Original Article

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Decreased serum calcium levels predict severe complications after initial diagnosis in patients with acute type B aortic dissection: A retrospective cohort study

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SUMMARY: This study sought to investigate the temporal variations in serum calcium concentrations among patients with acute type B aortic dissection (ATBAD) following initial diagnosis, document the incidence of severe complications, and evaluate their potential associations. In this retrospective analysis, we examined 42 consecutive patients diagnosed with ATBAD at Zhejiang Hospital between April 2019 and April 2024. Serum-ionized calcium levels were measured at admission and 24 hours post-admission. Based on changes in calcium levels, patients were categorized into either the elevated or decreased groups. Univariate and multivariate logistic regression analyses were performed to compare clinical characteristics and assess the incidence of severe complications following the initial diagnosis. The study further explored the association between 24-hour serum calcium levels, their dynamic changes, and the occurrence of severe complications in patients with ATBAD. The results showed that the decreased group had a significantly higher frequency of severe complications, including mortality, cardiac complications, acute renal failure, and organ hypoperfusion ($P < 0.05$), while no significant differences were observed for neurological or pulmonary complications ($P > 0.05$). Logistic regression revealed that a decline in serum calcium levels within 24 hours was an independent risk factor for severe complications (OR = 16.722, $P = 0.03$). The receiver operating characteristic (ROC) curve showed an area under the curve (AUC) of 0.864. Decreased serum calcium concentration is an independent predictor of severe complications in ATBAD patients, significantly associated with mortality, cardiac complications, acute kidney injury, and inadequate organ perfusion. No significant correlation with neurological and pulmonary complications was observed.

Keywords: Acute stanford type B aortic dissection, serum calcium, severe complications

1. Introduction

Acute aortic dissection (AAD) is a time-critical cardiovascular emergency associated with significant morbidity and mortality if not promptly diagnosed and treated. Without prompt treatment, the majority of patients succumb within hours to days after onset, with a mortality rate of approximately 1%–20% within the first 24 hours and up to 75% within two weeks (*1*). Based on the extent of the dissection, Stanford type B aortic dissection is defined as a dissection that does not involve the ascending aorta, specifically extending distal to the left subclavian artery into the descending thoracic aorta and beyond. When the onset occurs within 14 days, it is termed acute type B aortic dissection (ATBAD) (*2*). ATBAD accounts for 25% to 40% of all AAD cases and is characterized by acute onset, rapid progression, and high mortality. Its elevated mortality rate and complex pathological mechanisms have long been focal points and challenges in cardiovascular research (*3*). Currently, the 5-year survival rate for pharmacological treatment of ATBAD is approximately 60%, while the incidence of severe complications and mortality remains high (*4*). The underlying reasons include interruption of blood supply to specific vascular beds, such as the spinal cord, brain, heart, kidneys, intestines, or limbs. A cardinal pathophysiological hallmark of this condition is the localized inflammatory cascade, characterized

by inflammatory cell infiltration, extracellular matrix degradation, and phenotypic modulation of vascular smooth muscle cells (*5*). In recent years, someone (*6*) has also identified changes in inflammatory markers during the progression of AAD, suggesting a close and significant relationship between inflammation and AAD.

Recent evidence suggests that specific radiological features detected on computed tomography angiography (CTA) may serve as predictors for aortic-related adverse events (*7-9*). Nevertheless, the considerable financial burden and cumulative radiation exposure associated with serial CTA imaging often limit patient compliance with repeated examinations. Consequently, there is an urgent need to identify readily accessible, minimally invasive biomarkers with predictive value. In recent years, increasing studies have shown that changes in serum calcium ion levels are closely related to the occurrence and development of various cardiovascular and cerebrovascular diseases (*10-12*), yet their characteristics and clinical significance remain unclear. Calcium ions, as one of the essential ions for maintaining normal cellular functions and homeostasis, are closely involved in physiological processes such as cell membrane stability, nerve conduction, and myocardial contraction (*13*). Approximately 40% of total calcium in the blood circulation is bound to albumin, and thus influenced by albumin levels, necessitating the calculation of albumin-corrected serum calcium (*14*). Changes in serum calcium concentration and the occurrence and progression of aortic dissection may be related to multiple factors. Firstly, AAD is often accompanied by a severe inflammatory response, with the release of large amounts of inflammatory cytokines potentially leading to dysregulation of intracellular calcium metabolism, thereby causing a decrease in serum calcium levels (*15*). Secondly, AAD can result in impaired tissue perfusion and organ dysfunction, which may also affect the regulation and balance of calcium ions (*16*). Additionally, someone (*17*) has found an association between serum calcium levels and postoperative prognosis in AAD patients; low serum calcium levels may serve as an independent risk factor for poor prognosis, being related to extended hospital stays, increased incidence of complications, and other adverse outcomes. These findings suggest that calcium ions play an important role in maintaining cellular functions and regulating inflammatory responses. Currently, there is a lack of clinical evidence to elucidate the relationship between the decrease in serum calcium levels upon initial presentation and the occurrence of severe complications in ATBAD patients.

