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Article

Prognostic Value of Preoperative Ascending Aortic Diameter on Postoperative Acute Kidney Injury in Adult Cardiac Surgery

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Abstract

Background: Ascending aortic diameter (AAD) is commonly measured during ultrasound examinations in cardiac surgery patients and is critical for assessing their prognosis. AAD affects renal perfusion. However, the impact of AAD on the incidence of postoperative acute kidney injury (AKI) in cardiac surgery patients remains unclear. This study aims to explore the prognostic value of AAD for postoperative AKI in adult cardiac patients. **Methods**: This retrospective study included patients aged ≥18 years who underwent cardiovascular surgeries from April to July 2023 at Fuwai Hospital, China. Patients were categorized into two groups: the AKI group and the non-AKI group. Preoperative cardiac ultrasound values were collected the day before surgery. The primary endpoint was the incidence of AKI. Univariable and multivariable logistic regression analyses were conducted to identify independent risk factors for postoperative AKI. The receiver operating characteristic curve was utilized to evaluate model performance. The effectiveness of including AAD in the model was also assessed. **Results**: The study comprised 442 patients. Both univariable and multivariable analyses indicated that AAD is an independent predictor of postoperative AKI in both on-pump and off-pump cardiac patients ($p < 0.05$). To control for the confounding factor of cardiopulmonary bypass (CPB) time, a subgroup analysis was conducted, which showed that including AAD improved the area under the curve (AUC) from 0.67 to 0.72 ($p < 0.05$) in on-pump patients. **Conclusion**: AAD is a significant prognostic factor for postoperative AKI in adult cardiac surgery. Its prognostic value is particularly pronounced in on-pump patients. Patients with an enlarged AAD are at a higher risk of developing AKI and experiencing adverse outcomes.

Keywords

ascending aortic diameter; acute kidney injury; cardiac surgery

Introduction

The ascending aortic diameter (AAD) is the initial segment of the human heart's aorta, connecting the left ventricle to the aortic arch [1]. It serves as a critical vessel distributing oxygen-rich blood to tissues and organs throughout the body [2]. Accurate measurement of the AAD is essential for surgical planning and postoperative prognosis [3,4]. Advancements in medical imaging technologies have enhanced the precision of these measurements [5]. Changes in the AAD, such as dilation and constriction, can lead to decreased organ perfusion, affecting the kidney, brain, and liver, and subsequently influencing patient outcomes [6]. Therefore, the AAD is a significant focus in cardiovascular research [7].

Postoperative acute kidney injury (AKI) is a frequent complication following cardiac surgery, with incidence rates ranging from 5–42% [8,9]. AKI extends hospital stays, escalates costs, and heightens the risk of cardiovascular events [9]. Identifying high-risk patients through preoperative assessment is crucial for AKI prevention and management [10]. Factors including age, gender, preoperative creatinine levels, operative duration, type of surgery, comorbidities, and medical history are known predictors of postoperative AKI [11–13]. These prognostic factors are vital for enhancing perioperative renal protection and improving clinical outcomes [14].

The kidney's function is reliant on the pressure and volume of blood perfusion. Supplied by the ascending aorta, oxygenated blood reaches various organs [15], with several arteries branching from the aorta itself. Consequently, the ascending aorta is integral to renal perfusion and oxygenation. Assessing parameters such as the diameter, blood flow velocity, and hemodynamics of the ascending aorta can inform renal perfusion and function [4,16], particularly in patients requiring precise circulatory management during cardiac surgery.

The link between the AAD and renal function during the perioperative period of cardiac surgery remains poorly understood and warrants further investigation. This study aims to determine the prognostic value of the latest preoperative AAD, assessed via echocardiography, for postoperative AKI in adult cardiac surgery patients. We hypothesize that the AAD is an essential parameter for evaluating perioperative renal function in these patients.

Methods

Study Design and Participants

The inclusion criteria included: (1) age 18 to 80 years; (2) male or female; (3) cardiac surgery; (4) valve surgery; (5) vascular surgery. The exclusion criteria included: (1) emergency surgeries; (2) repeat surgeries; (3) procedures that were altered; (4) endoscopic surgeries; (5) missing crucial medical information; (6) errors in medical records. To adhere to the guideline of 10 events per variable in logistic regression, a sufficient number of events were observed, supporting the feasibility of constructing a multivariable model [17].

Variables, Outcomes, and Definitions

Demographic data included age, gender, and body mass index (BMI). Preoperative data encompassed comorbidities, surgery history, laboratory results such as hemoglobin, creatinine and serum albumin (ALB), and cardiac ultrasound testing results including ejection fraction (EF), aortic annulus diameter, AAD, left atrial anteroposterior diameter (LAAD), interventricular septum thickness, right ventricular anteroposterior diameter (RVAD), main pulmonary artery diameter, left pulmonary artery diameter (LPAD), right pulmonary artery diameter (RPAD), and cardiothoracic ratio. Operative data included Euroscore, intraoperative mean blood pressure (MAP), intraoperative infusion, blood loss, lowest temperature, operative time, and cardiopulmonary bypass time. AAD measurements were conducted by a professional sonographer using the two-dimensional echocardiographic parasternal long-axis standard section (Philips CX50), 2 cm above the sinus. The outcome was postoperative AKI, defined by the Kidney Disease: Improving Global Outcomes (KDIGO) classification. This study aimed to capture all categories within the AKI classification [9]. Prognostic outcomes such as postoperative mechanical ventilation time, intensive care unit (ICU), length of hospital stay (LOS), and hospital charges were also recorded and compared between the AKI and non-AKI groups.

