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Article

Prevalence, Clinical Features and Outcomes of Patients with Acute Aortic Dissection and Concomitant Lower Extremity Malperfusion

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Abstract

Objective: The aim of this study was to describe the prevalence and clinical characteristics of patients presenting with lower limb malperfusion (LLM) following an aortic dissection, and the outcomes of the patients repair of the dissection as the initial operative procedure. **Method**: We performed a retrospective medical record review at our single center of patients who presented with an aortic dissection complicated by LLM from January 2019 to June 2023, and analyzed the incidence, clinical characteristics, prognosis and reintervention of these patients. **Result**: The incidence of patients with an aortic dissection complicated by LLM was 6.3% (39/617) with mortality rate of 23% (9/39). LLM cases were associated with malperfusion of other organs in 77% (30/39) of patients. All surgical patients underwent initial aortic central repair, with a mortality rate of 26% (8/30). Mortality rates were 31.8% (7/22) for type A dissections and 12.5% (1/8) for type B dissections. Immediate femoral-femoral bypass grafting was performed in 10% (3/30) of cases following aortic central repair, with the majority of patients experiencing significant improvement in LLM with aortic central repair alone. The postoperative readmission rate due to LLM was 6.7% (2/30). **Conclusion**: Aortic dissection with lower limb malperfusion (LLM) is associated with increased pre- and postoperative mortality, especially in Type A aortic dissections versus Type B. However, for survivors of initial central aortic repair surgery, the rates of amputation and readmission for LLM are low.

Keywords

acute aortic dissection; lower extremity malperfusion; prevalence; clinical features and outcomes

Introduction

Aortic dissection is a life-threatening disease, mainly due to the high risk of death caused by aortic rupture, pericardial tamponade, and malperfusion resulting in organ failure. Malperfusion syndromes in acute aortic dissection (AAD) continue to be a predictor of early mortality and has been associated with worse survival. Specifically, lower limb malperfusion (LLM) due to aortic dissection occurs in 4–23% of patients with acute aortic dissection, which may result in permanent limb dysfunction or amputation if the diagnosis and treatment are delayed [1,2].

The primary goal of treatment is to restore perfusion of the lower limbs as soon as possible. Recent studies have suggested that a paradigm shift toward initial reperfusion followed by central aortic repair may be necessary in patients with AAD complicated by LLM, while others believe conventional emergent central aortic repair in AAD with LLM is still the gold-standard and treatment of choice [3–5]. Unfortunately, the optimal treatment strategy to treat LLM caused by aortic dissection is unknown.

The aim of this study was to describe the prevalence and clinical characteristics of patients presenting with LLM due to an aortic dissection, and outcomes patients undergoing repair of the aortic dissection as the initial intervention.

Method

A retrospective review of medical records for patients presenting with aortic dissection complicated by LLM at a single center from 2019 to 2023 was performed. The datasets used in this study are available from the corresponding author upon reasonable request. Statistical analysis was conducted using SPSS 26 (IBM Corp., Armonk, NY, USA). For normally distributed data with homogenous variances, paired sample *t*-tests were used for within-group comparisons, and independent sample *t*-tests were used for between-group comparisons. For non-normally distributed data, the Mann-Whitney U test was used for between-group comparisons, and the Wilcoxon signed-rank

