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Article

Risk Factors for Delayed Atrioventricular Block after Aortic Valve Surgery: A Retrospective Study

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Abstract

Objective: This study aimed to examine the potential factors that contribute to the occurrence of delayed high-grade atrioventricular block (DHAVB) following transcatheter aortic valve replacement (TAVR). **Methods**: A retrospective analysis was conducted on the clinical data of 115 patients who underwent TAVR at Jiaozhou Central Hospital of Qingdao Hospital between January 2018, and June 2023. A follow-up period of 30 days post-operation was observed for all patients. The patients were categorized into two groups on the basis of the occurrence of DHAVB: DHAVB group (n = 35) and control group (n = 80). The general clinical data preoperative and postoperative heart disease characteristics of the groups were compared. The risk factors associated with DHAVB after TAVR were analyzed. **Results**: The mean systolic blood pressure (SBP) level of the DHAVB group significantly increased compared with that of the control group, whereas the heart rate (HR) level significantly reduced ($p < 0.05$). The average preoperative left ventricular ejection fraction (LVEF) was significantly lower in the DHAVB group than in the control group ($p < 0.05$). The control group exhibited a significantly higher prevalence of preoperative QRS wave broadening, severe calcification of the aortic valve, and right bundle branch block than the control group ($p < 0.05$). Spearman's correlation and logistic regression analyses identified increased SBP, decreased HR, diminished LVEF, the presence of preoperative and postoperative right bundle branch block, and thickened interventricular septum were as risk factors for DHAVB in patients undergoing TAVR ($p < 0.05$). **Conclusion**: Close surveillance of blood pressure, heart rate, and cardiac function is recommended for individuals undergoing TAVR. Pre-operative and post-operative electrocardiography and echocardiography are valuable tools in identifying potential risk factors for DHAVB, offering a solid foundation for effective patient prognostic management.

Keywords

aortic valve; post-operation; atrioventricular block

Introduction

Transcatheter aortic valve replacement (TAVR) involves relocating the heart valve to the aortic valve area and inserting an interventional catheter through the tibial femoral artery to implant an artificial valve, thereby facilitating the restoration of cardiac valve function [1]. This surgical procedure has emerged as a primary approach for individuals afflicted with severe aortic valve stenosis or aortic insufficiency. It can be employed in patients dealing with aortic valve disease who are unsuitable for surgical valve replacement due to high-risk or surgical contraindications, ultimately enhancing their quality of life. Its clinical indications have gradually expanded to include patients at low surgical risk [2,3]. However, in the context of long-term clinical implementation of TAVR, complications related to cardiac block are commonly observed. Practitioners are particularly concerned about the emergence of left and right bundle branch block and atrioventricular block (AVB), requiring the use of pacing intervention. Delayed high-grade AVB (DHAVB) notably poses a significant threat to the life and wellbeing of patients [4–6]. These complications arise due to a multitude of factors, further exacerbating cardiac function decline in individuals with aortic valve stenosis. Consequently, this increase in heart failure and mortality risks negatively effect patient prognosis [7]. In addition, the incidence of DHAVB did not show any improvement despite advancements in the valvular system and surgical techniques, thus posing a challenge in promoting TAVR in surgically low-risk, younger individuals [8]. Therefore, obtaining effective strategies to evaluate and prevent the occurrence of DHAVB after TAVR treatment is crucial to enhance the prognosis of these patients. This study aimed to retrospectively analyze the clinical data and heart disease characteristics of patients who developed DHAVB following TAVR, identify potential risk factors with predictive value for DHAVB, and provide valuable insights for evaluating patient prognosis and implementing early interventions.

Table 1. Comparison of overall clinical data between the two groups.

Group	DHAVB group (n = 35)	Control group (n = 80)	t/χ^2	*p*
Age (years)	72.60 ± 2.67	72.50 ± 2.60	0.188	0.851
Gender			0.008	0.929
Male	20	45		
Female	15	35		
BMI (kg/m^2)	22.63 ± 1.06	22.81 ± 1.28	0.753	0.453
SBP (mmHg)	116.94 ± 5.40	111.99 ± 4.34	5.218	<0.001
DBP (mmHg)	76.17 ± 4.51	76.34 ± 3.65	0.209	0.835
HR (/min)	61.00 ± 3.99	65.14 ± 4.01	5.099	<0.001
Smoking history	19	38	0.448	0.503
History of cerebrovascular disease	8	14	0.452	0.502
Hypertension	11	21	0.325	0.569
Diabetes	4	8	0.053	0.818

DHAVB, delayed high-grade atrioventricular block; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate.