This study aims to conduct a retrospective observational analysis of the dynamic monitoring of serum calcium levels in ATBAD patients upon initial presentation, along with an integrative analysis of their clinical data and adverse events. This approach is not only expected to enhance our understanding of the underlying mechanisms of ATBAD development but also provide novel insights for optimizing clinical management strategies for this disease. Furthermore, the study offers crucial leads for exploring novel biomarkers and risk predictors for ATBAD, thereby providing a more accurate and effective foundation for improving patient outcomes and enhancing their quality of life. Collectively, our findings provide novel insights that may facilitate early recognition, risk stratification, and individualized therapeutic strategies for severe complications in patients with ATBAD.

2. Methods

2.1. Ethical statement

This retrospective study was approved by the Ethics Committee of Zhejiang Hospital (approval No. 2024 Preliminary Trial (080K)). The study was conducted by the principles of the 1964 Declaration of Helsinki and its subsequent amendments or comparable ethical standards. Due to the retrospective nature of this study, the requirement for informed consent was waived by the Institutional Review Board.

2.2. Research design

This single-center, retrospective observational study analyzed consecutive patients with confirmed ATBAD who presented to Zhejiang Hospital between April 2019 and April 2024. The inclusion criteria were as follows: (1) a diagnosis of ATBAD confirmed by computed tomography angiography (CTA) and magnetic resonance imaging (MRI), with symptom onset within the past 14 days; and (2) age ≥18 years. The exclusion criteria included: (1) the presence of connective tissue diseases, pregnancy, or traumatic dissection; (2) a history of aortic dissection surgery or concurrent surgical procedures; (3) comorbid conditions such as thyroid disorders, end-stage renal disease, severe infections, hematologic diseases, or malignant tumors; (4) long-term use of medications that could influence blood test results; and (5) incomplete medical records.

All eligible patients initially received standardized medical management. Calcium supplementation was withheld in patients presenting with hypocalcemia. In cases where major complications developed during conservative management, thoracic endovascular aortic repair (TEVAR) or conventional open surgical intervention under general anesthesia was indicated. Patients who refused surgical intervention continued with optimal medical therapy.

2.3. Study size and bias

In this study, we reviewed data from 42 patients with ATBAD. As this was a retrospective study, we had no

control over the choice of study design and sample size. Therefore, we cannot calculate a definite sample size based on pre-set models and assumptions.

We take steps to reduce bias, including standardized data collection, data validation, statistical analysis, and training of researchers. Nevertheless, there is a risk of selection bias, information bias, and statistical analysis bias. We will consider these potential sources of bias when interpreting the results.

Due to the small sample size, we need to interpret the results carefully and take into account potential biases and limitations. The results of this study may not apply to all acute aortic dissection patient populations, and further studies are needed to confirm and extend these findings.

2.4. Data collection

Data collection included baseline patient information and variables of interest following hospital admission. Patient demographics, disease-related details, and laboratory findings were extracted from the electronic medical record system. Demographic data included age, sex, smoking history, and alcohol consumption history, while disease-related information encompassed comorbidities such as hypertension and diabetes. Laboratory parameters collected at admission included hemoglobin, C-reactive protein (CRP), albumin, D-dimer, and serum levels of calcium, potassium, sodium, and chloride. Serum calcium levels were also measured 24 hours post-admission. For this study, blood test indicators were based on measurements obtained at admission and 24 hours thereafter.

