or overall survival ($P = .57$).

Conclusions: Proximal repair of ATAD resolves most cases of associated ALLI, and isolated ALLI does not affect short- or long-term survival. All patients with follow-up in our study who underwent extra-anatomic bypass developed asymptomatic graft occlusion, which could be attributed to competitive flow from the remodeled native arterial system. We believe that rapid and aggressive restoration of flow to the lower extremity is the best method to treat ALLI malperfusion syndrome. Close monitoring for the development of compartment syndrome is recommended. (J Vasc Surg 2022;■:1-8.)

Keywords: Acute limb ischemia; Acute type A aortic dissection; ATAD; Malperfusion syndromes

Acute Stanford type A aortic dissection (ATAD) is a highly morbid cardiovascular condition with an incidence of 2.9/100,000 person-years and a reported untreated in-hospital and 1-year mortality of 58% and 90%, respectively.[1-3] The current treatment for ATAD is open surgical repair, with operative mortality ranging from 15% to 30%.[4-7] End-organ malperfusion due to distal extension of the dissection flap causing passive or dynamic obstruction will occur in up to 40% of patients with ATAD.[1,4,8,9] The presence of malperfusion syndrome is a recognized risk factor leading to poor postoperative outcomes.[7,10-12] Although some surgeons have advocated intervention for peripheral vascular ischemia before proximal aortic repair, most surgeons have advocated for proximal repair first, followed by treatment of persistent peripheral malperfusion.[11-14] Lower extremity (LE) malperfusion has been reported to occur in up to 26% of ATAD presentations.[15] However, a relative paucity of studies have exclusively examined the outcomes of patients with ATAD and concomitant LE malperfusion. The aim of the present study was to investigate the

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outcomes of patients who had LE malperfusion after undergoing ATAD repair.

METHODS

Patients. Registry database medical records for all patients who underwent ATAD repair at our tertiary referral center between January 2002 and December 2018 were retrospectively queried. ATAD was defined as a dissection involving the ascending aorta and was considered acute if the interval between symptom onset and admission was <14 days. Patients with type B aortic dissection and chronic type A aortic dissection (interval from presentation >14 days) were excluded. The diagnosis of ATAD was confirmed by contrast-enhanced computed tomography scanning and/or preoperative or intraoperative echocardiography. Both techniques have a reported sensitivity and specificity as high as 97% to 100% for the diagnosis of ATAD.[16] Immediate proximal aortic repair was the standard treatment procedure for all patients who had presented with ATAD.

Variables collected. The demographic variables identified included sex, age, race/ethnicity (African American, White, and other), body mass index, and smoking. Medical history data included hypertension, chronic obstructive pulmonary disease, hyperlipidemia, atrial fibrillation, type 2 diabetes, peripheral artery disease, end-stage renal disease, and connective tissue disorder (Marfan, Turner, and Ehlers-Danlos syndromes). Perioperative variables included the presence of cardiogenic shock, cardiac tamponade, type of aortic repair, and the presence and vascular territory of malperfusion. Postoperative variables included neurologic deficits (stroke and paraplegia), respiratory complications (pneumonia, acute respiratory distress syndrome, ventilator-dependent respiratory failure), renal failure (defined as either serum creatinine of ≥4.0 mg/dL with an increase of ≥0.5 md/dL or a new requirement for dialysis postoperatively), and reoperation during the same hospitalization. All patients with ATAD were taken urgently to the operating room if they were deemed operative candidates. Malperfusion syndromes at presentation, including brain, spinal cord, bowel, renal, cardiac, and LE, were documented through a medical record review of the admission history and physical examination findings. Vascular surgery was consulted for any ATAD patient with acute lower limb ischemia (ALLI) on presentation. Notes from the initial vascular evaluation were reviewed for the degree of LE malperfusion, and the operative notes were reviewed for the type of vascular intervention performed. Physical examination findings and Doppler signals were used to diagnose ALLI.

End points. The primary endpoints were 30-day and 1-year mortality. Secondary endpoints included 24-hour mortality, length of stay, limb salvage, need for fasciotomy, reoperation, and neurologic, pulmonary, and renal complications.