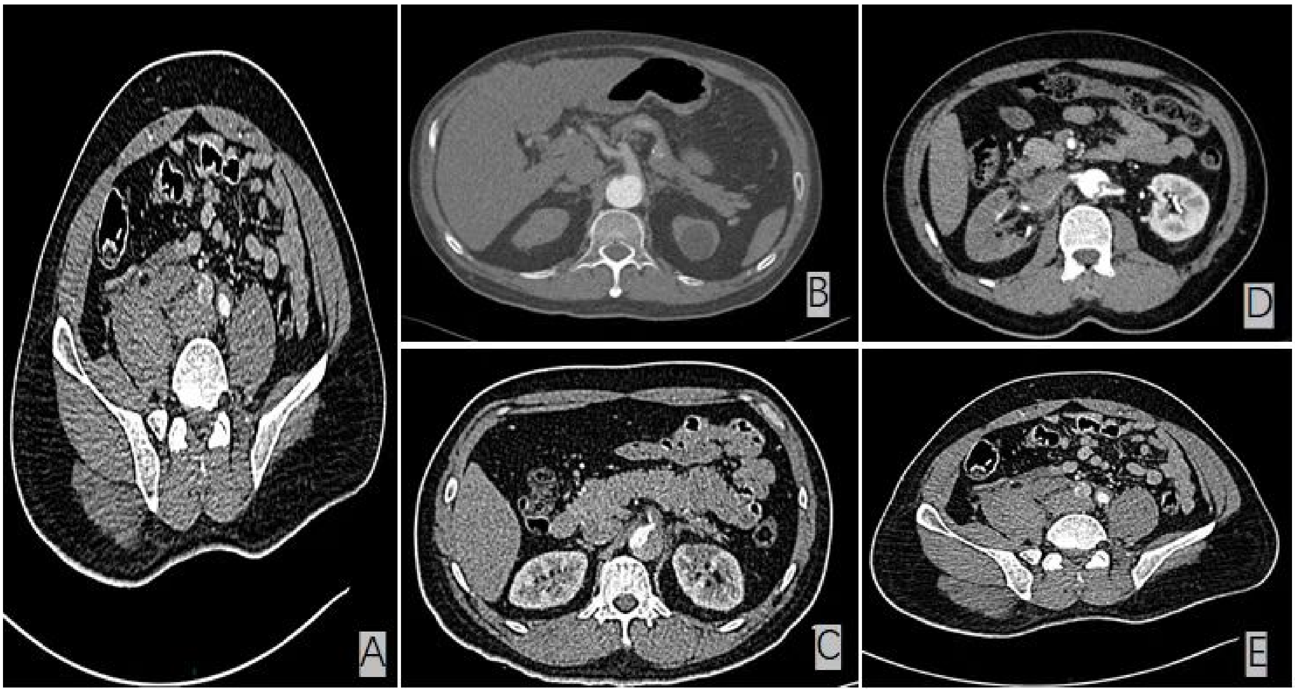

Fig. 1. Acute aortic dissection concomitant organ malperfusion. (A,E) Poor lower limb perfusion. (B) Poor perfusion of the abdominal aorta. (C) Inferior mesenteric perfusion deficiency. (D) Renal artery malperfusion.

Table 1. Demographics and preoperative variables.

Variable	Total (n = 39)	Type A (n = 26)	Type B (n = 13)
Age, year	56.2 ± 12.4	51.8 ± 12.7	52.3 ± 11.5
Male sex (n, %)	33 (85%)	21 (80%)	12 (92%)
Coronary artery disease (n, %)	1 (3%)	0	1 (8%)
Cardiovascular disease (n, %)	2 (5%)	2 (8%)	0
Chronic obstructive pulmonary disease (n, %)	1 (3%)	1 (4%)	0
Hypertension (n, %)	33 (85%)	22 (85%)	11 (85%)
Diabetes (n, %)	1 (3%)	1 (4%)	0
Smoking history (n, %)	8 (21%)	6 (23%)	2 (15%)
Alcohol use (n, %)	10 (26%)	9 (35%)	1 (8%)

test was used for within-group comparisons. Categorical data were expressed as percentages (%) and compared between groups using the chi-square test, corrected chi-square test, or Fisher's exact test for overall effectiveness. This retrospective analysis was approved by the hospital's ethics committee (ethics approval number 2024LL0430001) and preoperative patients and their families. LLM was defined as weak or absent pulsation of unilateral or bilateral femoral arteries and at least one of the following additional findings: pain, paresthesia or paralysis, decreased motor function, limb discoloration, or computed tomography demonstration of arterial obstruction of the affected limb/limbs by the dissection (Fig. 1). For patients with aortic dissection complicated by lower limb malperfusion, emergency surgical treatment is recommended according to the 2014 European Society of Cardiology Guidelines for the Management of Aortic Diseases (Class I, Level of Evidence B). The procedure involves resecting the primary tear in the aortic dissection under deep hypothermic circulatory arrest, replacing the aorta with a synthetic graft, and placing a stent in the descending aorta to expand the true lumen and increase distal aortic blood supply, thereby improving lower limb ischemia. Currently, there is no standardized guideline for intervention decisions, and the approach primarily relies on the clinical experience of the treating physician.

Patients were excluded if LLM was the result of an iatrogenic injury. The cohort was subdivided into Stanford type A and type B aortic dissections. Visceral ischemia was determined by computed tomography findings of branch occlusion or clinical abdominal symptoms, bowel ischemia or renal failure. Multiple visceral ischemia was defined as malperfusion of two or more visceral branches, excluding isolated bilateral renal artery ischemia.