Statistical Analysis

Statistical analysis was performed using SPSS software version 27.0 (IBM Corp, Armonk, NY, USA). A $p < 0.05$ was considered statistically significant. Data regarding patient procedures and anesthesia were extracted from medical records and validated by two medical researchers. Missing data were addressed using the multiple imputation method. Participants were categorized into the AKI and non-AKI groups. Continuous variables were presented as means $\pm$ standard deviations (SD), and categorical variables as frequencies and percentages. Differences between the 2 groups were assessed using the t-test for continuous variables and the χ^2 test for categorical variables. Variables with a $p < 0.05$ in multivariable logistic regression were included in the model construction, and receiver-operating characteristic curves (ROC) were used to assess the value of factors and models. Models with and without AAD were constructed to examine the impact of including AAD by evaluating the area under the curve (AUC). To mitigate the influence of extracorporeal circulation confounders, a subgroup analysis was conducted specifically for on-pump patients to further explore the prognostic value of AAD.

Results

In the overall cohort of 442 patients, the average age was 58.51 $\pm$ 11.65 years, with a significant male predominance (71.3%). The incidence of AKI in adult cardiac surgery was 10.41%, comprising 46 patients with AKI and 396 without.

Demographic, preoperative, and intraoperative variables for both on-pump and off-pump patients are presented in Table 1. Compared to the non-AKI patients, those with AKI were older, had a larger proportion of female patients, and had lower preoperative albumin levels and a longer AAD. During surgery, AKI patients received fewer infusions, had longer CPB durations, and exhibited higher intraoperative temperatures.

A multivariable logistic regression analysis was performed; Table 2 displays the results. Seven variables were significant in the final model: gender, albumin level, CPB time, AAD, left atrial anteroposterior diameter, left pulmonary artery diameter, and right pulmonary artery diameter. Adjusted analyses showed that being female, having lower preoperative albumin levels, longer CPB time, larger AAD, larger left atrial anteroposterior diameter, larger left pulmonary artery diameter, and smaller right pulmonary artery diameter were significantly associated with an increased risk of AKI.

There was no significant difference in the AUC across five models with or without four ultrasound measurements (ascending aorta diameter, left atrial anteroposterior diameter, left pulmonary artery diameter, and right pulmonary artery diameter) (Fig. 1).

The ROC curves for the five variables in on-pump and off-pump patients are depicted in Fig. 2. The ROC areas for CPB time and AAD were 0.65 and 0.61, respectively, with other ROC values below 0.6. The optimal predictive threshold for AAD, based on the Youden index, was 36.98.

Postoperative mechanical ventilation duration was 8 (6–12) hours in the non-AKI group and 9 (6–14) hours in

Table 1. Univariate analysis results of on-pump and off-pump patients.

	Non-AKI (n = 396)	AKI (n = 46)	p
Age (y)	58.13 ± 11.84	61.83 ± 9.38	0.04
Gender			0.01
Male	290 (73.23%)	25(54.35%)	
Female	106 (26.77%)	21(45.65%)	
Body mass index (kg/m^2)	25.28 ± 3.30	25.72 ± 4.71	0.54
Coronary heart disease	237 (59.85%)	28 (60.87%)	0.89
Valvular disease	150 (37.88%)	18 (39.13%)	0.87
Aortic disease	37 (9.34%)	5 (10.87%)	0.79
Hypertension	206 (52.02%)	24 (52.17%)	0.98
Diabetes mellitus	132 (33.33%)	16 (34.78%)	0.84
Stroke	41 (10.35%)	5 (10.87%)	0.80
COPD	75 (18.94%)	9 (19.57%)	0.92
Hypercholesterolemia	186 (46.97%)	22 (47.83%)	0.91
Atrial fibrillation	102 (25.76%)	12 (26.09%)	0.96
Pulmonary hypertension	59 (14.90%)	8 (17.39%)	0.66
Surgery history	71 (17.93%)	9 (19.57%)	0.79
Hemoglobin (g/L)	137 (123, 152)	136 (124, 148)	0.86
Intraoperative infusion (mL)	913 (527, 1105)	863 (575, 992)	0.07
Intraoperative blood loss (mL)	590.68 ± 93.02	586.76 ± 90.73	0.79
Creatinine (µmol/L)	71.31 ± 19.88	77.2 ± 18.98	0.51
Serum albumin (g/L)	41.17 ± 3.62	39.75 ± 3.58	0.01
Euroscore	3 (1, 4)	4 (2, 5)	0.30
Intraoperative lowest MAP (mmHg)	89.08 ± 21.02	86.98 ± 11.84	0.27
CPB time (min)	88.6 ± 14.50	127.57 ± 27.65	<0.001
Intraoperative lowest temperature (°C)	29.98 ± 3.56	30.48 ± 2.01	0.01
Operative time (min)	314.36 ± 13.51	341.5 ± 12.49	0.14
Ejection fraction (%)	57.69 ± 7.82	57.84 ± 6.46	0.90
Aortic annulus diameter (mm)	21.81 ± 2.32	21.73 ± 2.61	0.82
Ascending aorta diameter (mm)	34.88 ± 5.19	36.7 ± 4.80	0.02
Left atrial anteroposterior diameter (mm)	38.74 ± 6.72	41.29 ± 10.18	0.03
Interventricular septum thickness (in diastole) (mm)	10.58 ± 2.40	10.41 ± 2.36	0.65
Right ventricular anteroposterior diameter (mm)	24.3 ± 3.94	23.93 ± 3.97	0.55
Main pulmonary artery diameter (mm)	24.34 ± 3.31	25.13 ± 3.80	0.13
Left pulmonary artery diameter (mm)	15.27 ± 2.28	16.05 ± 2.85	0.04
Right pulmonary artery diameter (mm)	15.86 ± 2.85	14.66 ± 3.56	0.01
Cardiothoracic ratio (mm)	0.5 ± 0.08	0.51 ± 0.06	0.46

AKI, acute kidney injury; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; MAP, mean blood pressure.

the AKI group (p = 0.03). ICU length of stay (LOS) was 1 (0–2) days in the non-AKI group and 2 (1–3) days in the AKI group (p = 0.12). The length of hospital stay was 10.5 (9–14) days in the non-AKI group and 12 (10–14) days in the AKI group (p = 0.01). Hospital charges were 112,000 (92,000–140,000) RMB and 127,000 (106,000–146,000) RMB, respectively (p = 0.04). The exchange rate of the Chinese Yuan Renminbi (RMB) to the US Dollar (USD) is 1 RMB = 0.1364 USD.