ARTICLE HIGHLIGHTS

- **Type of Research:** A retrospective cohort study
- **Key Findings:** A total of 378 patients with acute type A aortic dissection underwent aortic repair. Of the 378 patients, 16% presented with acute lower limb ischemia (ALLI) and 9% presented with isolated limb malperfusion. Patients with any organ malperfusion had an increased 30-day and 1-year mortality but those with isolated ALLI did not.
- **Take Home Message:** Mortality after repair of acute type A aortic dissection was not associated with ALLI but was associated with any organ malperfusion.

Statistical analysis. The patients were divided into two groups: those with and those without LE malperfusion at presentation. Continuous variables are presented as the mean ± standard deviation and categorical variables as frequencies and percentages. For continuous variables, univariate two-group comparisons were performed using independent two-sample *t* tests or Wilcoxon rank sum tests, as appropriate. For categorical variables, univariate two-group comparisons were performed using χ^2 tests or Fisher's exact tests, as appropriate. Multivariate regression models were used to examine the association between the presence or absence of LE malperfusion and both primary and secondary outcomes. Any variable with $P < .1$ or thought to be related to the outcome of interest was included in the multivariate analyses. Kaplan-Meier curves were used for survival analysis. $P < .05$ was considered statistically significant. All analyses were performed using SAS, version 9.4 (SAS Institute Inc, Cary, NC).

Our institutional review board approved the present study, which was conducted in accordance with the Health Insurance Portability and Accountability Act and the prevailing ethical principles governing research. The requirement for patient informed consent was waived.

RESULTS

Study cohort characteristics

From 2002 to 2018, 378 patients underwent ATAD repair at our tertiary referral center. The baseline characteristics for the cohort are summarized in Table I. The mean ± standard deviation age was 57 ± 13 years (range, 22-88 years), 258 patients (68%) were men, and 199 (54%) were White. Most of the patients underwent hemiarch replacement (57%; n = 214), followed by ascending aortic replacement (23%; n = 85), and arch replacement (18%; n = 66) procedures. Of the 378 patients, 300 (80%) had a history of hypertension, 66 (18%) had a history of

Table I. Descriptive analysis of baseline characteristics, comorbidities, and perioperative and postoperative variables (n = 378)

Variable	Value
Baseline characteristics	
Age, years	56.9 ± 13.3
Race	
White	199 (54.1)
African American	151 (41.0)
Other	18 (4.9)
Male sex	258 (68.3)
BMI, kg/m^2	29.7 ± 6.5
Smoking	
None	168 (44.9)
Prior	72 (19.3)
Current	134 (35.8)
Comorbidities	
End-stage renal disease	16 (5.0)
Hypertension	300 (79.8)
COPD	51 (13.8)
Peripheral artery disease	34 (9.0)
Cerebrovascular disease	27 (7.2)
Prior cerebrovascular accident	19 (9.5)
Prior myocardial infarction	34 (11.3)
Hyperlipidemia	66 (17.5)
Atrial fibrillation	16 (4.4)
Type 2 diabetes	32 (8.5)
Connective tissue disorder	4 (1.1)
Perioperative variables	
Creatinine, mg/dL	1.6 ± 1.8
Transferred	267 (70.6)
Cardiogenic shock	58 (15.5)
Cardiac tamponade	61 (16.6)
Type of repair	
Ascending aorta	85 (22.7)
Hemiarch	214 (57.2)
Arch (partial or full)	66 (17.6)
Traditional elephant trunk	4 (1.1)
Frozen elephant trunk	5 (1.3)
Aortic valve morphology	
Tricuspid	351 (93.9)
Replacement tissue	1 (0.3)
Mechanical	11 (2.9)
Bicuspid	11 (2.9)
Postoperative outcomes	
Stroke	70 (22.5)
Paraplegia	9 (3.1)
Hemodialysis requirement	41 (13.9)
In-hospital reoperation	
Total	57 (27.3)
Mediastinal exploration	24 (42.1)
Sternal closure	13 (22.8)
Other	20 (35.1)
Renal failure	59 (19.8)
Pulmonary complications	89 (43.4)
Length of stay, days	16.1 ± 13.5
30-day mortality	73 (19.3)
1-year mortality	99 (32.0)

BMI, Body mass index; *COPD*, chronic obstructive pulmonary disease. Data presented as number (%) for categorical variables and mean ± standard deviation for continuous variables.

hyperlipidemia, 32 (9%) had type 2 diabetes, and 34 (9%) had peripheral artery disease. In addition, 267 patients (71%) were transferred from an outside hospital, and 124 (33%) had at least one organ system with malperfusion. Concomitant ALLI was observed in 62 patients (16%). For the patients with concomitant ALLI, the average age was 56 ± 12 years (range, 32-82 years). A total of 35 patients (9%) presented with isolated ALLI, and 27 patients (7%) had ALLI with concomitant malperfusion of at least one other organ system.