Blood samples were analyzed using standard clinical methodologies. Specifically, hemoglobin and high-sensitivity CRP levels were quantified using a fully automated hematology analyzer (Model BC-6800, Mindray Bio-Medical Electronics Co., Ltd., Shenzhen, China). D-dimer levels were measured with a fully automated coagulation analyzer (Model STA-R MAX, Stago, China). Additionally, serum concentrations of albumin, potassium, sodium, chloride, and calcium were measured with a fully automated biochemical and immunoassay analyzer (Model cobas 8000, Roche Diagnostics GmbH, China). For vascular imaging, a 64-slice CT scanner (Model NeuViz Epoch, Neusoft Medical Systems, China) was utilized. To enhance vascular visualization, a non-ionic contrast agent (Iopromide Injection, 100 mL: 76.89 g, Bayer) was administered intravenously. Furthermore, magnetic resonance imaging was conducted on a 3.0 Tesla scanner (Model SIGNA™ Premier Evo 3T, GE HealthCare, USA), where T1-weighted and T2-weighted images were acquired using standard protocols.

The occurrence of serious complications during conservative medical treatment for ATBAD patients was recorded (*18*). These complications included in-hospital all-cause mortality, cardiac-related complications (such as new-onset arrhythmias, heart failure, acute pericardial tamponade, and acute coronary syndrome), neurological complications (including cerebrovascular accidents and ischemic spinal cord injury), pulmonary complications (including pulmonary embolism and respiratory failure), acute kidney injury (AKI), and other organ perfusion disorders (including bowel necrosis, hepatic or splenic infarction, and acute lower limb ischemia/necrosis). Acute kidney injury (AKI) (*19*) was characterized by an increase in serum creatinine (Scr) of at least 0.3 mg/dL within 48 hours or a 1.5-fold rise from baseline within seven days. Hypocalcemia (*20*) was defined as a total serum calcium concentration of less than 2.12 mmol/L, assuming normal plasma protein levels. The albumin-corrected calcium was determined using the equation: total calcium + 0.019 * (49 - albumin).

2.5. Statistical analysis

SPSS 26.0 software was used for data analysis, with $P \leq 0.05$ considered statistically significant. Patients were categorized into "increased" and "decreased" groups based on their serum calcium ion concentrations 24 hours post-admission. The Shapiro-Wilk test was applied to assess the normality of the measurement data. Data following a normal distribution are presented as mean ± standard deviation (SD), and the *t*-test was employed for analyzing continuous variables. The chi-square test was used to evaluate categorical variables. For non-normally distributed data, the Mann-Whitney *U* test was utilized, and results are presented as median (interquartile range, IQR). Categorical data expressed as percentages were analyzed using the chi-square test. To identify risk factors, univariate and multivariate logistic regression analyses were performed to examine the effects of sociodemographic factors, disease-related data, and laboratory results on adverse outcomes while controlling for confounding variables. The correlation between influencing factors and the impact of changes in blood calcium concentration on adverse outcomes was determined by calculating odds ratios (OR) and 95% confidence intervals (CI). Furthermore, the area under the receiver operating characteristic (ROC) curve was used to evaluate the model's discriminative ability, and likelihood ratio tests along with calibration curves were utilized to assess the model's calibration.

2.6. Patient and public involvement

Neither patients nor members of the public were involved in the study design, conduct, reporting, or dissemination plans of this research.

3. Results

3.1. Comparison of baseline characteristics between groups

Among the 75 patients with AAD treated at our hospital, 20 were diagnosed with acute type A aortic dissection (AAAD) and 55 with ATBAD. This observational retrospective study initially included 42 ATBAD patients who met the inclusion criteria. After adjustments, 13 patients were identified with hypocalcemia upon admission, while 31 developed hypocalcemia within 24 hours post-admission. Based on changes in serum calcium levels from admission to 24 hours later, patients were categorized into two groups: the "decreasing" group (n = 29) and the "increasing" group (n = 13). There were no significant differences between the groups regarding sex, age, alcohol consumption, smoking history, history of diabetes, or history of hypertension (P > 0.05). Similarly, there were no statistically significant differences in baseline laboratory parameters, including hemoglobin, CRP, D-dimer, albumin, serum sodium, serum potassium, and serum chloride concentrations (P > 0.05) (Table 1). This indicates that the baseline characteristics of the two groups were comparable.