To mitigate the bias from CPB application, further subgroup analyses were conducted. In the on-pump subgroup, univariate analysis identified older age, lower serum albumin, larger AAD, and larger left pulmonary artery diameter as significant risk factors for AKI (Table 3). Multivariate analysis confirmed that female patients, those with lower albumin, longer CPB time, larger AAD, larger left atrial anteroposterior diameter, and larger right pulmonary artery diameter were at increased risk for AKI (Table 4).

Comparing two models with and without AAD, the inclusion of AAD significantly improved the AUC from 0.67 to 0.72 (DeLong: $p < 0.05$) (Fig. 3). Fig. 4 indicates that the ROC for AAD was 0.64 in on-pump patients. The optimal predictive threshold for AAD in on-pump patients, based on the Youden index, was 35.97.

Table 2. Multivariate analysis results of on-pump and off-pump patients.

	OR	95% CI	p
Age (y)	1.03	0.98–1.07	0.52
Gender	1.31	1.12–1.78	0.01
Body mass index (kg/m^2)	1.09	0.96–1.22	0.17
Coronary heart disease	1.71	0.22–2.35	0.49
Valvular disease	1.84	0.26–2.54	0.73
Aortic disease	1.51	0.13–2.24	0.39
Hypertension	1.31	0.61–2.81	0.44
Diabetes mellitus	1.79	0.78–3.11	0.26
Stroke	1.82	0.27–2.44	0.71
COPD	1.28	0.61–2.67	0.44
Hypercholesterolemia	1.77	0.78–3.92	0.18
Atrial fibrillation	1.18	0.62–3.45	0.12
Pulmonary hypertension	1.30	0.69–2.53	0.25
Surgery history	1.39	0.68–2.43	0.56
Hemoglobin (g/L)	0.94	0.89–1.91	0.83
Intraoperative infusion (mL)	1.00	1.00–1.00	0.51
Intraoperative blood loss (mL)	1.00	0.99–1.00	0.31
Creatinine (µmol/L)	1.09	0.97–1.21	0.37
Serum albumin (g/L)	0.74	0.23–0.93	0.01
Euroscore	1.03	0.72–1.49	0.51
Intraoperative lowest MAP (mmHg)	0.82	0.77–1.14	0.47
CPB time (min)	1.12	1.04–1.63	0.01
Intraoperative lowest temperature (°C)	1.03	0.98–1.09	0.44
Operative time (min)	1.01	0.93–1.05	0.92
Ejection fraction (%)	1.00	0.96–1.04	0.93
Aortic annulus diameter (mm)	0.98	0.84–1.18	0.93
Ascending aorta diameter (mm)	1.12	1.03–1.22	0.01
Left atrial anteroposterior diameter (mm)	1.05	1.01–1.17	0.04
Interventricular septum thickness (in diastole) (mm)	0.96	0.81–1.16	0.77
Right ventricular anteroposterior diameter (mm)	1.00	0.88–1.13	0.91
Main pulmonary artery diameter (mm)	1.08	0.97–1.15	0.19
Left pulmonary artery diameter (mm)	1.23	1.02–1.52	0.04
Right pulmonary artery diameter (mm)	0.71	0.66–0.92	0.02
Cardiothoracic ratio (mm)	1.00	0.07–1.99	0.25

OR, odds ratio; CI, confidence interval.

In on-pump patients, the duration of postoperative mechanical ventilation was 7 (5–11) hours in the non-AKI group and 9 (5–14) hours in the AKI group ($p = 0.02$). The ICU LOS was 1 (0–2) days in the non-AKI group and 2 (1–3) days in the AKI group ($p = 0.17$). The length of hospital stay was 10 (7–13) days in the non-AKI group and 11.5 (10–13) days in the AKI group ($p = 0.01$). Hospital charges were 116,000 (98,000–142,000) RMB and 137,000 (119,000–156,000) RMB, respectively ($p = 0.03$).

Discussion

Previous research has scarcely explored the prognostic value of AAD for postoperative AKI in cardiac surgery [3,16,18]. This study is the first to assess the prognostic value of AAD for AKI. We retrospectively analyzed preoperative and intraoperative data, employed methods to minimize confounding factors, and established the prognostic significance of AAD for AKI after cardiac surgery in adult patients, particularly in on-pump procedures. The principal finding is that higher preoperative AAD is associated with an increased risk of AKI postoperatively. In addition, additional independent risk factors include female, lower albumin levels, longer CPB duration, larger left atrial anteroposterior diameter, larger left pulmonary artery diameter, and smaller right pulmonary artery diameter. AAD showed higher significance in on-pump patients subgroup.

In this study, the incidence of postoperative AKI was 10.41% in the whole cohort, aligning with the range re-

Table 3. Univariate analysis results of on-pump patients.