Table 2. Dissection-related variables.

Variable (n,%)	Total (n = 39)	Type A (n = 26)	Type B (n = 13)	Preoperative death (n = 9)
LLM laterality				
Right	13 (33%)	10 (38%)	3 (23%)	3 (33%)
Left	16 (41%)	11 (42%)	5 (38%)	3 (33%)
Bilateral	10 (26%)	5 (19%)	5 (38%)	3 (33%)
Isolated LLM	9 (23%)	4 (15%)	5 (38%)	2 (22%)
Concomitant viscerorenal malperfusion				
Celiac trunk	13 (33%)	9 (35%)	4 (31%)	3 (33%)
SMA	11 (28%)	10 (38%)	1 (8%)	3 (33%)
Renal	25 (64%)	17 (65%)	8 (62%)	6 (67%)
Multiple viscerorenal vessels	13 (33%)	9 (35%)	4 (31%)	5 (56%)

LLM, lower limb malperfusion; SMA, superior mesenteric artery.

The need for surgical intervention for LLM was determined by the operating surgeon based on the severity and persistence of symptoms. All operative interventions first repaired the aortic dissection. Low limb interventions were defined as extra-anatomic bypass (femoral-femoral or axillo-femoral), iliac stenting or amputation. The study protocol was approved by our institutional review board with a waiver of patient consent.

The incidence of lower limb intervention, postoperative complications, in-hospital mortality rate, and readmission for LLM are reported. The data was independently extracted by two surgeons and one radiologist, and any discrepancies were clarified through consensus.

A descriptive univariate analysis was performed for all variables. Normally distributed continuous variables were described as mean and standard deviation (SD), and non-normally distributed continuous variables as median and interquartile range (IQR). Categorical variables are described as frequency counts and percentage. A p-value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS statistical software v27 (IBM Corp., Armonk, NY, USA).

Result

Based on the variables mentioned in the Table 1 and Table 2, the study included 39 individuals, 26 with Type A and 13 with Type B. 85% of the individuals in the cohort were males, and the average age is 56.2 ± 12.4 years. 85% of patients in both Type A and Type B individuals had hypertension. Coronary artery disease (CAD) was present in 3% of individuals in the whole cohort, while cardiovascular disease (CVD) was present in 5%. Chronic obstructive pulmonary disease (COPD) was present in 3% of the Type A individuals but none in Type B. 23% of individuals in Type A and 15% in Type B had a history of smoking.

A total of 39 individuals were included in the study, with 26 individuals categorized as Type A and 13 as Type B. Notably, 9 individuals experienced a preoperative death, 22% patients was isolated LLM, and two preoperative deaths were all type A aortic dissection cases. 33% individuals had right-sided LLM, 41% had left-sided LLM, and 26% had bilateral LLM. Most LLM patients had concomitant viscero-renal malperfusion, with renal malperfusion being the most common, 33% individuals had malperfusion involving the celiac trunk, of which 28% involved the superior mesenteric artery (SMA). The incidence of type B aortic dissection (8%) was significantly lower than that of type A aortic dissection (38%). 33% of patients had malperfusion involving multiple vessels.

Table 3 shows the various parameters between preoperative death and surgery. Out of the 30 surgical cases, 9 were reported as preoperative deaths. The myoglobin values were significantly higher in preoperative death cases (82.05 ± 47.28) compared to surgical cases (42.45 ± 20.12) ($p = 0.03$). The lactic acid values were significantly higher in preoperative death cases (11.3 [3.60–13.70]) compared to surgical cases (4.15 [1.35–12.65]) ($p = 0.05$). The fibrinogen values were also significantly higher in preoperative death cases (25.26 ± 8.63) compared to surgical cases (7.34 ± 2.16) ($p = 0.00$). In contrast, the erythrocyte count, leukocyte count, lymphocyte count, hemoglobin values, D-dimer values, prothrombin time, troponin values and creatine kinase MB showed no statistical difference between the two groups.

Table 4 presents surgical and perioperative parameters. In patients with Type A aortic dissection, the duration from onset to surgery averaged 28.0 ± 17.3 hours, and the surgical time averaged 8.41 ± 0.53 hours. The extracorporeal circulation time was 228.73 ± 20.61 minutes, with 3 patients from the Type A aortic dissection group undergoing concurrent femoral artery bypass surgery. The ventilator and intensive care unit (ICU) times were notably longer in the Type A group compared to the Type B group. Additionally, 3 patients, including two with Type A dissection, received continuous renal replacement therapy (CRRT) treatment post-surgery. The postoperative mortality rates differed between the two groups, with 7 patients succumbing

Table 3. Laboratory examination variables.

