Comparison of Staged and Concomitant Percutaneous Coronary Intervention in Patients Undergoing Transcatheter Aortic Valve Replacement: A Retrospective Cohort Study

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AIM: This study aims to compare the clinical outcomes of concomitant versus staged percutaneous coronary intervention (PCI) in patients with severe aortic valve disease and significant coronary artery stenosis undergoing transcatheter aortic valve replacement (TAVR).
METHODS: We retrospectively analyzed 180 patients with severe aortic valve disease and significant coronary artery stenosis who underwent TAVR with PCI during the same hospitalization. Patients were treated using either a concomitant strategy (PCI and TAVR performed on the same day) or a staged strategy (procedures performed on different days). Procedural success, valve hemodynamics, and perioperative complications were compared between strategies.
RESULTS: Overall procedural success was achieved in 168 of 180 patients (93.3%), without a significant difference between the concomitant and staged groups (92.2% vs. 97.4%, $p = 0.467$). Transvalvular pressure gradients decreased markedly after TAVR in both groups, from 81.7 (66.3, 99.6) mmHg to 20.0 (12.7, 24.8) mmHg in the concomitant group and from 75.2 (63.2, 97.8) mmHg to 14.9 (8.4, 27.3) mmHg in the staged group (both $p < 0.001$). Perioperative mortality occurred in 6 (4.3%) patients in the concomitant group and in none of the staged group ($p = 0.343$). Rates of permanent pacemaker implantation (1.4% vs. 0%), myocardial infarction (0.7% vs. 2.6%), major bleeding (2.1% vs. 0%), stroke (5.0% vs. 0%), and acute kidney injury (13.5% vs. 12.8%) were infrequent in both groups (all p-values > 0.05).
CONCLUSIONS: In this cohort, both concomitant and staged PCI strategies achieve high procedural success, and no statistically significant differences in early clinical outcomes are observed between the two strategies. Nevertheless, the definitive optimal timing of PCI remains to be elucidated by future large-scale studies with extended follow-up.

Keywords: aortic valve disease; coronary artery disease; percutaneous coronary intervention; transcatheter aortic valve replacement; hybrid cardiac procedures

Introduction

Transcatheter aortic valve replacement (TAVR) has become an alternative to surgical aortic valve replacement for the management of aortic valve disease across all risk categories [1,2]. The availability of both transfemoral and transapical access routes has expanded the applicability of TAVR, enabling the treatment of anatomically suitable patients with aortic stenosis (AS) and aortic regurgitation (AR).

Coronary artery disease (CAD) is commonly observed in patients undergoing TAVR, with an estimated prevalence ranging between 33.8% and 63.0%. The overlap is not an unexpected phenomenon, as aortic valve disease and CAD share many underlying etiological factors, including advanced age, atherosclerosis, dyslipidemia, diabetes mellitus, and hypertension [3]. The co-occurrence of CAD may adversely impact long-term prognosis after TAVR. According to the 2025 ESC/EACTS Guidelines, percutaneous coronary intervention (PCI) may be considered in those undergoing TAVR who have significant coronary artery stenosis (>70%) in proximal segments (Class IIb recommendation) [4].

Despite these recommendations, the most appropriate timing of PCI in relation to TAVR remains unclear. It is highly variable in contemporary practice, with certain medical centers performing PCI concomitantly and others favoring a staged strategy, with each approach offering potential procedural and clinical advantages; however, robust comparative evidence remains limited [5]. Therefore, the present study sought to compare the clinical outcomes associated with concomitant versus staged PCI in patients undergoing TAVR, with a particular focus on peri-procedural safety and early post-procedural clinical outcomes.

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Methods

Patient Enrollment and Study Design

This study retrospectively examined a cohort of 180 patients who underwent TAVR at Beijing Anzhen Hospital between September 2018 and September 2023. All individuals received either staged or concomitant PCI during the same hospitalization period. Patients included in the concomitant group underwent PCI and TAVR on the same day. Conversely, those who underwent the two procedures on separate days during the same hospitalization were categorized in the staged group. Diagnoses and procedures were defined according to the International Classification of Diseases-Tenth Revision (ICD-10) and Ninth Revision (ICD-9) [6], based on the data obtained from the institutional electronic medical record system.