	Non-AKI (n = 307)	AKI (n = 44)	p
Age (y)	56.82 ± 12.33	61.73 ± 9.59	0.01
Gender			0.02
Male	228 (74.27%)	25 (56.82%)	
Female	79 (25.73%)	19 (43.18%)	
Body mass index (kg/m^2)	25.12 ± 3.4	25.85 ± 4.76	0.33
Coronary heart disease	180 (58.63%)	26 (59.09%)	0.95
Valvular disease	140 (45.60%)	21 (47.73%)	0.79
Aortic disease	33 (10.75%)	5 (11.36%)	0.80
Hypertension	193 (62.87%)	28 (63.64%)	0.92
Diabetes mellitus	110 (35.83%)	16 (36.36%)	0.95
Stroke	33 (10.75%)	5 (11.36%)	0.90
COPD	55 (17.92%)	8 (18.18%)	0.97
Hypercholesterolemia	141 (45.93%)	22 (50.00%)	0.61
Atrial fibrillation	72 (23.45%)	11 (25.00%)	0.82
Pulmonary hypertension	46 (14.98%)	7 (15.91%)	0.87
Surgery history	55 (17.92%)	8 (18.18%)	0.97
Hemoglobin (g/L)	139 (125, 157)	137 (124, 150)	0.82
Intraoperative infusion (mL)	770 (569, 970)	769 (609, 915)	0.76
Intraoperative blood loss (mL)	595.75 ± 81.17	588.89 ± 92.25	0.61
Creatinine (μmoI/L)	71.74 ± 13.49	78.21 ± 16.09	0.52
Serum albumin (g/L)	41.27 ± 3.59	40.04 ± 3.04	0.03
Euroscore	3 (2, 4)	4 (2, 5)	0.46
Intraoperative lowest MAP (mmHg)	89.92 ± 20.01	86.99 ± 21.45	0.71
CPB time (min)	114.29 ± 19.24	133.36 ± 16.23	0.06
Intraoperative lowest temperature (°C)	27.22 ± 1.79	29.86 ± 2.5	0.24
Operative time (min)	322.77 ± 12.67	351.45 ± 13.28	0.16
Ejection fraction (%)	58.28 ± 7.84	57.9 ± 6.45	0.76
Aortic annulus diameter (mm)	21.99 ± 2.31	22.01 ± 2.48	0.85
Ascending aorta diameter (mm)	34.79 ± 5.56	36.96 ± 4.74	0.01
Left atrial anteroposterior diameter (mm)	39.35 ± 6.90	41.67 ± 10.25	0.15
Interventricular septum thickness (in diastole) (mm)	10.58 ± 2.62	10.46 ± 2.40	0.77
Right ventricular anteroposterior diameter (mm)	24.44 ± 4.14	23.95 ± 4.06	0.46
Main pulmonary artery diameter (mm)	24.46 ± 3.25	25.23 ± 3.84	0.15
Left pulmonary artery diameter (mm)	15.23 ± 2.36	16.11 ± 2.88	0.09
Right pulmonary artery diameter (mm)	15.79 ± 3.06	14.79 ± 3.4	0.03
Cardiothoracic ratio (mm)	0.51 ± 0.09	0.48 ± 0.06	0.53

ported in previous studies [19]. Both univariate and multivariate analyses confirmed the predictive value of preoperative AAD for the occurrence of postoperative AKI.

In the overall cohort of 442 patients, multivariate logistic regression identified AAD as a prognostic factor for postoperative AKI. The results indicated that gender, serum albumin, and CPB time are risk factors for postoperative AKI after cardiac surgery, consistent with previous research. However, this study primarily examined the predictive value of cardiac ultrasound findings and did not encompass all pertinent factors.

In all patients, the prognostic value of AAD was statistically significant in both univariate and multivariate analyses. However, the ROC value of AAD for AKI was 0.61, suggesting its limited prognostic utility in the entire cohort. Consequently, further exploration of the cut-off value was deemed unnecessary. Additionally, no significant differences were found between models with and without AAD.

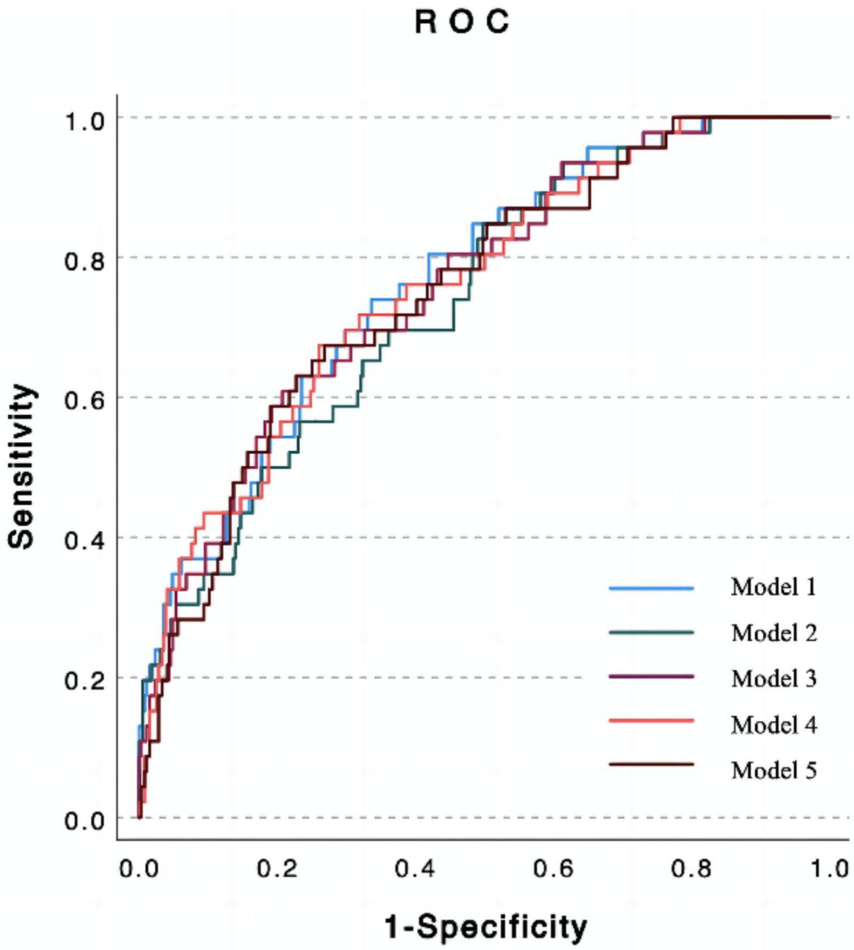
Patients undergoing CPB exhibited a higher risk of postoperative AKI, potentially introducing a confounding bias in the statistical analysis. Subgroup analysis of on-pump patients revealed that AAD retains prognostic significance in both univariate and multivariate analyses ($p < 0.05$), and enhanced the models significantly ($p < 0.05$). AAD demonstrated a higher AUC than CPB, indicating a superior prognostic value in this subgroup. Further studies are required to assess other confounding factors affecting AKI post-cardiac surgery.