Of the 62 patients who presented with ALLI, 46 underwent proximal aortic repair only and 16 underwent a concomitant LE vascular intervention (Fig 1). Six amputations (9.7%) were required in this ALLI group, with two unsuccessful revascularization procedures. Fasciotomies were performed in 18 patients. Of these patients, five required peripheral vascular procedures. Of the ALLI group, 10 (16%) underwent fasciotomy for documented compartment syndrome.

Among the 46 patients who underwent isolated proximal repair, 6 died within the first 24 hours postoperatively, and their LE perfusion was not assessed. Of the 40 patients who survived past 24 hours, 34 (85%) experienced resolution of their ALLI. The remaining six patients had irreversible LE ischemia, four of whom died. One patient required an above-the-knee amputation and one a below-the-knee amputation.

Among the 16 patients who underwent a concomitant LE vascular procedure, 10 had LE bypass procedures for their limb ischemia (seven femorofemoral; one axillary-femorofemoral; two axillofemoral procedures), with 1 patient dying within 24 hours due to refractory coagulopathy and hypotension. The other six patients underwent endovascular or open interventions: three with stenting and aortic fenestration, one with thrombectomy, one with an interposition graft, and one with endarterectomy. Six patients underwent extra-anatomic bypass and had adequate follow-up imaging studies available, with an average follow-time of 64 months (range, 8-134 months). All six patients demonstrated

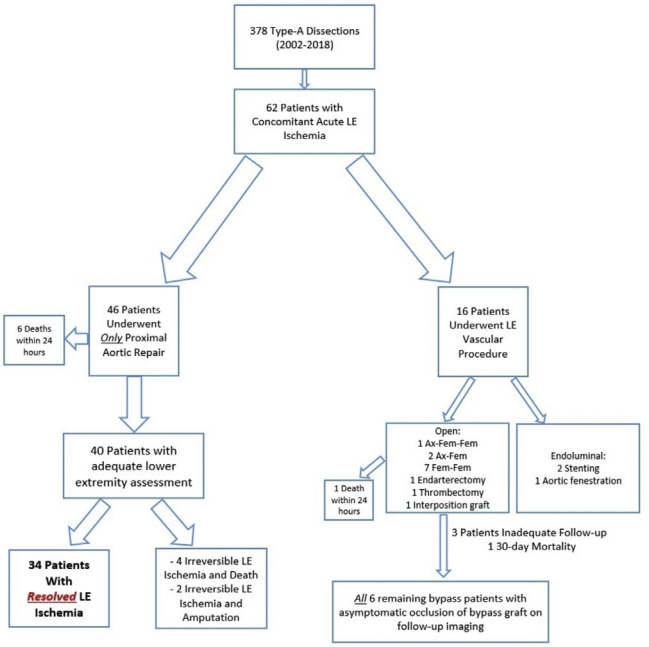

Fig 1. Diagram of patient outcomes. *Ax-Fem,* Axillofemoral; *Ax-Fem-Fem,* axillary-femorofemoral; *Fem-Fem,* femorofemoral; *LE,* lower extremity.

asymptomatic occlusion of their bypass grafts with remodeling of the dissected aortoiliac segments and restoration of axial patency (Fig 2).