Inclusion criteria for patient selection were as follows: (i) individuals diagnosed with severe aortic valve disease requiring surgical intervention, confirmed by preoperative echocardiography and found suitable for TAVR by the surgical team; (ii) the presence of at least one coronary artery stenosis of ≥70%, confirmed by preoperative coronary angiography or computed tomography angiography, qualifying criteria for coronary revascularization; and (iii) performance of both TAVR and PCI during the same hospital admission.

Exclusion criteria included: (i) patients with other clinically significant valvular diseases; (ii) those with comorbidities significantly affecting life expectancy (such as malignancy), incomplete clinical data, or unavailable in-hospital outcome records; and (iii) patients who declined follow-up or participation.

In this study, outpatient staged PCI procedures were not considered because a substantial proportion of staged coronary revascularization is performed at referring hospitals, limiting access to complete procedural and follow-up data. Restricting the study population to patients who received both procedures during the same hospitalization ensured data completeness and consistency in outcome assessment.

Data Collection and Definitions

Data for this study were primarily sourced from the electronic medical records system and routine follow-up records. Baseline demographic information, including age, sex, and body mass index, was collected for all patients. Clinical information included primary diagnoses, comorbidities, medical history, and preoperative laboratory and imaging tests. The number of coronary arteries affected and the degree of stenosis were identified by reviewing the coronary angiography reports. Perioperative data, including surgical records, laboratory markers, and echocardiographic findings, were extracted from inpatient medical records.

Clinical endpoints were defined according to established consensus criteria where applicable. Procedural outcomes were evaluated based on the Valve Academic Research Consortium (VARC)-3 framework [7]. Perioperative mortality was defined as death occurring during surgery or within 30 days postoperatively. Technical success for the TAVR procedure was defined as fulfillment of all the following conditions: absence of intraprocedural mortality, successful delivery and retrieval of the device, accurate deployment of a single transcatheter heart valve in the intended anatomical position, and no requirement for unplanned conversion to open surgery or occurrence of major complications related to the device, vasculature, or cardiac structure procedural process. Similarly, the technical success of PCI was defined as achieving a residual stenosis of less than 20% in the target lesion with restoration of Thrombolysis in myocardial infarction grade III flow, without device-related complications [8].

Serum creatinine and urine output were assessed for 7 days following TAVR, and acute kidney injury (AKI) was defined according to the "Kidney Disease: Improving Global Outcomes" (KDIGO) criteria [9]. Bleeding events were recorded as major events when they required clinical intervention.

The primary outcome of our study was a composite procedural success endpoint, defined by the authors based on the achievement of both TAVR and PCI procedural success and the absence of major early adverse events, including: (i) technical success of both TAVR and PCI procedures; (ii) absence of perioperative mortality; (iii) favorable hemodynamic performance at discharge, defined as a transvalvular gradient of <20 mmHg and less than moderate aortic regurgitation; (iv) no requirement for unplanned cardiac surgical interventions. Secondary outcome comprised individual rates of procedural complications, including permanent pacemaker implantation (PPI), periprocedural myocardial infarction, major bleeding events, stroke, and AKI.

Surgical Procedure

For patients undergoing the concomitant strategy, PCI was performed immediately before TAVR, and both procedures were performed in a hybrid operating room. The concomitant strategy and surgical workflow have been described previously [10]. After successful induction of general anesthesia, standard aseptic preparation and draping were performed, followed by systemic heparinization. The right common jugular vein was punctured, and a central venous catheter was inserted along with a 6F sheath. A temporary pacing lead was then advanced through the 6F sheath. PCI was performed according to the standard protocol (Fig. 1A).

Following completion of PCI in the concomitant group, TAVR was then performed during the same procedural session. For the transfemoral approach, percutaneous access to the common femoral artery was obtained under fluoroscopic and/or ultrasound guidance. For the transapical approach, a left thoracotomy was performed through the fifth intercostal space along the anterior axillary line to the mid-

