Medicina Intensiva 50 (2026) 502342

medicina intensiva

http://www.medintensiva.org/en/

ORIGINAL ARTICLE

Operative mortality predictors in patients with acute type A aortic dissection

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Received 23 June 2025; accepted 23 September 2025
Available online 25 October 2025

KEYWORDS
Acute type A aortic dissection;
Operative mortality;
Neutrophil-lymphocyte ratio;
Aortic ascending diameter

Abstract
Objective: To develop a model capable of predicting risk factors for operative in-hospital mortality in patients diagnosed with acute type A aortic dissection, that includes inflammatory biomarkers and imaging variables of the ascending aorta in the acute phase.
Design: Unicentric retrospective analysis.
Setting: Cardiac surgery unit.
Patients: Adult patients undergoing cardiac surgery after acute type A aortic dissection, during a 11-year period.
Main variables of interest: Pre- and intraoperative risk factors for mortality, inflammatory markers and ascending aortic diameter, at the time of diagnosis.
Results: 120 patients were analysed. The presence of preoperative visceral ischemia (OR) 7.48, 95% confidence interval (CI) (1.98—28.18); (p: 0.003); redo cardiac surgery (OR: 10.07, 95% CI (1.62—62.27); (p: 0.013); preoperative dual antiplatelet therapy (OR: 7.21, 95% CI (1.45–35.69); (p: 0.015) and the neutrophil/lymphocyte ratio (OR: 1.11; 95% CI (1.03—1.20); (p: 0.006) were independent predictors for operative mortality in the analysed sample. These risk factors were included in a model to predict operative mortality, which also included ascending aortic diameter, with an area under the ROC curve of 0,793 ± 0,052; IC 95% (0,691–0,895); (P < 0,0001).
Conclusions: The inclusion of variables that quantify inflammatory activity, as well as imaging variables at the time of diagnosis of acute type A aortic dissection, may contribute to a more accurate estimate of surgical risk.
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https://doi.org/10.1016/j.medine.2025.502342
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PALABRAS CLAVE
Disección aórtica aguda tipo A;
Mortalidad operatoria;
Índice neutrófilo/linfocitario;
Diámetro aorta ascendente

Predictores de mortalidad operatoria en pacientes con disección aórtica aguda

Resumen
Objetivo: Elaborar un modelo para predecir los factores de riesgo de mortalidad operatoria hospitalaria en pacientes diagnosticados de disección aórtica aguda tipo A, que incluya marcadores de inflamación y variables de imagen de la aorta ascendente en el momento agudo.
Diseño: Unicentrico, análisis retrospectivo.
Ámbito: Servicio de cirugía cardiaca.
Pacientes: Adultos sometidos a cirugía cardiaca tras disección aórtica aguda tipo A, durante un periodo de 11 años.
Variables de interés principales: Factores de riesgo de mortalidad pre e intraoperatorios, marcadores de inflamación y diámetro de aorta ascendente, en el momento del diagnóstico.
Resultados: Se analizaron 120 pacientes. La presencia de isquemia visceral preoperatoria Odds Ratio (OR) 7,48, intervalo de confianza (IC) al 95% (1,98-28,18); (p: 0,003); el antecedente de cirugía cardiaca previa OR: 10,07 IC 95% (1,62-62,27); (p: 0,013); la doble antiagregación preoperatoria OR: 7,21; IC 95% (1,45-35,69); (p: 0,015) y el índice neutrófilo/linfocitario OR: 1,11; IC 95% (1,03-1,20); (p: 0,006) fueron predictores independientes de mortalidad operatoria en la muestra analizada. Estos factores de riesgo se incluyeron en un modelo para predecir la mortalidad operatoria al que, además, se añadió el diámetro de la aorta ascendente, con un área bajo la curva ROC de 0,793 $\pm$ 0,052; IC 95 % (0,691-0,895); (P < 0,0001).
Conclusiones: La inclusión de variables que cuantifiquen la actividad inflamatoria, así como variables de imagen en el momento del diagnóstico de la disección aórtica aguda de tipo A pueden ayudar a una estimación más ajustada del riesgo quirúrgico.
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Introduction