Comparisons

Patients with any malperfusion. The 124 patients with preoperative malperfusion of any organ system had a significantly greater prevalence of peripheral artery disease and cardiogenic shock at presentation than those who did not (14% vs 7% [$P = .03$] and 27% vs 10% [$P < .01$], respectively; Supplementary Table I, online only). Patients without malperfusion were more likely to be current smokers and to have a history of atrial fibrillation (24% vs 11% [$P = .01$] and 6% vs 1% [$P = .02$], respectively). On univariate analysis, patients with malperfusion of any organ had a greater need for postoperative hemodialysis (20% vs 11%; $P = .04$), were more likely to have renal failure (30% vs 15%; $P < .01$), were more likely to have pulmonary complications (37% vs 55%, $P = .02$); and to have higher 30-day and 1-year mortality rates (27% vs 16% [$P = .01$] and 41% vs 28% [$P = .02$], respectively). After adjusting for other variables, malperfusion was associated with postoperative renal failure (odds ratio [OR], 2.9; 95% confidence interval [CI], 1.6-5.5; $P < .01$) and increased 30-day (OR, 1.8; 95% CI, 1.1-3.3; $P = .04$) and 1-year (OR, 1.8; 95% CI, 1.1-3.0; $P = .04$) mortality (Supplementary Table II, online only). Using Kaplan-Meier survival curves, overall survival was significantly decreased in the malperfusion group ($P < .01$; Fig 3).

Patients with isolated LE malperfusion. A total of 35 patients with isolated LE malperfusion had a significantly greater proportion of a history of peripheral artery disease than those without malperfusion (23% vs 8%; $P < .01$; Table II). No significant differences were found between patients who had isolated LE malperfusion and those who did not for length of stay, renal or neurologic outcomes, and 30-day and 1-year mortality (Table II). No differences were found in survival between patients with isolated LE ischemia and patients without malperfusion syndrome ($P = .57$; Fig 4).

DISCUSSION

ATAD continues to be one of the most challenging and highly morbid diseases facing cardiovascular surgeons. Along with other preoperative risk factors, the presence of malperfusion syndromes can significantly complicate the treatment of patients with ATAD and can lead to adverse outcomes. In our study, patients who presented with ATAD and concurrent isolated LE malperfusion did not have increased mortality compared with those without malperfusion. The prevalence of end-organ malperfusion after ATAD was 33% in our study, which is in accordance with other studies reporting end-organ malperfusion rates of 26% to 40% in these patients.[1,4,8,9]

The presence of malperfusion syndromes has been frequently associated with poor outcomes. This has been hypothesized to be a byproduct of a deleterious inflammatory cascade resulting from end-organ ischemia–reperfusion.[12] In a study by Mehta et al,[7] the incidence of in-hospital complications, including malperfusion of the central nervous system, heart, liver or gut, kidneys, and limbs, was significantly greater for the patients who died. These findings were mirrored in a 25-year study by Santini et al,[10] in which the predictors of in-hospital death for patients presenting with ATAD were studied. They found that myocardial ischemia, bowel ischemia, kidney failure, and neurologic deficits were independent predictors of in-hospital death.[10] In our study, multivariate analysis revealed that malperfusion was associated with increased 30-day and 1-year mortality and postoperative renal failure. When considering overall survival, patients with any malperfusion syndrome had a significant survival disadvantage. These findings have obvious therapeutic implications, with early and aggressive surgical correction of the dissection playing an important role in preventing such complications. For patients with malperfusion, reestablishing blood flow to the affected organs using endoluminal techniques such as stenting and/or fenestration could prove critical in restoring vital organ perfusion and subsequently lowering postoperative morbidity and mortality.

In our study, LE malperfusion occurred in 16% of the patients presenting with ATAD. Approximately one half of these patients had concomitant malperfusion of other organ systems. When considering the outcomes of

Fig 2. a, Computed tomography angiogram illustrating left common iliac artery occlusion. Follow-up computed tomography scan showing iliac recanalization **(b)** and occlusion of femorofemoral bypass graft **(c)**.

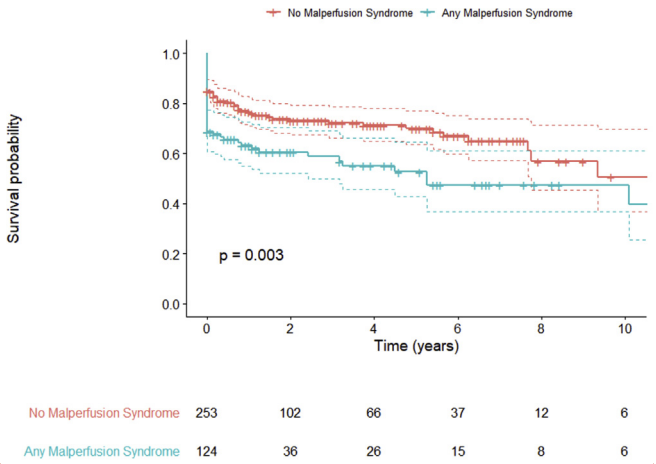

Fig 3. Survival analysis of patients with any malperfusion syndrome vs those without malperfusion.