3.2. Comparison of severe complications after initial diagnosis between groups

No statistically significant differences were observed between the two groups regarding neurological and pulmonary complications (P > 0.05). However, significant differences were observed in the incidence of in-hospital all-cause mortality (27.6% *vs*. 0%), cardiac complications (31.0% *vs*. 0%), acute kidney injury (48.3% *vs*. 7.7%), and other organ perfusion disorders (44.8% *vs*. 7.7%) (P < 0.05). In the increasing group, 5 patients (38.5%) experienced severe complications, whereas 27 patients (93.1%) in the decreasing group developed severe complications. The difference between the two groups was statistically significant (P < 0.05) (Table 2).

3.3. Univariate and multivariate analysis

Relevant risk factors were used as the independent variable, and the occurrence of severe complications after initial diagnosis was considered the dependent variable. Initially, univariate logistic regression analyses were performed for all potential variables. Subsequently, variables demonstrating statistical significance (P < 0.05) in the univariate analysis were entered into a multivariate logistic regression model to identify independent risk factors. The analysis revealed that early changes in serum calcium levels were an independent risk factor for severe complications after initial diagnosis. Compared to the group with increased calcium levels, patients in the decreased calcium group had a significantly higher risk of developing severe complications after initial diagnosis (OR = 16.722, 95% CI = 2.545–109.877, P = 0.03) (Table 3).

3.4. Model discrimination and calibration

The ROC curve was generated based on the prediction model, resulting in an area under the curve (AUC) of 0.864 (95% CI: 0.751–0.977, P = 0.001), the Youden index was 0.644, the sensitivity was 84.4%, the specificity was 80.0%, and the best cutoff value was 0.0250. This indicates that the model has strong discriminative ability. The ROC curve for the prediction model is presented in Figure 1. Furthermore, the likelihood ratio test yielded a χ^2 value of 16.347 (P <

Table 1. Clinical data categorized by changes in serum calcium levels

Clinical features	Total n = 42	Decreased group n = 29	Increased group n = 13	Statistical value	P-value
Age (years)	59.29 ± 16.10	59.10 ± 14.69	59.69 ± 19.54	t = 0.108	0.914[a]
Gender [n(%)]				χ^2 = 0.116	0.733[c]
Male	36 (85.71)	24 (82.75)	12 (92.31)		
Female	6 (14.29)	5 (17.24)	1 (7.69)		
Smoking [n (%)]	17 (40.48)	11 (37.93)	6 (46.15)	χ^2 = 0.252	0.616[b]
Drinking [n (%)]	14 (33.33)	9 (31.03)	5 (38.46)	X^2 = 0.014	0.906[c]
Hypertension [n (%)]	31 (73.81)	23 (79.31)	8 (61.54)	χ^2 = 0.691	0.406[c]
Diabetes mellitus [n (%)]	6 (14.29)	5 (17.24)	1 (7.69)	X^2 = 0.116	0.733[c]
Hb on admission (g/L), mean (SD)	137.55 ± 27.11	138.48 ± 28.00	135.46 ± 26.00	T = -0.330	0.743[a]
CRP on admission (mmol/L), median (IQR)	4.96 (18.97)	3.93 (27.89)	9.51 (13.64)	Z = 2.119	0.145[d]
D-dimer on admission (mmol/L), median (IQR)	3.27 (1.52, 13.07)	4.02 (1.70, 20.00)	2.33 (0.74, 10.08)	Z = 1.079	0.299[d]
Albumin on admission	37.92 (38.17, 46.33)	41.71 ± 5.82	38.29 (33.35, 46.81)	Z = -0.639	0.523[d]
Serum potassium on admission (mmol/L), mean (SD)	3.47 ± 0.35	3.40 ± 0.06	3.63 ± 0.40	T = 2.012	0.051[a]
Serum sodium on admission (mmol/L), mean (IQR)	139.64 (138.39, 141.92)	139.70 (138.57, 142.25)	139.32 (136.77, 140.58)	Z = 1.041	0.308[d]
Serum chloride on admission (mmol/L), mean (IQR)	105.75 (103.78, 107.55)	106.10 (104.25 , 107.65)	104.00 (101.60 , 107.10)	Z = 2.986	0.084[d]

[a]Independent samples t-test, [b]Pearson's chi-squared test, [c]Calibration Pearson's chi-square test, [d]Mann-Whitney U test.