Mortality related to acute type A dissection (ATAAD) surgery has only slightly decreased in recent years. Operative mortality of ATAAD is around 22% in most major recent reports.[1,2] Chest pain remains the most common initial symptom, but the clinical profile is highly variable, and mortality is particularly increased in patients with preoperative malperfusion, cardiac tamponade and/or cardiogenic shock. Scores such as the German Registry of Acute Aortic Dissection Type A (GERAADA) demonstrated association between these complications and 30-day mortality.[3,4] Some plasma biomarkers such as D-dimer, tenascin-C or myosin heavy chain, not yet routinely available in emergency departments, act as diagnostic and prognostic markers for acute aortic dissection.[5–8] The neutrophil-lymphocyte ratio (NLR) has been identified as a predictor of adverse outcomes in many cardiovascular diseases, such as congestive heart failure and coronary artery disease.[9–15] It is a not expensive, essential and easily accessible laboratory test. High NLR is 90% sensitive and 89% specific for the diagnosis of aortic dissection.[14] Increased accessibility to CT imaging in the last decade has favored the early diagnosis of ATAAD. Furthermore, a recent study suggests a correlation between ascending aorta length measured by CTA at the time of diagnosis of ATAAD and operative mortality.[16]

Therefore, we propose the development of a prognostic model for operative mortality in patients diagnosed with ATAAD, including the NLR as a measure of inflammation and the largest diameter of the ascending aorta, measured by non-ECG-synchronized CTA at the time of diagnosis, along with the most common risk markers.

Patients and methods

This is a retrospective and longitudinal study with a cohort design. Patients older than 18 with diagnosis acute type A aortic dissection undergoing urgent or emergent cardiac surgery were analysed. The study was done according to strengthening the reporting of observational studies in epidemiology (STROBE) guidelines.[17] The study protocol (identification number PI21-2505) received full approval by both the local Institutional Research Review Committee and the Clinical Research Ethics Committee. The study period included January 2013 to December 2023. The clinical and demographic variables were prospectively collected. All patients gave their preoperative written informed consent for the analysis of their anonymized data. *Operative mortality* was defined as mortality occurring within 30 days of operation.

Statistical analysis

Statistical analysis was performed using IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp. Continuous variables were expressed as mean and standard deviation or as median and interquartile range (IQR), for non-normal distributions. The Kolmogorov-Smirnov test was used to determine the normality of each variable. Categorical variables were expressed as absolute

values and percentages. Association between variables was identified by the Chi-squared or Fisher's exact test, when categorical, and by Student's T-test or Mann Whitney U-test, when continuous, according to normality criteria. Association between analysed variables and operative mortality in univariate analysis (P < 0.2) were entered into backward and forward stepwise logistic regression models. A *Spearman's correlation* was run to determine the relationship between aortic diameter and malperfusion. Multicollinearity was assessed using variance inflation factor. The model was further developed and validated using the bootstrap approach. Bootstrapping was performed to derive 95% confidence intervals (CI) for estimates. Accuracy was measured by the area under the receiver operating characteristic (ROC) curve analysis. A P value <0.05 was considered significant.

Results

Preoperative and intraoperative variables were analysed in 120 consecutive patients undergoing ATAAD (Table 1). Mean age was 63.1 (11.2) years (median, 64 years) (IQR: 39–86) and 28.3% were women. Chest pain was the initial symptom in 72.5% of cases. At diagnosis, 33.3% of patients required intravenous inotropic support, 32.5% had echocardiographic signs of cardiac tamponade, 10.8% were intubated, and 9.2% required preoperative cardiopulmonary resuscitation (CPR). The supra-aortic vessels were involved in the aortic dissection in 41.7% of cases (1 vessel dissected in 22 patients, 2 in 17, and 3 in 11). According to TEM (type/entry location/malperfusion) classification of the aortic dissection,[17] the primary entry tear was located in *zone E0* in 24 patients (20%), *zone E1* in 83 (69.2%), *zone E2* in 10 patients (8.3%) and *zone E3* in 3 cases (2.5%). Collagen disease was previously diagnosed only in 9 patients and only 1 of them died after surgery. A pathological examination of the aorta was performed in 72.5% of patients. Aortic media dehiscence, without significant degenerative or inflammatory changes, was identified in 57.5% of cases, arteriosclerotic changes in 39.1% and cystic medial necrosis in 3.4%.