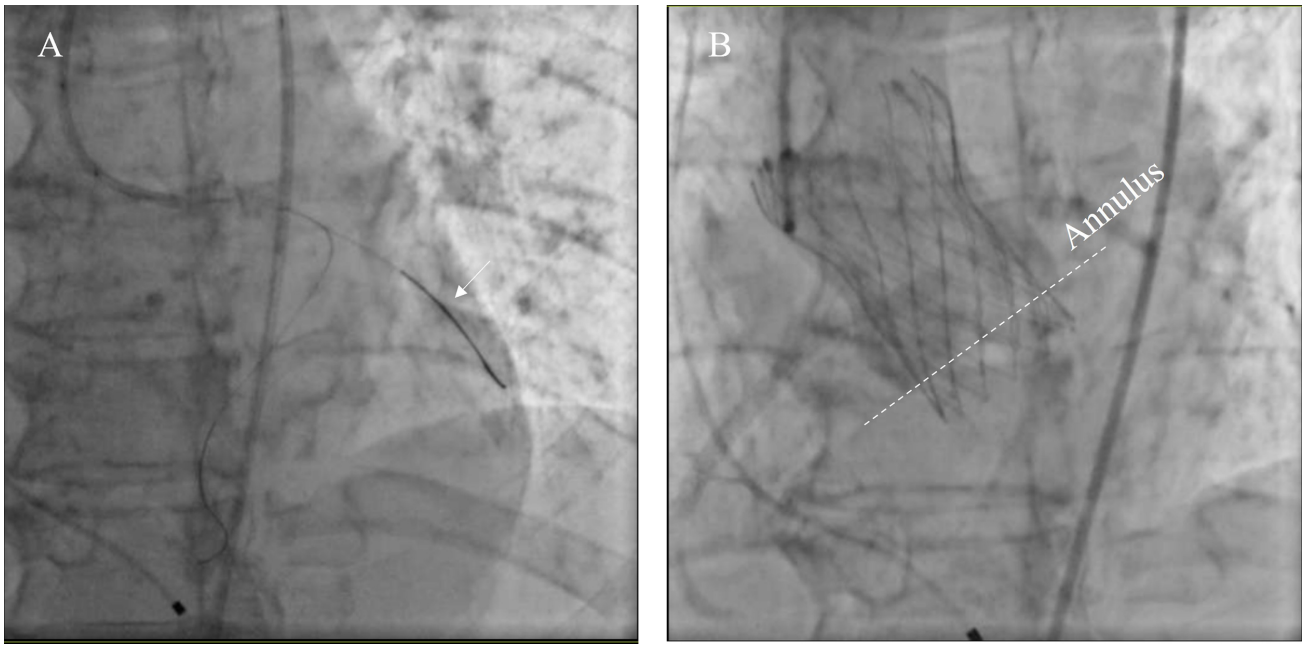

Fig. 1. Representative fluoroscopic images illustrating the concomitant percutaneous coronary intervention and transcatheter aortic valve replacement procedures. (A) Coronary angiography showing the guidewire crossing the target coronary lesion (arrow) during percutaneous coronary intervention. (B) Fluoroscopic image demonstrating the expanded transcatheter heart valve after deployment across the native aortic valve.

clavicular line. The epicardial fat was carefully dissected, and the pericardium was incised to expose the left ventricular apex. A double purse-string suture was placed using 3-0 Prolene with felt pledgets, avoiding the puncture site of the left anterior descending artery.

Subsequently, a guidewire was advanced across the aortic valve, followed by balloon dilation under rapid ventricular pacing at a rate of 120–180 beats per minute. Finally, the valve delivery system was advanced along the guidewire, and the transcatheter heart valve was deployed (Fig. 1B). Before removing the delivery system, transesophageal echocardiography was performed to assess the function of the prosthetic valve, confirming accurate positioning, normal leaflet motion, and absence of clinically significant paravalvular leak.

Follow-up

Follow-up information was obtained through outpatient clinic visits and review of the electronic medical record system. Patients were scheduled for follow-up at 1, 3, 6, and 12 months after the procedure, and annually thereafter. The follow-up period was calculated from the date of the index procedure to the most recent available recorded clinical evaluation. The follow-up deadline for this study was 18 December 2025. During each follow-up clinic visit, patients underwent an electrocardiogram and a transthoracic echocardiography (TTE) as part of routine clinical evaluation. Follow-up assessments aimed to record improvement in clinical symptoms and functional status, cardiac and valvular performance, and any adverse clinical outcomes, including death, stroke, PPI, and heart failure-related hospitalization.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA; version 27) and RStudio (version 2024.09.0+375, Posit Software, PBC, Boston, MA, USA).