Table 2. Comparison of preoperative characteristics of heart disease between the two groups.

Group	DHAVB group (n = 35)	Control group (n = 80)	t/χ^2	*p*
LVEF (%)	51.59 ± 3.67	54.83 ± 2.95	5.009	<0.001
NYHA			0.198	0.656
I, II	19	47		
III, IV	16	33		
Intraventricular block	8	19	0.011	0.917
Sinus bradycardia	11	25	0.001	0.985
QRS broadening	16	21	4.227	0.040
Severe aortic valve calcification	15	19	4.269	0.039
Atrial fibrillation	3	8	0.057	0.811
Left bundle branch block	6	17	0.257	0.612
Right bundle branch block	7	5	4.925	0.026

LVEF, left ventricular ejection fraction; NYHA, New York Heart Association.

Methods

Data Sources

This study is a retrospective analysis, employing a combination of analytical and observational approaches. It focuses on inpatients who underwent TAVR treatment in Jiaozhou Central Hospital of Qingdao Hospital's Cardiology Department from January 2018, to June 2023. A total of 115 patients were included in the analysis. DHAVB is defined as the occurrence of second- or third-degree AVB more than 48 h post-TAVR without an alternative identifiable cause, persisting for at least 24 h, or necessitating pacemaker implantation: the patients were divided into two groups on the basis of whether the abovementioned conditions occurred within 30 days [9]: DHAVB group (n = 35) and control group (n = 80). A notable detail that in this study, a retrospective statistical analysis of pre-existing patient database records was solely performed. The patients/participants provided their written informed consent to participate in this study. A written informed consent was also obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Patients who meet the indications recommended in the 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease and underwent TAVR procedure at Jiaozhou Central Hospital of Qingdao medical facility; (2) individuals aged 18 years and above; (3) patients who were receiving their initial TAVR treatment; (4) fully documented pertinent clinical data and associated examination findings.

Exclusion criteria: (1) Admission to the hospital due to acute cardiovascular incidents like acute myocardial infarction and acute cerebrovascular disease; (2) sudden onset of heart failure; (3) prior occurrence of atrial fibrillation or atrial flutter; (4) presence of severe valve disease not suitable for TAVR treatment; (5) advanced stage kidney disease; (6) existence of systemic illnesses and cancerous growths like tumors; (7) presence of congenital heart de-

Table 3. Comparison of characteristics of preoperative hematological index between the two groups.

Group	DHAVB group (n = 35)	Control group (n = 80)	t/χ^2	*p*
Hb (g/L)	132.45 ± 20.35	133.25 ± 18.68	1.234	0.411
NEU (%)	74.23 ± 12.34	73.23 ± 14.23	1.935	0.073
K^+ (mmol/L)	3.97 ± 0.13	4.01 ± 0.15	1.421	0.325
LDL (mmol/L)	2.77 ± 0.45	2.69 ± 0.32	2.034	0.055
Scr (µmol/L)	82.35 ± 10.11	79.32 ± 12.03	1.931	0.075

Hb, hemoglobin; NEU, neutrophil ratio; K^+, serum potassium; LDL, low density lipoprotein; Scr, serum creatinine levels.

fects; (8) requirement for pacemaker insertion; (9) complication involving abnormal thyroid function or severe electrolyte imbalances.

Observed Index

Overall Clinical Data

The essential clinical information, including but not limited to age, gender distribution, body mass index (BMI), systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), smoking habits, history of cerebrovascular disease, hypertension, and diabetes, were meticulously gathered and meticulously scrutinized for comparative analysis between the two distinct groups.

Preoperative Characteristics of Heart Disease

The data on preoperative heart diseases were collected for comparison between the two groups. These heart diseases include left ventricular ejection fraction (LVEF), New York Heart Association (NYHA) grade, presence of intraventricular block, sinus bradycardia, broadening of QRS wave, severe calcification of aortic valve, atrial fibrillation, left bundle branch block, and right bundle branch block. The characteristics of these diseases were analyzed and compared between the two groups.

Characteristics of Preoperative Hematological Index

Prior to the operation, routine laboratory biochemistry and blood tests were conducted, encompassing parameters such as hemoglobin (Hb), neutrophil ratio (NEU), serum potassium (K^+), low density lipoprotein (LDL), serum creatinine levels (Scr), and other relevant factors.

Postoperative Characteristics of Heart Disease

Various attributes associated with heart diseases that occur following a surgical procedure were comparatively analyzed, specifically focusing on the measurements obtained through echocardiography and electrocardiogram after TAVR. These attributes include but are not limited to left ventricular posterior wall thickness, interventricular septum thickness, valve implantation, occurrence of atrial fibrillation, and the presence of left bundle branch block and right bundle branch block. A comprehensive understanding of the postoperative heart conditions can be obtained by examining and contrasting these characteristics.