Table 4. Multivariate analysis results of on-pump patients.

	OR	95% CI	*p*
Age (y)	1.03	0.97–1.07	0.42
Gender	1.38	1.14–1.95	0.04
Body mass index (kg/m^2)	1.10	0.97–1.21	0.11
Coronary heart disease	1.67	0.19–2.22	0.47
Valvular disease	1.87	0.27–2.71	0.82
Aortic disease	1.22	0.03–1.49	0.14
Hypertension	1.25	0.57–2.66	0.58
Diabetes mellitus	1.77	0.78–3.19	0.22
Stroke	1.76	0.25–2.33	0.66
COPD	1.27	0.62–2.65	0.42
Hypercholesterolemia	1.75	0.77–2.99	0.27
Atrial fibrillation	1.23	0.71–3.33	0.23
Pulmonary hypertension	1.31	0.67–2.31	0.35
Surgery history	1.43	0.42–1.98	0.61
Hemoglobin (g/L)	0.98	0.88–1.56	0.78
Intraoperative infusion (mL)	1.00	0.92–1.05	0.92
Intraoperative blood loss (mL)	1.00	0.97–1.01	0.28
Creatinine (µmol/L)	1.08	0.97–1.22	0.39
Serum albumin (g/L)	0.78	0.32–0.98	0.01
Euroscore	1.50	0.89–1.88	0.67
Intraoperative lowest MAP (mmHg)	0.78	0.67–1.24	0.47
CPB time (min)	1.03	1.01–1.09	0.04
Intraoperative lowest temperature (°C)	1.19	0.97–1.31	0.67
Operative time (min)	1.02	0.89–1.19	0.86
Ejection fraction (%)	1.00	0.94–1.06	0.88
Aortic annulus diameter (mm)	1.00	0.78–1.24	0.92
Ascending aorta diameter (mm)	1.14	1.04–1.26	0.02
Left atrial anteroposterior diameter (mm)	1.08	1.03–1.14	0.04
Interventricular septum thickness (in diastole) (mm)	0.97	0.81–1.16	0.71
Right ventricular anteroposterior diameter (mm)	0.92	0.86–1.13	0.81
Main pulmonary artery diameter (mm)	1.02	0.67–1.23	0.77
Left pulmonary artery diameter (mm)	1.18	0.97–1.49	0.13
Right pulmonary artery diameter (mm)	0.82	0.67–0.98	0.02
Cardiothoracic ratio (mm)	0.81	0.49–1.54	0.42

This study determined that in adult cardiac surgery patients, higher preoperative AAD values were associated with an increased risk of postoperative AKI. Under ultrasound examination, an AAD below 30 mm is considered normal, while a measurement exceeding 35 mm indicates dilation. An increase of 5 mm is diagnosed as dilation, representing a significant 10% relative expansion. Based on the average and standard deviation values of AAD in preoperative patients, those with an AAD exceeding 35 mm before surgery, particularly more than 3 mm above the average preoperative reference value of 34 mm, should receive careful intraoperative fluid and blood pressure management due to their elevated risk of postoperative AKI. The slight clinical difference in average AAD between the two groups was less than 3 mm, yet it was highly significant [20].