The surgical procedures performed were: Bentall procedure in 45 patients (37.5%), David procedure in 1 case (0.8%), supracoronary Dacron aortic graft in 61 patients (50.8%) and associated aortic arch and supra-aortic vessels replacement by Dacron grafts in 13 cases (10.8%). Operative mortality occurred in 37 patients (30.8%). The causes of death were hemorrhagic complications in 16 patients, multiorganic failure in 9, cardiogenic shock in 6, neurological complications in 4 and respiratory failure associated to sepsis in 2. In the multivariate analysis, risk factors associated with operative mortality included preoperative dual antiplatelet therapy, prior cardiac surgery, NLR and preoperative visceral ischemia (Table 2). (Fig. 1). These variables were then analysed using bootstrap approach for the internal model validation for binary clinical risk prediction models (Table 3 and 4) and combined in a model to predict operative mortality, which also included ascending aortic diameter, with ROC curve of 0.793 ± 0.052; IC 95% (0.691−0.895); (P < 0.0001). (Figs. 1 and 2). A significant correlation was identified between ascending aortic diameter and symptomatic malperfusion. In this case, the ascending aortic diameter was 51.9 ± 7.8 mm vs. 55.8 ± 12.1 mm in patients without signs of malperfusion (p: 0.036).

Discussion

Early surgical treatment is the strategy that mostly reduces mortality in ATAAD. In recent years, the hybrid approach has improved outcomes when the aortic arch is affected.[18] However, a significant reduction in perioperative mortality or neurological complications has not been achieved.[1,2,4,19–21] Preoperative neurological injury, cardiogenic shock secondary to pericardial tamponade and organ hypoperfusion were described as risk factors for mortality in ATAAD.[22] The latter associates to progressive increase in mortality, rising to over 85% in patients who presented malperfusion in two or more organs.[21] Despite all this, surgery has demonstrated its superiority over conservative treatment. Scores such as the German Registry of Acute Aortic Dissection Type A (GERAADA) identified some strongest risk factor for mortality. However, as in the case of the EuroSCORE scale, the adjustment showed a moderate discriminatory ability predicting operative mortality.[4]

Therefore, we propose the use of two easily accessible indicators, added to those already studied, and attempt to more accurately predict mortality in these patients: the NLR and the diameter of the ascending aorta, measured by CT. Diagnostic imaging methods for ATAAD have improved significantly throughout this century.[5] In a recent publication, Pan[16] et al. described an association between 30-day mortality and two variables identified in preoperative CTA after ATAAD: pericardial effusion and ascending aorta length. Pericardial tamponade is already indirectly assessed in the GERAADA score and the ascending aorta length could be correlated to aortic elastin disruption and potentially predicting worse outcomes after surgery. In fact, the inclusion of ascending aortic diameter measured by CT provide better discrimination predicting operative mortality. A negative correlation between ascending aortic diameter and clinical and radiological malperfusion has been observed: preoperative malperfusion was more frequent in patients with smaller ascending aortic diameter. This could be explained by a larger reduction of the true lumen, from the origin of the dissection in the ascending aorta, and more severe hypoperfusion in patients with a closer to normal ascending aortic diameter, without correlation to the anatomopathological findings.

Secondly, various biomarkers have been correlated with adverse outcomes after ATAAD surgery. For example, D-dimer increased early and presents high diagnostic sensitivity during the first hour after ATAAD.[6,7] Since the middle layer of the aorta is affected, markers of endothelial injury, such as metalloproteinase, soluble elastin fragments and tenascin-C, could be also used as early diagnostic methods.[5–8] Limited availability is the main disadvantage in identifying these biomarkers. Several studies have highlighted the importance of inflammatory activity in aortic pathology. Neutrophil-mediated injury in the adventitia plays a key role in the progression of the dissection and causes secondary neutrophilia, with massive accumulation of neutrophils in the injured area. Furthermore, lymphopenia is observed as a response to stress, induced by cortisol.