Statistical Analyses

All data in this study were analyzed using IBM SPSS Statistics for Windows (version 28.0, IBM Corp., Armonk, NY, USA). The measurement data, which included the mean ± standard deviation, were expressed as ($\bar{x} \pm$ s). Statistical calculations were conducted using T-test. Categorical variables were expressed as frequencies (%) and compared using χ^2 test. The indices that exhibited differences between the two groups were further examined for their association with the risk factors of DHAVB after TAVR through Spearman's correlation and multivariate unconditional logistic regression analyses. $p < 0.05$ indicated statistically significant difference.

Results

Comparison of Overall Clinical Data among the Two Groups

Noteworthy disparities were observed in the average age, BMI, DBP, sex ratio, smoking history, history of cerebrovascular disease, history of hypertension, and history of diabetes between the two groups. However, a notable detail that the average SBP level in the DHAVB group was considerably higher than in the control group. Conversely, the HR level in the DHAVB group was significantly lower ($p < 0.05$, Table 1).

Comparison of Preoperative Characteristics of Heart Disease between the Two Groups

No notable variations were found in the preoperative NYHA grade, percentage of intraventricular block, occurrence of sinus bradycardia, occurrence of atrial fibrillation, and occurrence of left bundle branch block between the two groups. However, the average preoperative LVEF in the DHAVB group was notably lower than in the control group. Additionally, the proportion of broadened QRS wave, se-

Table 4. Comparison of the characteristics of postoperative heart disease between the two groups.

Group	DHAVB group (n = 35)	Control group (n = 80)	t/χ^2	p
Left ventricular posterior wall thickness (mm)	11.00 ± 0.66	10.50 ± 0.48	4.688	<0.001
Septal thickness (mm)	11.07 ± 0.60	10.54 ± 0.48	5.001	<0.001
Valve inserted too deep	15	28	0.642	0.423
Atrial fibrillation	9	19	0.051	0.821
Left bundle branch block	12	24	0.208	0.648
Right bundle branch block	15	18	4.931	0.026

Table 5. Correlation between differences between two groups and occurrence of DHAVB after TAVR.

Index	SBP	HR	LVEF	QRS broadening	Severe aortic valve calcification	Before treatment right bundle branch block	Left ventricular posterior wall thickness	Septal thickness	After treatment right bundle branch block
R	0.410	–0.427	–0.415	0.192	0.193	0.207	0.393	0.374	0.207
p	<0.001	<0.001	<0.001	0.040	0.039	0.026	<0.001	<0.001	0.026

TAVR, transcatheter aortic valve.

Table 6. Risk factors of DHAVB after TAVR.

Index	β	S.E.	Wald	p	OR (95% CI)
SBP	0.163	0.059	7.554	0.006	1.177 (1.048–1.322)
HR	−0.207	0.079	6.840	0.009	0.813 (0.696–0.949)
LVEF	−0.198	0.095	4.350	0.037	0.820 (0.681–0.988)
QRS broadening	0.440	1.253	0.123	0.725	1.553 (0.133–8.092)
Severe aortic valve calcification	0.822	0.738	1.240	0.265	2.275 (0.535–9.666)
Before treatment Right bundle branch block	1.322	0.626	4.458	0.035	3.750 (1.099–12.791)
Left ventricular posterior wall thickness	0.983	0.545	3.247	0.072	2.671 (0.917–7.778)
Septal thickness	1.572	0.631	6.208	0.013	4.816 (1.399–16.586)
After treatment Right bundle branch block	0.949	0.434	4.782	0.029	2.583 (1.103–6.048)

OR, odds ratio; CI, confidence interval.

vere calcification of aortic valve, and right bundle branch block were significantly higher in the DHAVB group ($p < 0.05$, Table 2).

Comparison of Characteristics of Preoperative Hematological Index between the Two Groups

No notable variations were observed in the levels of Hb, NEU, K^+, LDL, and Scr between the two groups ($p > 0.05$, Table 3).

Comparison of the Characteristics of Postoperative Heart Disease between the Two Groups

No notable disparities were identified in terms of the percentage of valve implantation, atrial fibrillation, and left bundle branch block between the two groups, with statistical significance ($p > 0.05$). However, the average left ventricular posterior wall thickness, interventricular septum thickness, and proportion of right bundle branch block in the DHAVB group were considerably greater than those in the control group ($p < 0.05$, Table 4).