patients with isolated LE malperfusion, no significant differences were found in the incidence of postoperative renal dysfunction, neurologic outcomes, length of stay, and 30-day or 1-year mortality. In addition, no significant difference in long-term survival was seen between patients with ATAD and no malperfusion syndrome and those with isolated LE ischemia. Some studies have shown increased mortality in patients with LE malperfusion.[13,17,18] However, these studies did not examine LE malperfusion in isolation and were restricted to univariate analyses. In our study, patients with LE malperfusion were significantly more likely to experience other malperfusion syndromes, reinforcing the need to analyze isolated LE malperfusion when studying the outcomes related to ALLI in patients with ATAD. It would appear that malperfusion of other organ systems increases the risk of postoperative complications for patients presenting with LE and other organ system malperfusion. In addition, compartment syndrome is a common and feared complication of ALLI that can lead to devastating consequences.[19,20] In our cohort, 16% of the ALLI patients had documented compartment syndrome requiring fasciotomy, necessitating close monitoring for the development of this complication.

Controversy still exists concerning the timing of aortic repair vs initial malperfusion-directed interventions. Some groups have advocated delaying surgical repair for patients with malperfusion syndromes.[12] However, mortality has been shown to be higher for patients with ATAD who had undergone delayed definitive aortic repair.[12] Other more selective studies have shown that visceral revascularization before definitive aortic repair can improve outcomes.[14,21] Despite the theoretical benefits of delaying ATAD repair to correct malperfusion, the risk of aortic rupture can be as high as 17% for patients with delayed operative treatment.[13] In our study, most patients with LE ischemia experienced resolution of their ischemia with proximal ATAD repair, which is in accordance with findings from other studies.[12,21-23]

We have advocated for femoral perfusion of the ischemic leg in patients with ALLI and ATAD.[24] Axillary cannulation has become the standard of care for ATAD since it offers cerebral perfusion during circulatory arrest. Because isolated femoral cannulation has been attributed to higher rate of strokes in patients with ATAD,[25] concomitant axillary and femoral cannulation might be beneficial.[24] This might decrease the lower extremity ischemia time and the associated inflammatory cascade, subsequently reducing the risk of limb loss and the development of compartment syndrome. In our study, 10 patients underwent axillary and femoral cannulation, none of whom required an amputation.

In our study, all six patients who underwent extra-anatomic bypasses for ALLI with follow-up computed tomography angiography showed eventual recanalization of the occluded vessel with thromboses of the bypass graft. The latter can be attributed to the competitive flow from the remodeled native arterial system.

Our series spanned several years when endovascular treatment was not widely accepted as the standard of care for lower extremity ischemia in the setting of

Table II. Baseline characteristics, comorbidities, perioperative variables, and postoperative outcomes stratified by isolated lower extremity (LE) malperfusion