Table 1 Factors associated to operative mortality: univariate analysis.

Variable Preoperative risk factors	Non survivors n: 37 n (%)	Survivors n: 83 n (%)	p
Female sex	9 (24.3)	25 (30.1)	0.515
Arterial hypertension	32 (86.4)	59 (71)	0.069
Diabetes mellitus	4 (10.8)	5 (6)	0.455
Dyslipemia	8 (21.6)	24 (28.9)	0.404
Preoperative stroke	4 (10.8)	11 (13.2)	1.000
Chronic lung disease	2 (5.4)	9 (10.8)	0.500
Coronary disease	4 (10.8)	3 (3.6)	0.200
Chronic renal disease	1 (2.7)	5 (6)	0.665
Redo cardiac surgery	4 (10.8)	2 (2.4)	0.072
Atrial fibrillation	8 (21.6)	6 (7.2)	0.023
Preoperative inotropic support	14 (37.8)	26 (31.3)	0.485
Preoperative intubation	4 (10.8)	9 (10.8)	1.000
Preoperative CPR	3 (8.1)	8 (9.6)	1.000
Cardiac tamponade	15 (40.5)	24 (28.9)	0.209
Spinal ischemia	1 (2.7)	3 (3.6)	1.000
Visceral ischemia	9 (24.3)	5 (6)	0.010
Renal ischemia	12 (32.4)	11 (13.2)	0.014
Lower limb ischemia	4 (10.8)	3 (3.6)	0.200
Intimal tear E1 zone	25 (67.5)	58 (69.8)	0.800
Secondary aortic regurgitation	17 (45.9)	33 (39.7)	0.526
Supraaortic vessels dissection	13 (35.1)	37 (44.5)	0.333
Preoperative treatment			
Antiplatelet theraphy	9 (24.3)	19 (22.8)	0.864
Dual antiplatelet theraphy	5 (13.5)	3 (3.6)	0.045
Anticoagulation	8 (21.6)	8 (9.6)	0.075
Beta-blockers	12 (32.4)	21 (25.3)	0.419
Calcium antagonist	3 (8.1)	10 (12.04)	0.752
Angiotensin converter enzyme inhibitors	17 (45.9)	30 (36.1)	0.310
	Mean (DS) or median [IQR]*	Mean (DS) or median [IQR]*	p
Age (years)	64.8 (11.3)	62.4 (11.2)	0.291
Haemoglobin (g/dL)	13.3 (2.1)	13.1 (1.9)	0.634
Creatinine (mg/dl)	1.2 (0.4)	1.2 (1.09)	0.958
GFR (ml/min/1.73 m^2)	62.2 (23.01)	72.5 (25.3)	0.200
Neutrophil ($\times 10^3/\mu L$)	10.04 (49.49)	8.9 (3.4)	0.165
Lymphocyte ($\times 10^3/\mu L$)	1.1 [8.04] *	1.4 [25.4] *	0.275
Monocyte ($\times 10^3/\mu L$)	7.4 (7.3)	6.06 (2.4)	0.130
NLR	9.4 (6.4)	6.7 (4.8)	0.013
Leucocyte count ($\times 10^3/\mu L$)	13.01 (4.7)	11.9 (3.7)	0.210
Platelet count ($\times 10^3/\mu L$)	154 [216] *	174 [410] *	0.025
Ascending aorta diameter (mm)	50 [33] *	51 [45]*	0.150
LVEF (%)	58.6 (7.01)	60.8 (7.5)	0.143
EuroSCORE II (%)	10 [40] *	6.4 [74]*	0.133
GERAADA score (%)	23.4 [71.2] *	15.8 [59.1] *	0.011
Surgical variables			
CPB time (min)	211.4 (72.9)	175.4 (44.2)	0.001
Aortic clamp time (min)	98.9 (45.6)	88.6 (39.4)	0.209
Total circulatory arrest time (min)	28.6 (17.4)	28.6 (18.01)	0.994

GFR: glomerular filtration rate; CPR: cardiopulmonary resuscitation; NLR: neutrophil-lymphocyte ratio; LVEF: left ventricular ejection fraction, GERAADA: German Registry of Acute Aortic Dissection Type A; CPB: cardiopulmonary bypass.