Table 2. Comparison of severe complications based on serum calcium level changes

Prognostic outcome	Total $n = 42$	Decreased group $n = 29$	Increased group $n = 13$	*P*-value
All deaths in the hospital [*n* (%)]	8 (19.05)	8 (27.59)	0 (0.00)	0.043[b]
Cardiac complications [*n* (%)]	9 (21.43)	9 (31.03)	0 (0.00)	0.038[b]
Neurological complications [*n* (%)]	10 (23.81)	9 (31.03)	1 (7.69)	0.211[a]
AKI [*n* (%)]	15 (35.71)	14 (48.28)	1 (7.69)	0.029[a]
Pulmonary complications [*n* (%)]	15 (35.71)	11 (37.93)	4 (30.77)	0.921[a]
Poor perfusion of other organs [*n* (%)]	14 (33.33)	13 (44.83)	1 (7.69)	0.045[a]
Total[*n* (%)]	32 (76.19)	27 (93.10)	5 (38.46)	0.001[a]

[a]Calibration Pearson's chi-square test, [b]Fisher's exact test.

Table 3. Univariate and multivariate analysis of the severe complications group

Variables	Univariate model OR (95%CI)	*P*-value	Multivariate model OR (95%CI)	*P*-value
Gender	0.241 (0.040 - 1.461)	0.122		
Age	0.979 (0.937 - 1.023)	0.342		
Smoking	3.529 (0.646 - 19.280)	0.145		
Drinking	1.222 (0.263 - 5.682)	0.798		
Hypertension	4.333 (0.943 - 19.905)	0.059		
Diabetes mellitus	46210361.473 (46210361.473 - 46210361.473)	0.999		
Laboratory results				
Hb on admission	1.023 (0.995 - 1.051)	0.108		
CRP on admission	1.003 (0.975 - 1.031)	0.850		
D-dimer on admission	1.035 (0.942 - 1.138)	0.470		
Albumin on admission	1.122 (0.996 - 1.265)	0.058		
Serum potassium on admission	0.055 (0.004 - 0.719)	0.027	6.765 (0.446 - 102.511)	0.168
Serum sodium on admission	1.153 (0.899 - 1.478)	0.262		
Serum chloride on admission	1.146 (0.898 - 1.461)	0.273		
Serum calcium on admission	1629.822 (0.624 - 4258494.703)	0.065		
Serum calcium 24 hours of admission	0.000 (0.000 - 1.291)	0.057		
Changes in serum calcium after admission				
Increased group	ref		ref	
Decreased group	21.600 (3.501 - 133.278)	0.001	16.722 (2.545 - 109.877)	0.003

0.001), indicating a good fit of the calibration curve.

4. Discussion

AAD is a life-threatening medical emergency that often presents with hemodynamic alterations and structural changes in the aortic wall (*21,22*). Calcium ions, as an essential electrolyte in the body, play a crucial role in cardiovascular function and the stability of the vascular wall. This retrospective study aimed to evaluate the prognostic value of early serum calcium ion concentration changes within 24 hours of admission for predicting the occurrence of severe complications after initial diagnosis in patients with ATBAD. Using univariate and multivariate logistic regression analyses, we sought to explore the relationship between early serum calcium changes and adverse outcomes, providing insights into the occurrence and progression of severe complications in ATBAD patients and uncovering potential underlying mechanisms.

Our findings revealed that serum calcium levels in ATBAD patients within 24 hours of admission were generally lower than the normal range, suggesting that hypocalcemia may be a significant pathophysiological feature of this disease. This observation aligns with the study by Vianello *et al.* (*15*), which also indicated that hypocalcemia might be associated with the pathogenesis of AAD. Alterations in serum calcium levels may be associated with the inflammatory response in AAD, which is characterized by endothelial-mediated pro-inflammatory mechanisms. These mechanisms involve the release of various inflammatory mediators from injured vascular cells, including pro-inflammatory cytokines (such as interleukin-6 [IL-6]), pro-coagulant factors, and endothelial-derived factors (*15,23-25*). Hypocalcemia may also exacerbate AAD progression by impairing vascular smooth muscle cell (VSMC) function, increasing vascular wall fragility, and promoting dissection (*26,27*). This imbalance may lead to structural and functional abnormalities in the aortic wall, worsening the disease and increasing the risk of complications, ultimately affecting short-term prognosis. Previous research (*28*) has demonstrated that IL-6 can enhance the expression of calcium-sensing receptors (CaSR) in both the parathyroid glands and renal tissue, resulting in decreased serum calcium concentrations.