Variable	Isolated LE malperfusion		*P* value
	No (n = 254)	Yes (n = 35)	
Baseline characteristics			
Age, years	57 ± 14	56 ± 11	.52
Race			.67
White	137 (55.5)	17 (50.0)	
African American	98 (39.7)	16 (47.1)	
Other	12 (4.9)	1 (2.9)	
Female sex	78 (30.7)	14 (40.0)	.27
BMI, kg/m^2	29.6 ± 6.5	28.7 ± 6.9	.44
Smoking			.31
None	106 (42.2)	14 (40.0)	
Prior	59 (23.5)	5 (14.3)	
Current	86 (34.3)	16 (45.7)	
Comorbidities			
Preoperative dialysis	12 (5.5)	1 (3.4)	.64
Hypertension	199 (79.0)	28 (80.0)	.89
COPD	35 (14.2)	5 (14.3)	.98
Peripheral artery disease	17 (6.7)	8 (22.9)	.002
Cerebrovascular disease	21 (8.3)	1 (2.9)	.25
Previous cerebrovascular accident	14 (10.7)	1 (5.9)	.54
Previous myocardial infarction	23 (11.3)	2 (7.4)	.54
Hyperlipidemia	48 (18.9)	4 (11.4)	.28
Atrial fibrillation	15 (6.1)	0 (0.0)	.14
Type 2 diabetes	22 (8.7)	0 (0.0)	.07
Connective tissue disorder	3 (1.2)	0 (0.0)	1.0
AV morphology			.97
Bicuspid	10 (4.0)	1 (2.9)	
Mechanical	7 (2.8)	1 (2.9)	
Tricuspid	235 (93.2)	33 (94.2)	
Perioperative variables			
Creatinine on admission, mg/dL	1.6 ± 1.9	1.5 ± 0.6	.64
Transferred	179 (70.5)	27 (77.1)	.41
Shock	25 (10.0)	5 (14.3)	.43
Tamponade	38 (15.2)	1 (3.1)	.06
Postoperative outcomes			
Length of stay, days	16 ± 13	20 ± 14	.09
Stroke	46 (22.1)	5 (14.3)	.29
Paraplegia	0 (0.0)	2 (5.9)	.50
Perioperative hemodialysis	21 (10.8)	5 (14.7)	.51
Renal failure	29 (14.6)	8 (25.0)	.14
In-hospital reoperation	36 (25.9)	8 (30.8)	.61
Pulmonary complications	51 (37.5)	14 (53.8)	.12
24-hour mortality	10 (3.9)	2 (5.7)	.62
30-day mortality	40 (15.7)	4 (11.4)	.51
1-year mortality	56 (27.6)	5 (18.5)	.32

AV, Aortic valve; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease.
Data presented as number (%) for categorical variables and mean ± standard deviation for continuous variables.

ATAD. In our present practice, we treat profound lower extremity ischemia at the beginning of the procedure with perfusion of the ischemic limb through a side branch off the pump.[24] Persistent ischemia after completion of the proximal repair should prompt further investigation. At present, endoluminal revascularization should be preferred over extra-anatomic bypass when feasible.

Study limitations. The present study had several limitations. The retrospective method allows for determination of an association and not causation. An inherent selection bias existed because our institution is a referral center. Generalizability was limited because our study was not population based. The multivariate analysis accounted only for identified variables; however, several unmeasured risk factors could have also contributed to confounding. We did not have adequate data to determine whether the timing of repair or delay were predictors of worse outcomes. Only a few patients underwent frozen elephant trunk repair, because it was not the standard of care at our center during most of the study period, limiting our ability to determine its effectiveness in the management of LE malperfusion. Because of the urgent nature of ATAD, ALLI was diagnosed using clinical findings, often without noninvasive vascular laboratory confirmation. In addition, most of our patients were transferred from outside hospitals, and cross-sectional imaging studies were not repeated owing to concerns of excessive radioactive contrast exposure. None of our patients were treated initially by revascularization followed by definitive aortic repair, limiting our ability to draw conclusions regarding the effectiveness of this approach.

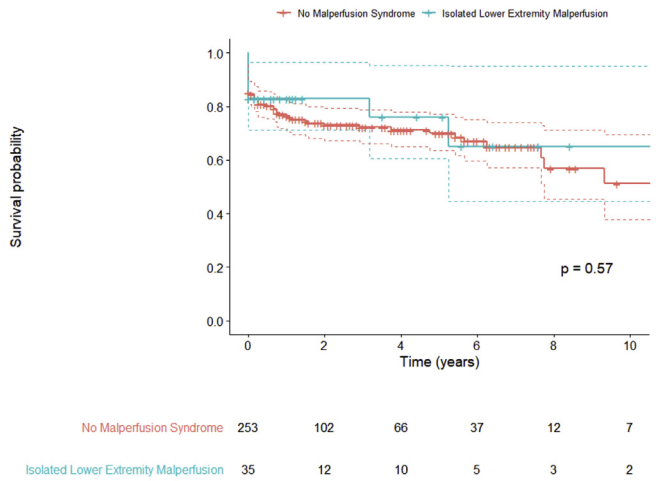

Fig 4. Survival analysis of patients with isolated lower extremity (LE) malperfusion vs those without malperfusion syndromes.