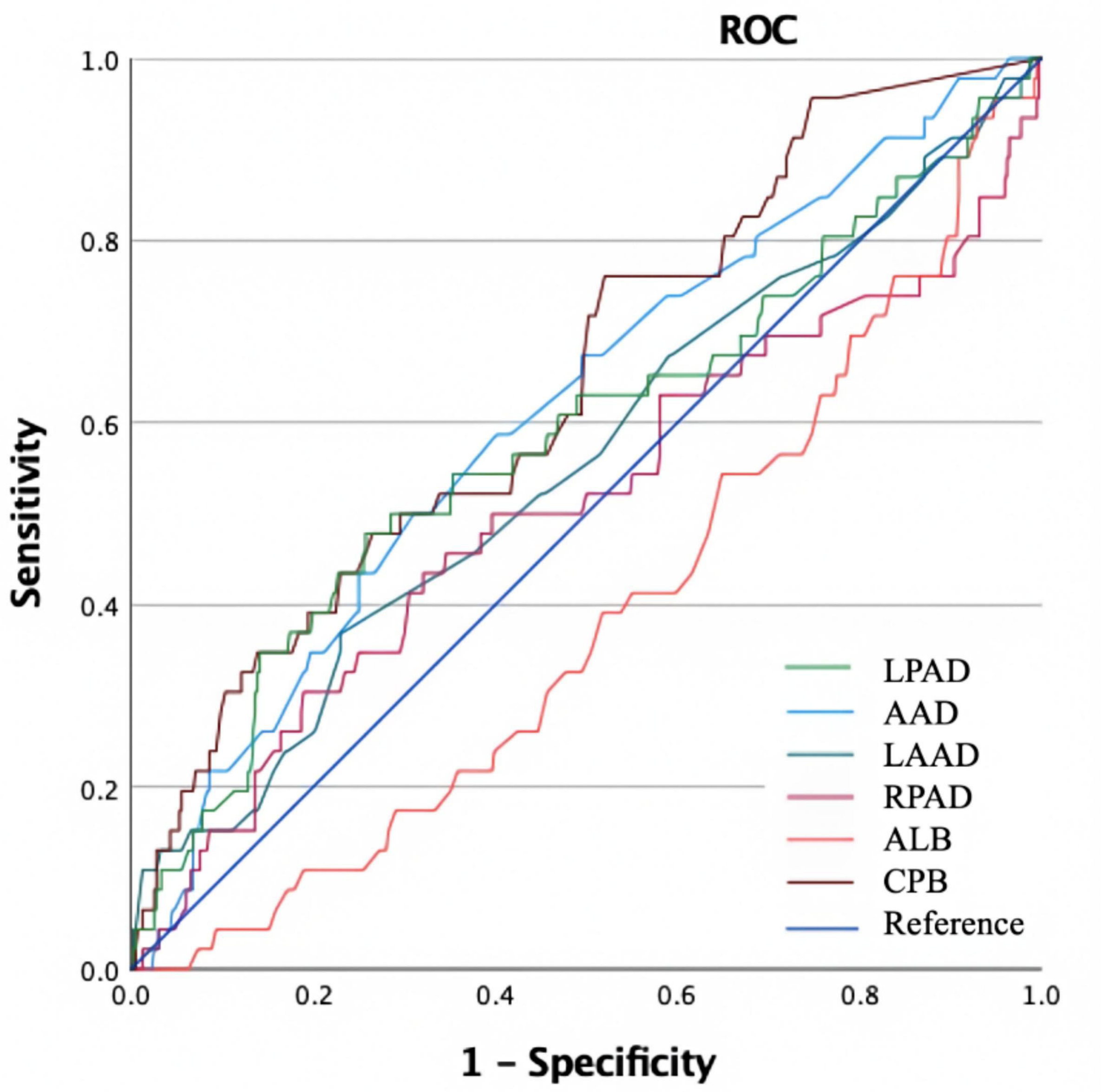
The potential mechanisms by which AAD may affect renal perfusion and contribute to AKI are multifaceted, stemming from various perioperative factors. The common denominator is reduced renal perfusion leading to renal injury. The ascending aorta, as the primary artery, supplies oxygen and perfusion to the kidneys [6], which receive 20% of the total cardiac output. The renal arteries stem from the ascending aorta, so its dilation may reflect changes in renal vascular function and compensatory capacity [15]. Cardiopulmonary bypass, associated with nonpulsatile flow, altered hemodynamics, reduced oxygen delivery, inflammation, and oxidative stress, can all contribute to AKI. Renal perfusion during CPB correlates directly with mean arterial pressure (MAP). AAD dilation might induce hemodynamic fluctuations, impacting renal perfusion and oxygenation. Furthermore, dilation may signal changes in the elasticity and structure of the arterial intima, indicative of a decline in medium-sized artery elasticity. Inflammation could also cause AAD dilation, reflecting reduced com-



	Model 1	Model 2	Model 3	Model 4	Model 5
AUC	0.77	0.74	0.76	0.76	0.75

	p	ΔAUC
Model 1 vs. Model 2	0.06	0.03
Model 1 vs. Model 3	0.48	0.01
Model 1 vs. Model 4	0.51	0.01
Model 1 vs. Model 5	0.39	0.02
Model 2 vs. Model 3	0.36	–0.02
Model 2 vs. Model 4	0.38	–0.02
Model 2 vs. Model 5	0.58	–0.01
Model 3 vs. Model 4	0.98	0.00
Model 3 vs. Model 5	0.79	0.01
Model 4 vs. Model 5	0.66	0.01

Fig. 1. Receiver-operating characteristic curves for 5 models in on-pump and off-pump patients. Model 1, gender + serum albumin + CPB time + AAD + LAAD + LPAD + RPAD. Model 2, gender + serum albumin + CPB time + LAAD + LPAD + RPAD. Model 3, gender + serum albumin + CPB time + AAD + LPAD + RPAD. Model 4, gender + serum albumin + CPB time + AAD + LAAD + RPAD. Model 5, gender + serum albumin + CPB time + AAD + LAAD + LPAD. CPB, cardiopulmonary bypass; AAD, ascending aorta diameter; LAAD, left atrial anteroposterior diameter; LPAD, left pulmonary artery diameter; RPAD, right pulmonary artery diameter; AUC, area under the curve; ROC, receiver-operating characteristic curves.