Variable	Preoperative death (n = 9)	Surgical cases (n = 30)	p value
Erythrocyte (10^{12}/L)	4.25 [3.69–4.62]	4.38 [3.98–4.75]	0.52
Leukocyte (10^9/L)	16.01 [12.15–19.65]	13.12 [8.85–17.65]	0.13
Lymphocyte (10^9/L)	1.30 [1.06–2.17]	0.85 [0.59–1.24]	0.09
Hemoglobin (g/L)	134.00 [115.00–147.00]	134.00 [118.50–144.50]	0.70
D-dimer (mg/L)	7.70 [1.36–14.52]	7.12 [3.50–16.81]	0.70
Myoglobin (ng/L)	82.05 ± 47.28	42.45 ± 20.12	0.03※
Lactic acid (mmol/L)	11.30 [3.60–13.70]	4.15 [1.35–12.65]	0.05※
Prothrombin time (s)	4.92 [2.27–13.60]	10.15 [2.75–13.53]	0.42
Fibrinogen (g/L)	25.26 ± 8.63	7.34 ± 2.16	0.00※
Troponin (pg/L)	13.00 [9.00–76.00]	22.05 [8.99–25.34]	0.81
Creatine kinase isoenzyme MB (u/L)	76.00 [39–160]	22.05 [14.60–72.30]	0.70

"※" indicating differences.

Table 4. Surgical and perioperative variables.

Variable	Type A (n = 22)	Type B (n = 8)
Onset to surgery time (h)	28.00 ± 17.30	120.87 ± 101.53
Surgical time (h)	8.41 ± 0.53	1.29 ± 0.45
Extracorporeal circulation time (min)	228.73 ± 20.61	0
Femoral to femoral bypass (n, %)	3.00 (13.6%)	0
Iliac stenting	0	0
Amputation	0	0
Ventilator time (h)	67.13 ± 143.16	1.63 ± 1.31
ICU time (h)	45.93 ± 10.72	7.13 ± 6.55
CRRT (n, %)	2.00 (9.0%)	1.00 (12.5%)
Intra-hospital mortality (n, %)	7.00 (31.8%)	1.00 (12.5%)

ICU, intensive care unit; CRRT, continuous renal replacement therapy.

to complications in the Type A dissection group and 1 patient in the Type B dissection group.

There was an average follow-up duration of 22.78 ± 18.25 months. Subsequently, three patients required readmission, with one individual undergoing treatment due to a cerebral infarction, and two patients returning for femoral artery bypass surgery to due to lower limb claudication. Notably, there were no fatalities or amputations in the follow-up cohort.

Discussion

Our retrospective study revealed an incidence of 6.3% (39/617) for patients with aortic dissection complicated by LLM, among which isolated LLM accounted for 23% (9/39), with a preoperative mortality rate of 23% (9/39). The majority of LLM cases were associated with malperfusion of other organs in 77% (30/39) of cases. All surgical patients underwent initial aortic central repair, with a mortality rate of 26% (8/30). Postoperative mortality rates were 31.8% (7/22) for type A dissections and 12.5% (1/8) for type B dissections. Immediate femoral-femoral bypass grafting was performed in 10% (3/30) of cases following central aortic repair, with the majority of patients experiencing significant improvement in LLM with aortic central repair alone. The postoperative readmission rate due to LLM was 6.7% (2/30).

The readmission rate for patients with inadequate lower extremity perfusion was 6.7% (2/30). Observations from an international registry on acute aortic dissection have shown that compromised lower limb arterial perfusion accompanies 9.7% of aortic dissection cases [6]. Our study indicates a 6.3% incidence rate of aortic dissection patients presenting with LLM. There is an ongoing debate over the most effective method to address LLM, with some clinicians opting to first treat the threatened limb, while our approach favors primary intervention on the proximal aortic dissection. Several studies have reported the resolution of compromised perfusion in other organs following proximal aortic repair alone, and our center's experiences also confirm this strategy. In cases where central aortic repair does not resolve the issue of blood supply to the lower limbs, stent graft placement in the central aorta has been shown to improve limb ischemia without the need for further interventions, as reported by Plotkin *et al.* [7].