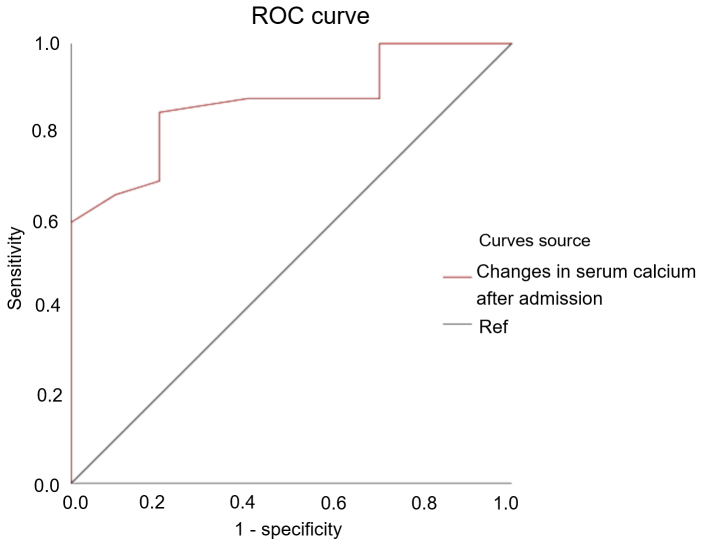

Figure 1. ROC curve of serum calcium level changes and the occurrence of severe complications after initial diagnosis in ATBAD patients. The presented figure illustrates the Receiver Operating Characteristic (ROC) curve for assessing the diagnostic performance of serum calcium changes following patient admission. The x-axis quantifies the false positive rate (1-specificity), while the y-axis represents sensitivity (true positive rate). The purple curve indicates the performance of the test, with values approaching the upper left corner reflecting superior discriminatory ability between positive and negative cases. The diagonal black line serves as a reference for a random classifier, suggesting the baseline performance. The area under the curve (AUC) is a critical metric for evaluating the test's accuracy; an AUC of 1 indicates perfect discrimination, whereas an AUC of 0.5 signifies no diagnostic value. This ROC analysis indicates that changes in serum calcium levels may provide clinically relevant diagnostic information, necessitating further investigation to establish their role in patient management.

Furthermore, inhibiting CaSR has been reported to benefit the cardiovascular system in COVID-19 patients, while calcium supplementation was found to be harmful (*29*). Serum calcium levels may also influence complications in ATBAD through effects on vascular tone and oxidative stress (*30,31*). *In vitro* studies show glutathione (GSH) relies on calcium for vasorelaxation *via* endothelial NO production. Low calcium might impair this, increasing vascular stress. Moreover, oxidative stress in conditions like Marfan syndrome shows disrupted GSH systems, suggesting similar issues in ATBAD, potentially worsened by calcium imbalances. Thus, maintaining calcium homeostasis could be crucial for managing ATBAD severe complications.

Given the dynamic changes in serum calcium levels, we performed a subgroup analysis, which revealed a strong association between these changes and the occurrence of severe complications after initial diagnosis. In this study, we selected mortality, cardiac, renal, pulmonary, neurological complications, and poor organ perfusion as indicators of severe complications in ATBAD patients after initial diagnosis (*18*), as these complications not only reflect the severe impact of dissection on vital organ function but also have significant prognostic value. Our results demonstrated that the incidence of severe complications was significantly higher in the hypocalcemia group compared to the hypercalcemia group ($P = 0.001$), particularly in terms of mortality ($P = 0.043$), cardiac complications ($P = 0.038$), acute kidney injury ($P = 0.029$), and poor organ perfusion ($P = 0.043$). This finding is consistent with previous studies, which have emphasized the regulatory role of calcium ions as a critical second messenger in cellular inflammation, influencing the activation of inflammatory cells, secretion of inflammatory mediators, and the overall inflammatory response. Serum calcium is also involved in regulating myocardial contraction and vascular endothelial function, with fluctuations in calcium levels being crucial for cardiovascular homeostasis. A drop in serum calcium can disrupt endothelial function and alter hemodynamics, contributing to the onset of AAD (*32-34*). Additionally, calcium serves as a crucial regulator in vascular smooth muscle cells (VSMCs) proliferation and apoptosis. Disruption of intracellular calcium homeostasis may lead to dysregulation of calcium-dependent proteins, subsequently promoting vascular calcification, increased arterial stiffness, and enhanced cellular adhesion. These pathological changes may ultimately contribute to the development of aortic dissection (*35*).