* Median [IQR].

Table 2 Multivariate analysis: predictive variables for operative mortality.

Variable	OR	IC (95%)	p
Dual antiplatelet therapy	7.21	1.45—36.69	0.015
NLR	1.11	1.03—1.20	0.006
Visceral ischemia	7.48	1.98—28.18	0.003
Redo cardiac surgery	10.07	1.62—62.27	0.013
GERAADA score	1.02	0.99- 1.05	0.160
EuroSCORE II	1.02	0.99—1.05	0.111
Ascending aorta diameter	0.97	0.93—1.01	0.151

NLR: neutrophil-lymphocyte ratio.

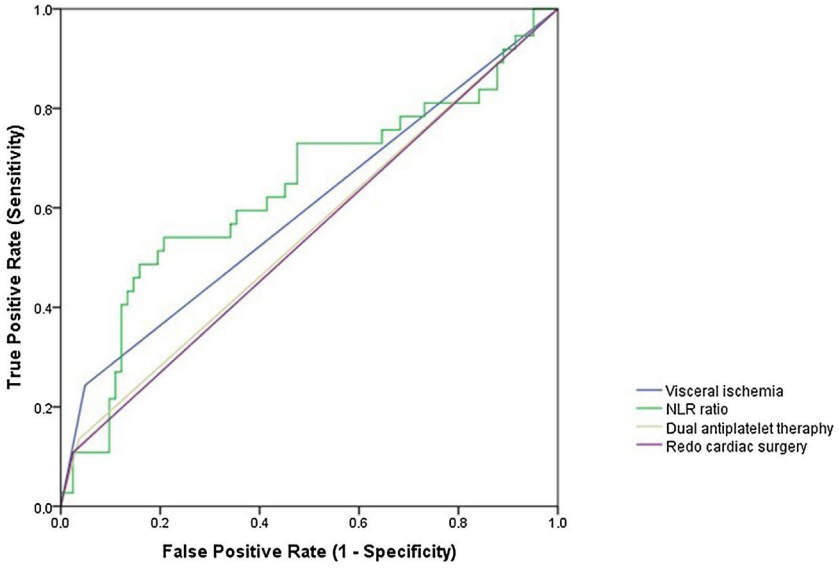

Figure 1 ROC curves including risk factors for operative mortality in analysed cohort.

Table 3 Multiple logistic regression analysis for operative mortality (validated with bootstrap approach).

Variable	Beta coefficient	CI (95%)	SE	p
Dual antiplatelet therapy	1.976	0.414—22.277	4.248	0.002
NLR	0.109	0.026—0.226	0.049	0.007
Visceral ischemia	2.013	0.546—4.250	3.037	0.003
Redo surgery	2.310	0.264—23.161	7.460	0.002
Constant	−2.227	−3.526 to −1.382)	0.532	0.001

NLR: neutrophil-lymphocyte ratio.

Table 4 Prediction model of operative mortality after ATAAD surgery with the risk factors identified in multiple logistic regression analysis.

Variable	ROC curve	SE	CI (95%)	p
Dual antiplatelet therapy	0.549	0.059	0.434–0.665	0.391
Neutrophil-to-lymphocyte ratio (NLR)	0.635	0.059	0.520–0.751	0.018
Visceral ischemia	0.597	0.059	0.481–0.713	0.090
Redo cardiac surgery	0.542	0.059	0.427–0.657	0.466
GERAADA score	0.662	0.052	0.561–0.763	0.005
EuroSCORE	0.648	0.059	0.533–0.764	0.017
Ascending aorta diameter	0.396	0.058	0.282–0.509	0.092
Model[a]	0.774	0.056	0.665–0.884	<0.0001
Model + ascending aorta diameter[b]	0.793	0.052	0.691–0.895	<0.0001

[a] Hosmer Lemeshow (H–L) value: 0.772.
[b] Hosmer Lemeshow (H–L) value: 0.660.