Correlation between Differences between Two Groups and Occurrence of DHAVB after TAVR

The Spearman's correlation analysis revealed positive correlations between SBP, preoperative QRS wave broadening, severe calcification of the aortic valve, presence of right bundle branch block, postoperative thickness of the left ventricular posterior wall, interventricular septum thickness, and right bundle branch block in patients who underwent TAVR and the occurrence of DHAVB. Meanwhile, negative correlations were observed between HR and LVEF and DHAVB in the same group of patients ($p < 0.05$, Table 5).

Risk Factors of DHAVB after TAVR

The multivariate logistic regression analysis showed that higher SBP, lower HR, lower LVEF, preoperative and postoperative right bundle branch block, and thicker interventricular septum were risk factors for DHAVB after TAVR ($p < 0.05$, Table 6).

Discussion

With the advancing age of the population, the prevalence of valvular degenerative disorders is progressively increasing year after year. Among these disorders, aortic stenosis or incomplete closure is a frequently encountered valvular heart condition in the clinical setting [9,10]. Currently, aortic valve replacement stands as the primary therapeutic approach for patients afflicted with severe aortic insufficiency or stenosis. However, a significant proportion of these patients are elderly individuals who exhibit reduced surgical tolerance and susceptibility to other procedures. Moreover, the elderly population often presents with a diverse range of comorbidities, thereby limiting the clinical efficacy observed postoperatively [11,12]. Although the utilization of TAVR has greatly benefited patients with high risks or surgical contraindications, the potential occurrence of AVB at varying degrees following TAVR treatment is a concerning issue. This complication adversely affects the hemodynamic stability and prognosis, and, in severe instances, it can even pose a life-threatening risk to patients [13,14]. Therefore, the clinical characteristics of DHAVB following TAVR and the associated risk factors must be explored. Such undertakings hold tremendous significance in terms of effectively evaluating prognosis and implementing timely intervention measures.

In this investigation, the clinical characteristics of 115 patients who had TAVR was retrospectively analyzed. The findings demonstrated that increased SBP, diminished HR, reduced LVEF, the presence of preoperative and postoperative right bundle branch block, and increased thickness of the interventricular septum were risk factors for the development of DHAVB following TAVR. High SBP and low HR serve as indicators of abnormal hemodynamics within the cardiovascular system. Conversely, a low LVEF is often an indication of heart failure, impaired cardiac coordination, or a decrease in cardiac function. These conditions can induce arrhythmias and potentially result in the development of DHAVB. The presence of DHAVB has been associated with significant cardiovascular disruptions and can further exacerbate the existing hemodynamic abnormalities. Therefore, monitoring SBP, HR, and LVEF is crucial in evaluating the cardiac health status and predicting the risks associated with arrhythmias and DHAVB [15,16]. Kerola *et al.* [17] investigated the underlying causes of AVB and showed that a low LVEF level holds significant relevance as a crucially influential risk factor. This conclusion was reached by means of athrough a meticulous retrospective study, which encompassed a substantial sample size, thereby enhancing the robustness and reliability of its findings. While Kerola *et al.*'s study [17] did not explicitly focus on patients exhibiting DHAVB following TAVR, the convergence of their findings with those of the current study accentuates its clinical significance and highlights the consistent pattern observed across studies. Consequently, the inclusion of this relevant research further reinforces and strengthens the implications and applicability of the present study's outcomes within the broader context of cardiac research.

The relationship between the aortic valve and the cardiac conduction system in terms of anatomical adjacency serves as the foundation for the occurrence of abnormal conduction following TAVR. The His bundle, which courses through the central fibrous body to reach the membranous part of the interventricular septum, subsequently bifurcates the left bundle branch towards the left side, displaying minor variations in certain cases [18]. The His bundle lies in close proximity to the aortic valve, whereas the left bundle branch lies adjacent to the fibrous triangle's base, situated between the uncrowned valve and the right coronary valve. Throughout the process of inserting a guide wire, performing balloon dilatation, and implanting the valve, direct mechanical harm can be inflicted upon the conduction system, potentially resulting in various degrees of AVB due to subsequent outcomes such as edema, inflammation, and ischemia [19,20]. The right bundle exhibits a relatively slender morphology than the left bundle. It lies in proximity to the endocardium and receives blood supply from a single blood vessel. This particular arrangement renders the right bundle more susceptible to right ventricular pressure load and stretch injury of the interventricular septal muscle. This susceptibility predisposes individuals to the development of AVB [21]. The findings of the present study indicated that the presence of right bundle branch block either prior to or following TAVR serves as a risk factor for DHAVB. Remarkably, these results align with the previously established conclusion of Auffret *et al.* [22] who demonstrated a significantly higher incidence of postoperative conduction block and permanent pacemaker implantation in patients with pre-existing right bundle branch block [23].