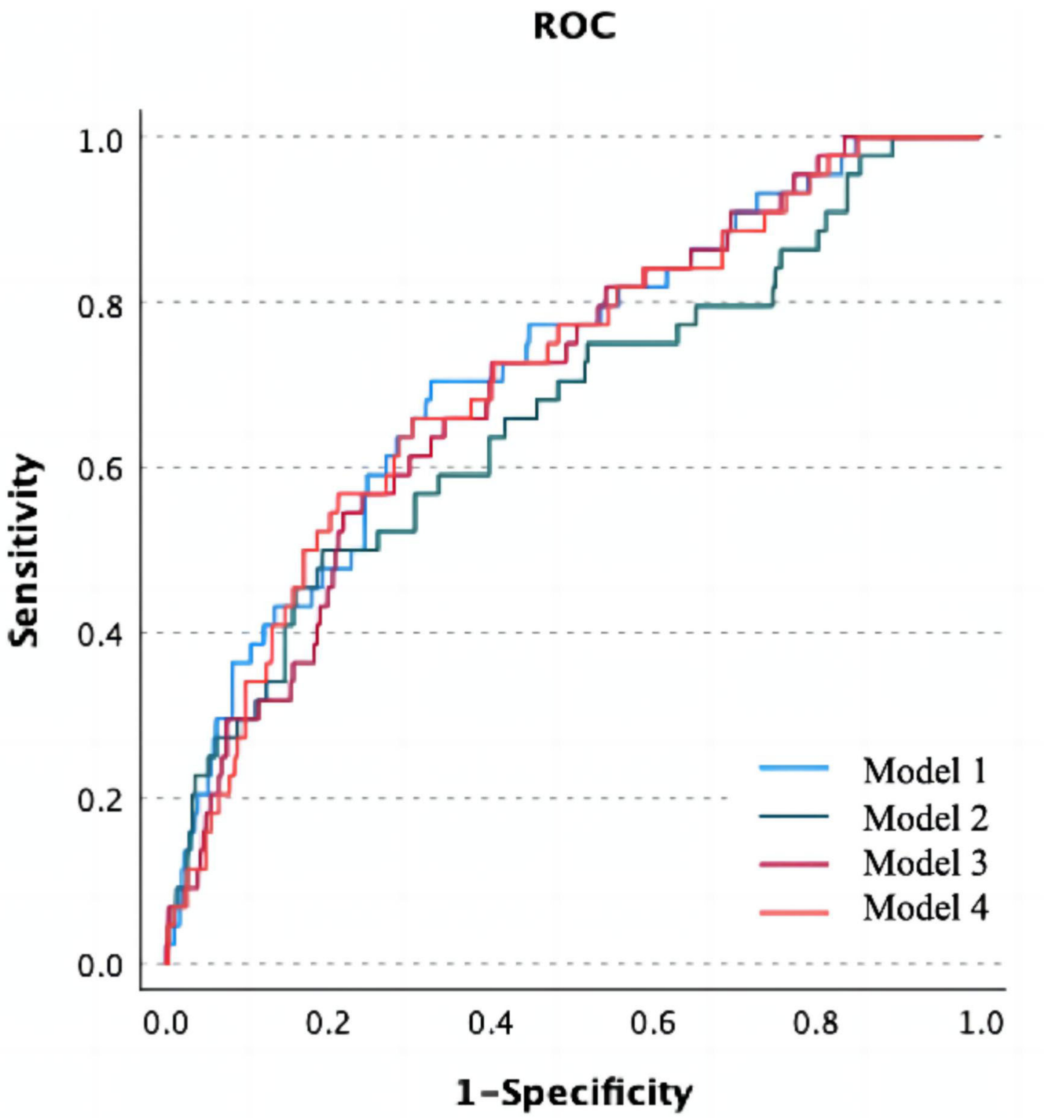


	LPAD	AAD	LAAD	RPAD	ALB	CPB
AUC	0.59	0.61	0.56	0.51	0.39	0.65

Fig. 2. Receiver-operating characteristic curves for individual risk factors in on-pump and off-pump patients. CPB, cardiopulmonary bypass; AAD, ascending aorta diameter; LAAD, left atrial anteroposterior diameter; LPAD, left pulmonary artery diameter; RPAD, right pulmonary artery diameter; ALB, albumin.

pensatory capacity in arteries with intimal pathologies [21]. Therefore, preoperative AAD measurement is crucial, particularly for high-risk patients.