Moreover, mortality and AKI, both of which showed significant differences between the hypocalcemia and hypercalcemia groups, are consistent with existing literature. Wang *et al.* (*36*) identified low calcium concentrations as an independent predictor of all-cause mortality and proposed that calcium levels could potentially serve as a prognostic biomarker for assessing the severity of renal impairment in patients with AKI. Correspondingly, Bi *et al.* (*37*) revealed that hypocalcemia during intensive care unit (ICU) admission represents a high-risk factor for developing AKI. In this context, hypocalcemia can trigger the opening of

calcium channels in renal cells, facilitating calcium influx and subsequent cellular overload, thereby further exacerbating kidney damage (*38*). This cascade of events underscores the complex interplay between calcium dysregulation and renal cell injury.

These findings indicate that patients with persistently low or progressively decreasing serum calcium levels tend to have more severe conditions, with a higher incidence of severe complications and mortality. In contrast, patients whose serum calcium levels gradually return to normal tend to have more favorable clinical outcomes. The trend in serum calcium levels may serve as an important indicator of disease severity and prognosis in ATBAD patients. Dynamic monitoring of serum calcium levels could provide valuable insights for risk assessment and clinical decision-making.

The lungs, being the only organ that receives the entire cardiac output, are rich in neutrophils and act as a major filter for venous blood. AAD-induced lung injury has unique characteristics, with inflammation being a widely accepted mechanism of injury (*39,40*). This manifests as vascular endothelial cell (VEC) damage and increased microvascular permeability, leading to decreased compliance, increased intrapulmonary shunting, and refractory hypoxemia. Serum calcium levels may potentially modulate the integrity and permeability of the blood-brain barrier (BBB). Prior studies (*41*) have shown that hypocalcemia can disrupt cellular adhesion within the barrier. Prolonged extracellular calcium depletion increases neuronal apoptosis, exacerbating neurological damage and worsening patient outcomes (*42,43*). Notably, for postoperative complications, the incidence rates of both neurological and pulmonary complications were comparable between the two groups, with no statistically significant differences observed ($P > 0.05$). This discrepancy could be because serum calcium changes may not be the primary factor contributing to acute lung or neurological injuries, or the effects of serum calcium may be masked by other confounding factors.

Through comprehensive univariate and multivariate logistic regression analyses, we further established that a decline in serum calcium levels within the first 24 hours of admission serves as an independent predictor of severe clinical complications. Notably, statistical analysis did not confirm a significant association between two post-admission calcium concentrations and serious complications of aortic dissection ($P > 0.05$). In conclusion, in clinical practice, a single blood calcium level cannot effectively indicate or predict the possibility of serious complications in patients with aortic dissection. The statistically significant elevated odds ratio (OR) substantiates the robust association between early calcium level reduction and adverse clinical outcomes following initial diagnosis. This suggests that dynamic monitoring of serum calcium, especially downward trends, could serve as an early warning sign for the development of severe complications after initial diagnosis. Moreover, the constructed prediction model demonstrated high discriminatory power through ROC curve analysis (AUC = 0.864), confirming the clinical utility of serum calcium changes as a predictive marker. The model's good sensitivity and specificity further support its reliability and effectiveness, offering clinicians a tool to identify high-risk patients early and implement timely interventions.

This study acknowledges several methodological limitations inherent in its design, primarily arising from the constrained sample size and retrospective nature of the investigation, which potentially introduce selection and information biases. Within the current research framework, a comprehensive assessment of additional prognostic biomarkers and clinically relevant variables was not feasible, and the employment of a composite outcome metric for severe complications inevitably limits the granular analysis of individual clinical events. To mitigate these research constraints, future investigations should prioritize large-scale, multicenter prospective studies designed to validate the current findings, meticulously explore the nuanced relationship between serum calcium fluctuations and associated clinical complications, and systematically elucidate the complex pathophysiological mechanisms underlying calcium dysregulation in ATBAD.

5. Conclusion

In conclusion, early declines in serum calcium levels can serve as an independent risk factor for the development of severe short-term complications in ATBAD patients. This dynamic pattern may act as an early warning signal for the occurrence of severe complications after initial diagnosis and may also reflect key pathological mechanisms underlying the disease. These findings provide clinicians with a novel basis for assessing and predicting the progression of severe complications and surgical indications in ATBAD patients, thereby facilitating more precise risk stratification and personalized treatment strategies.

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