Different statistical methods were applied to different factors in this study to control the interference of confounding factors on the results. Patient age and gender, which have been associated with increased risk of cardiac conduction issues post-TAVR [23], were adjusted in the logistic regression analysis to ensure they did not skew the association between identified risk factors and DHAVB. The influence of history of cerebrovascular disease and preoperative characteristics of heart disease was analyzed between the two groups [24]. Multivariate analysis was utilized to account for their potential confounding effect on the relationship between TAVR and DHAVB. The results reveal that after adjusting for these confounders, elevated systolic blood pressure, decreased heart rate, and reduced left ventricular ejection fraction remained significant predictors of DHAVB post-TAVR. This finding suggests that while confounding factors undoubtedly play a role in DHAVB development, the identified risk factors maintain a strong and independent association with DHAVB occurrence.

Prior research showed numerous factors capable of influencing the likelihood of postoperative conduction block in patients who undergo TAVR. For instance, Hamdan *et al.* [25] posit that a more profound level of valve implantation possesses the potential to diminish the risk of postoperative development of left bundle branch block to a certain extent [24]. Conversely, Vijayakumar *et al.* [26] argue that excessively deep valve implantation can trigger alterations in postoperative cardiac hemodynamics, thereby rendering the patient more susceptible to thrombosis and necessitating long-term administration of anticoagulants, which, in turn, increases the peril of atrial ischemia and delayed complete heart block [27]. Patients' clinical characteristics play a crucial role in their risk of developing new AVB or requiring permanent pacemaker implantation after TAVR [25,26,28–30]. These clinical characteristics include baseline conduction abnormalities, aortic valve calcification, diabetes, and a history of coronary artery bypass grafting. However, the present study did not find any statistically significant differences in the proportion of deep valve implantation or the prevalence rate of underlying diseases and previous treatment history between the two groups. A notable detail that this lack of significant differences may be attributed to the limited sample size of patients included in the study. Hence, further research with a larger sample size is needed to fully explore the relationship between these clinical characteristics and the risk of post-TAVR complications. Consequently, further research in this area is encouraged to enhance the reliability and applicability of the conclusions drawn.

While providing valuable insights into the risk factors for DHAVB following TAVR, this study has several limitations that must be acknowledged. First, the follow-up period of 30 days post-operation may not fully capture the long-term incidence and risk factors of DHAVB. Considering that DHAVB can manifest beyond this timeframe, a longer follow-up period could be instrumental in offering a more comprehensive understanding of long-term outcomes and risk factors associated with TAVR. Moreover, certain potential confounders, such as the type of valve used (balloon-expandable *vs.* self-expanding), the depth of valve implantation, and pre-operative medication use (e.g., beta-blockers or calcium channel blockers), were not comprehensively collected in the dataset. The absence of these data limits the ability to adjust for these variables in the statistical analysis, potentially affecting the robustness of the findings. Conducting multicenter, long-term follow-up, large-scale studies with comprehensive data collection could enable a more nuanced understanding of the factors contributing to DHAVB post-TAVR. Such studies could not only validate the findings of the present study but also potentially reveal additional insights into the prevention and management of DHAVB, thereby improving patient outcomes following TAVR.

Conclusion

The findings of this study provide valuable insights suggesting that patients undergoing TAVR must diligently observe and track their blood pressure, heart rate, and overall cardiac function. Additionally, patients are highly recommended to undergo thorough pre-operative and post-operative assessments, such as electrocardiogram and echocardiography, which are proven to be effective in assessing the presence of potential risk factors associated with DHAVB. These diagnostic procedures not only play a crucial role in confirming the existence of risk factors but also serve as a vital foundation for managing patient prognosis effectively.

Availability of Data and Materials

The original contributions presented in the study are included in the article, and further inquiries can be directed to the corresponding author.

Author Contributions

QW: designed the study, writing manuscripts and data processing. YT: data entry and writing manuscript. YJ: designed the study, draft touch-ups and guidance on writing. All authors contributed to the article and approved the submitted version. 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

The studies involving human participants were reviewed and approved by the Ethics Committee of Qingdao Fifth People's Hospital (approval no. 20171226). The patients/participants provided their written informed consent to participate in this study. A written informed consent was also obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article. The study was conducted in accordance with the Declaration of Helsinki.

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Conflict of Interest

The authors declare no conflict of interest.

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