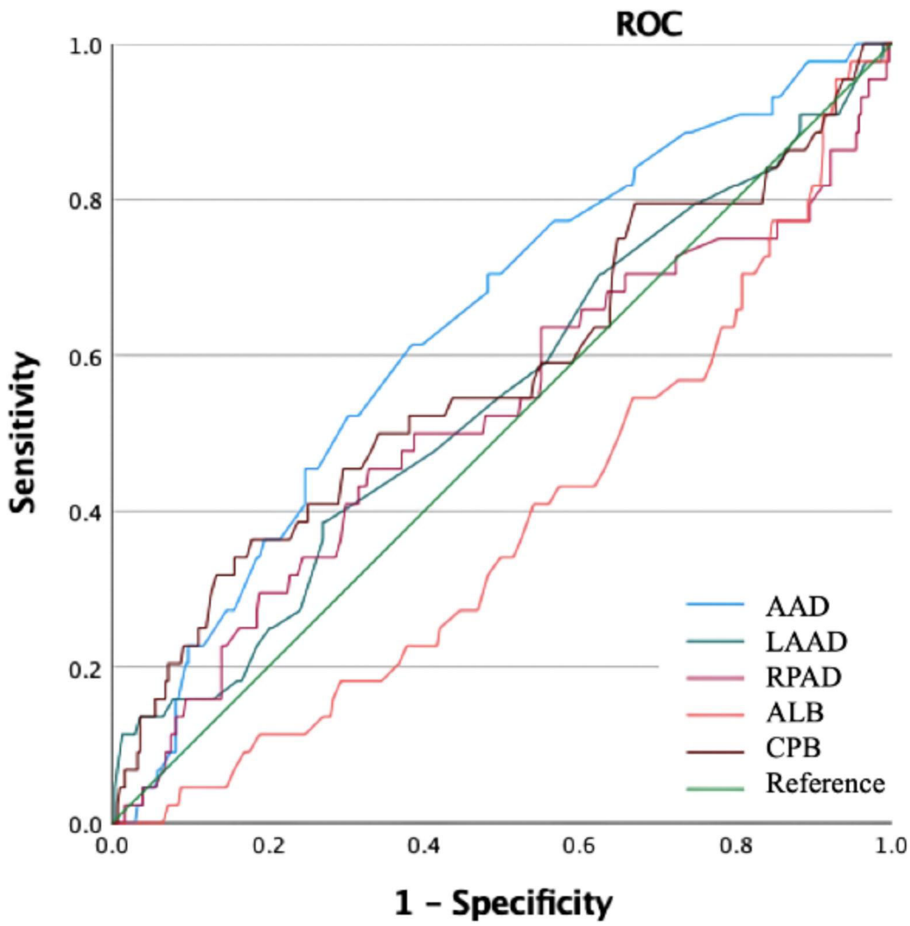
AKI is a common complication in cardiac surgery. The kidney is particularly sensitive to ischemia and hypoxia resulting from hemodynamic fluctuations during these procedures [15]. Consequently, the incidence of AKI is higher in cardiac surgery patients than in those undergoing other types of surgeries [16]. Patients with AKI require continuous monitoring and treatment to maintain organ function and stability, which results in prolonged mechanical ventilation, extended ICU stays, and longer hospitalizations, thereby increasing costs and impairing postoperative recovery [8]. This study examined the postoperative hospital outcomes for patients in both the AKI and non-AKI groups. It found that preoperative AAD dilation impacts the structure and function of the renal artery and the oxygen supply to the kidneys through anatomical, pathological, and pathophysiological effects. Patients who underwent CPB exhibited a higher incidence of AKI, as preoperative AAD di-



	Model 1	Model 2	Model 3	Model 4
AUC	0.72	0.67	0.70	0.71

	p	ΔAUC
Model 1 vs. Model 2	0.03	0.05
Model 1 vs. Model 3	0.33	0.02
Model 1 vs. Model 4	0.48	0.01
Model 2 vs. Model 3	0.26	–0.03
Model 2 vs. Model 4	0.07	–0.04
Model 3 vs. Model 4	0.68	–0.01

Fig. 3. Receiver-operating characteristic curves for 4 models in on-pump patients. Model 1, gender + serum albumin + CPB time + AAD + LAAD + RPAD. Model 2, gender + serum albumin + CPB time + LAAD + RPAD. Model 3, gender + serum albumin + CPB time + AAD + RPAD. Model 4, gender + serum albumin + CPB time + AAD + LAAD. CPB, cardiopulmonary bypass; AAD, ascending aorta diameter; LAAD, left atrial anteroposterior diameter; RPAD, right pulmonary artery diameter.



	AAD	LAAD	RPAD	ALB	CPB
AUC	0.64	0.55	0.52	0.39	0.57

Fig. 4. Receiver-operating characteristic curves for individual risk factors in on-pump patients. CPB, cardiopulmonary bypass; AAD, ascending aorta diameter; LAAD, left atrial anteroposterior diameter; RPAD, right pulmonary artery diameter.

lation reduced renal compensatory capacity and increased stress from CPB, thereby elevating the risk of AKI. The occurrence of AKI diminishes the quality of postoperative recovery, underscoring the significance of preoperative ultrasound examination of AAD values for predicting patient outcomes. Patients with AAD dilation demonstrated poorer postoperative prognoses [8,16]. Additionally, patients who develop AKI during hospitalization often have poor long-term postoperative outcomes, highlighting the need for further studies to investigate the impact of AAD dilation on long-term prognosis [16].

The strengths of this study include a sufficient sample size that supports the evidence based on statistical calculations. It incorporated multiple potential factors affecting postoperative AKI and used univariate, multivariate, ROC, and subgroup analysis to control for confounding variables.

However, the study has several limitations. Firstly, it is retrospective and lacks certain data; for example, continuous central venous pressure was not available from electronic records, and cardiac index could only be monitored using specific equipment. Prospective studies are needed to address these issues by including and documenting postoperative hemodynamics, histories of vasoactive drug use, and other pre- or postoperative complications. Secondly, this is a single-center study with a limited sample size. Multi-center studies with larger samples, employing the same ultrasound examination techniques, are required to further validate the conclusions by assessing the relationship between preoperative ultrasound AAD values and postoperative AKI. Thirdly, this study focused solely on the prognostic value of AAD for postoperative AKI. Further research is necessary to enhance the understanding of AAD across different AKI classifications. Finally, long-term patient outcomes were not followed in this study. The significant impact of AKI on long-term prognosis calls for follow-up studies to explore the potential effects of AAD on patient outcomes.

Conclusion

In conclusion, AAD is a valuable preoperative cardiac ultrasound parameter for patients undergoing cardiac surgery, who typically receive such measurements preoperatively [4,5,7]. Higher preoperative AAD values are associated with an increased likelihood of postoperative AKI. AAD holds significant prognostic value for postoperative AKI in adult cardiac surgery patients, particularly those undergoing on-pump procedures.

Availability of Data and Materials

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Author Contributions

DD, DB, QL, and RA helped in the design ofthe work and drafting the manuscript. SY, YJ, and FY helped with critical suggestions for the trial design and statistical analyses. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

The study was carried out in accordance with the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Chinese Academy of Medical Sciences Fuwai Hospital (NO.2024-2272) and patients had previously signed a consent form for the use of their medical records for researches.

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Conflict of Interest

The authors declare no conflict of interest.

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