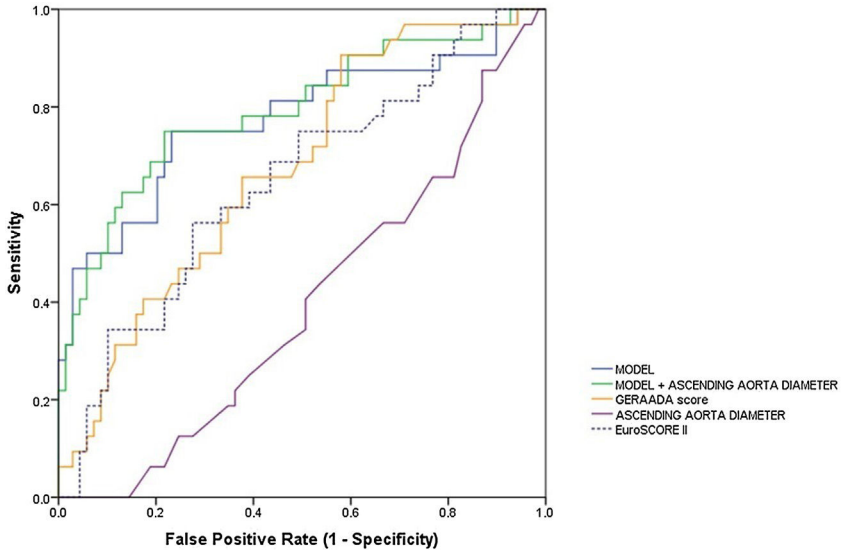

Figure 2 ROC curves predicting operative mortality in analysed cohort according GERAADA score, EuroSCORE II, ascending aorta diameter and developed prognostic models.

The neutrophil-to-lymphocyte ratio (NLR) has been identified as a novel predictor of adverse outcomes in many cardiovascular diseases, as well as congestive heart failure and coronary artery disease.[8–10] An elevated NLR has been associated with progressively severe symptoms in peripheral arterial disease, and furthermore, it is associated to poor outcome in critical limb-threatening ischemia.[12,23] An elevated NLR has shown a sensitivity of 89% and a specificity of 91% in the diagnosis of aortic dissection and has been helpful in predicting in-hospital mortality in patients with aortic dissection associated with pericardial effusion.[9,13] Furthermore, the NLR is an easy accessible biomarker in the emergency room.

The inclusion of both variables in an ATAAD operative mortality estimation model improves the predictive capacity of both the model designed with our cohort and the one estimated using the GERAADA score. Therefore, both variables are cost-effective and convenient to measure and should be considered when estimating operative mortality.

In conclusion, the predictive capacity for operative mortality in ATAAD improves when models included two readily available variables: the ascending aorta diameter and the NLR. Although open repair remains the procedure of choice and the reference standard, identifying patients with higher surgical risk might provide a new tool for decision-making guiding to less invasive therapies (such as Endo-Bentall) and/or hybrid procedures.[18,24]

Limitations

This is a retrospective single-center study, with a long period of recruitment and therefore, the population might not be representative enough. The measurement of the ascending aorta was performed without ECG-synchronized CTA, which might imply some inaccuracy in the analysed results.

CRediT authorship contribution statement

All authors contributed to acquisition, analysis, or interpretation of data for the work and final approval to the version to be published. B. Segura and Y. Carrascal contributed also to the conception, design, draft and critical revision of the work for important intellectual content.

Declaration of generative AI and AI-assisted technologies in the writing process

No Artificial Intelligence has been used in the process of generating or writing the manuscript.

Funding

None.

Declaration of competing interest

The authors declare that they have no conflicts of interest.

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