The diagnosis of impaired lower extremity arterial perfusion impairment is often based on clinical symptoms such as numbness, sensory abnormalities, pain, and decreased skin temperature. Some patients may not exhibit clinical symptoms of LLM, yet enhanced CT scans can display significant perfusion deficits. This could be due to anatomical features that mitigate the severity of the dissection, such as a dynamic flap causing intermittent flow obstruction, partial obstruction by a static dissection flap, or sufficient collateral circulation from arteries including the iliolumbar, internal iliac, deep circumflex, epigastric, and deep femoral arteries [8]. Nagamine *et al.* [9] and others have conducted a retrospective assessment of the perfusion status of the entire aorta and its branches to evaluate the outcomes of central aortic repairs. In the absence of biomarkers for determining the extent of LLM, abnormalities in imaging data can serve as a valuable supplement.

Acute aortic dissection (AAD) typically begins without specific symptoms, and although many patients experience sudden chest pain, it's often misdiagnosed as myocardial infarction or other heart-related conditions. Various biomarkers have been established to diagnose cardiac events, particularly creatine kinase MB (CK-MB) and cardiac troponin T (cTnT), which have a long history of specificity and sensitivity in detecting myocardial infarction (MI) [10]. These biomarkers' levels often reflect the severity of the cardiac condition. Some biomarkers, such as D-dimer, matrix metalloproteinases, soluble elastin fragments, and soluble ST2, have been reported to help diagnose and detect AAD, and are capable of quickly differentiating the causes of chest pain [11–13]. However, aside from D-dimer, most of these biomarkers have not been widely implemented in clinical practice [13]. Our study found elevated levels of fibrinogen in the preoperative death group, which may indicate an overactive coagulation and fibrinolytic system, meriting further investigation into the underlying mechanisms. The comparisons of three laboratory indicators—Myoglobin, Lactic Acid, and Fibrinogen—between preoperative mortality and surgical patients are statistically significant. These three indicators may serve as risk factors for clinicians to assess in-hospital preoperative mortality in patients with aortic dissection.

Patients with Type A dissection underwent surgery significantly sooner than those with Type B (7.2 hours versus 38.2 hours), consistent with other research [7]. Patients with LLM were treated sooner than those without LLM. The postoperative mortality rate was markedly higher in Type A dissection patients at 31.8%, compared to 12.5% in Type B dissection patients. Additionally, only two patients were readmitted for claudication and underwent femoral-femoral bypass surgery, which resulted in symptomatic improvement. It's important to note that when an aortic dissection presents with LLM, it often indicates poor perfusion to other organs as well. These patients face a high risk of mortality prior to surgery, irrespective of LLM issues. In patients with Lower Limb Malperfusion, the mortality rate for those who did not receive early reperfusion is significantly higher than for those who did. Malperfusion also affects surgical mortality, with patients experiencing malperfusion having a significantly higher surgical mortality rate than those without malperfusion.

Therefore, the primary objective of central aortic repair *vs.* restoring blood flow to ischemic limbs is to address organ malperfusion [14]. Based on our data, prioritizing central aortic repair remains the preferred treatment strategy.

The limitations of this study are largely attributed to its retrospective nature, including treatment bias and a small sample size, from a single center. None of the patients with aortic dissection in this cohort underwent a limb-first intervention; hence, we cannot comment on the outcomes of this strategy. In addition, the small number of study patients which could lead to selection bias, thus larger multi-center studies are necessary.

Limitation

The limitations of this study are largely attributed to its retrospective nature, including treatment bias and small sample size. No patients with aortic dissection in this cohort underwent limb-first intervention; hence, we cannot comment on the outcomes of this strategy. The small number of study patients, which could lead to selection bias, thus, larger, multi-center studies are necessary.

Conclusion

Aortic dissection with lower limb malperfusion (LLM) is associated with elevated risks of pre- and postoperative mortality, especially in Type A aortic dissections versus Type B. However, for survivors of initial central aortic repair, the rates of amputation and readmission for LLM are notably low.

Availability of Data and Materials

The datasets used in this study are available from the corresponding author upon reasonable request.

Author Contributions

JX and YP primarily contributed to data collection, data analysis, result interpretation, and manuscript writing. AK, CL, and YF are primarily responsible for research design, writing, and translating manuscripts. ZL was mainly responsible for the conceptualization and design of the study. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This retrospective analysis was approved by the hospital's ethics committee (ethics approval number 2024LL0430001) and preoperative patients and their families.

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Conflict of Interest

The authors declare no conflict of interest.

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