CONCLUSIONS

In our study, 16% of the patients with ATAD presented with concomitant acute lower limb ischemia. Proximal repair of the ATAD resolved most of the associated acute LE ischemia. Malperfusion syndromes were associated with increased postoperative and long-term mortality and renal failure. However, isolated acute LE ischemia did not affect short- or long-term mortality or other postoperative complications. We believe that rapid and aggressive restoration of flow is the best method to treat acute LE ischemia malperfusion syndrome. Close monitoring for the development of compartment syndrome is recommended. Concomitant perfusion of the ischemic LE off the cardiopulmonary bypass circuit might be beneficial for these patients.

AUTHOR CONTRIBUTIONS

Conception and design: AN, AR, AS, MW, TN, HN, DT, LK
Analysis and interpretation: AN, AR, AS, LK
Data collection: AR
Writing the article: AN, AR
Critical revision of the article: AN, AR, AS, MW, TN, HN, DT, LK
Final approval of the article: AN, AR, AS, MW, TN, HN, DT, LK
Statistical analysis: AN
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Overall responsibility: LK

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Supplementary Table I (online only). Baseline characteristics, comorbidities, perioperative variables, and postoperative outcomes stratified by any malperfusion

Variable	Malperfusion None (n = 254)	Malperfusion Any (n = 124)	*P* value
Baseline characteristics			
Age, years	57 ± 14	56 ± 12	.59
Race			.74
White	137 (55.5)	62 (51.2)	
African American	98 (39.7)	53 (43.8)	
Other	12 (4.9)	6 (5.0)	
Female sex	78 (30.7)	42 (33.9)	.54
BMI, kg/m^2	29.6 ± 6.5	29.7 (6.7)	.98
Smoking			.01
None	106 (42.2)	62 (50.4)	
Prior	86 (34.3)	48 (39.0)	
Current	59 (23.5)	13 (10.6)	
Comorbidities			
Preoperative dialysis	12 (5.5)	4 (3.8)	.52
Hypertension	199 (79.0)	101 (81.5)	.57
COPD	35 (14.2)	16 (13.0)	.76
Peripheral artery disease	17 (6.7)	17 (13.7)	.03
Cerebrovascular disease	21 (8.3)	6 (4.8)	.22
Previous cerebrovascular accident	14 (10.7)	5 (7.1)	.41
Previous myocardial infarction	23 (11.3)	11 (11.3)	.99
Hyperlipidemia	48 (18.9)	18 (14.5)	.29
Atrial fibrillation	15 (6.1)	1 (0.9)	.02
Type 2 diabetes	22 (8.7)	10 (8.1)	.84
Connective tissue disorder	3 (1.2)	1 (0.8)	.74
AV morphology			.32
Bicuspid	10 (4.0)	1 (1.0)	
Mechanical	7 (3.0)	4 (3.0)	
Tricuspid	235 (93.0)	117 (96.0)	
Perioperative variables			
Creatinine on admission, mg/dL	1.6 ± 1.9	1.7 ± 1.6	.64
Transferred	179 (70.5)	88 (71.0)	.92
Shock	25 (10.0)	33 (26.8)	<.001
Tamponade	38 (15.2)	23 (19.7)	.28
Postoperative outcomes			
Length of stay, days	16 ± 13	17 ± 14	.36
Stroke	46 (22.2)	24 (23.1)	.86
Paraplegia	0 (0.0)	9 (9.3)	<.001
Perioperative hemodialysis	21 (10.8)	20 (19.6)	.04
Renal failure	29 (14.6)	30 (30.0)	.002
In-hospital reoperation	36 (25.9)	21 (30.0)	.53
Pulmonary complications	51 (37.5)	38 (55.1)	.02
24-Hour mortality	10 (3.9)	13 (10.5)	.01
30-Day mortality	40 (15.7)	33 (26.6)	.01
1-Year mortality	56 (27.6)	43 (40.6)	.02

AV, Aortic valve; *BMI,* body mass index; *COPD,* chronic obstructive pulmonary disease.
Data presented as number (%) for categorical variables and mean ± standard deviation for continuous variables.

Supplementary Table II (online only). Multivariate analysis of patients with any malperfusion

Any malperfusion	OR (95% CI)	*P* value
Postoperative renal failure	2.9 (1.6-5.5)	<.01
30-Day mortality	1.8 (1.1-3.3)	.04
1-Year mortality	1.8 (1.1-3.0)	.04

CI, Confidence interval; *OR,* odds ratio.