Count data were presented as n (%), and inter-group comparisons were conducted using either Pearson's Chi-Square test or Fisher's Exact Test, as appropriate, depending on the sample size and the minimum expected counts. The normality of continuous variables was assessed using the Shapiro–Wilk test and visual inspection of histograms and Q–Q plots. Continuous variables following a normal distribution were expressed as mean ± standard deviation, and differences between two groups were assessed using the Student's *t*-test. Non-normally distributed continuous variables were presented as median with interquartile range (IQR), and comparisons between two groups were performed using the Mann-Whitney U test or the Wilcoxon rank-sum test. For within-group comparisons of echocardiographic parameters measured before and after TAVR, paired analyses were performed separately in the concomitant and staged groups.

Univariable logistic regression analyses were initially performed to evaluate the association between each variable and the occurrence of AKI. Variable selection for the multivariable model followed a two-step approach. First, variables were identified based on established clinical relevance

Table 1. Comparison of baseline characteristics between the concomitant and staged groups.

Characteristics	Concomitant group (n = 141)	Staged group (n = 39)	χ^2/Z/t value	*p*-value
Age, years	74.0 (70.0, 79.0)	73.0 (68.0, 78.0)	1.017	0.308
Male, n (%)	83 (58.9%)	26 (66.7%)	0.778	0.378
BMI, kg/m^2	24.2 (22.2, 27.4)	26.1 (23.6, 27.4)	–1.722	0.085
≥NYHA III, n (%)	99 (70.2%)	22 (56.4%)	2.641	0.104
Comorbidities, n (%)				
Hypertension	97 (68.8%)	29 (74.4%)	0.450	0.502
Diabetes mellitus	45 (31.9%)	9 (23.1%)	1.136	0.286
Atrial fibrillation	14 (9.9%)	1 (2.6%)	-	0.197
COPD	10 (7.1%)	2 (5.1%)	-	1.000
Peripheral artery disease	22 (15.6%)	5 (12.8%)	0.185	0.667
Smoking history, n (%)	24 (17.0%)	6 (15.4%)	0.059	0.808
Drinking history, n (%)	11 (7.8%)	4 (10.3%)	-	0.743
Diseased vessels, n	2.0 (1.0, 3.0)	3.0 (1.0, 3.0)	-	0.220
LM stenosis ≥50%, n (%)	15 (10.6%)	2 (5.1%)	-	0.372
Proximal LAD Stenosis ≥70%, n (%)	72 (51.1%)	20 (51.3%)	0.001	0.981
Previous PCI, n (%)	11 (7.8%)	4 (10.3%)	-	0.743
Previous cardiac surgery, n (%)	2 (1.4%)	0	-	1.000
Previous MI, n (%)	17 (12.1%)	3 (7.7%)	-	0.573
Hematocrit, %	36.6 ± 5.5	37.1 ± 6.3	–0.399	0.692
TnI, ng/L	20.1 (8.7, 85.7)	34.2 (15.4, 212.5)	–1.051	0.293
CK-MB, µg/L	2.2 (1.4, 3.1)	2.1 (1.7, 3.3)	–0.566	0.571
Serum creatinine, µmol/L	79.3 (66.2, 99.6)	81.0 (69.7, 105.4)	–0.706	0.480

Abbreviations: BMI, body mass index; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; LM, left main (coronary artery); LAD, left anterior descending (coronary artery); PCI, percutaneous coronary intervention; MI, myocardial infarction; TnI, Troponin I; CK-MB, Creatine Kinase-MB.

-, indicates that Fisher's exact test was used.

to AKI (e.g., age, baseline renal function) or biological plausibility, rather than relying solely on statistical significance in univariable analysis. This strategy was used to reduce the risk of omitting clinically important confounders. Second, given the limited number of AKI events, the number of covariates included in the multivariable model was deliberately restricted in accordance with the widely recommended guideline of approximately 10 outcome events per variable, thereby minimizing the risk of overfitting. Multicollinearity was assessed among included covariates, and no substantial multicollinearity was observed (all variance inflation factors <2). Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were reported. A two-sided *p*-value < 0.05 was considered statistically significant.

Results

Comparison of Baseline Characteristics Between the Two Groups

The baseline characteristics of 180 enrolled patients are presented in Table 1, including 141 patients in the concomitant PCI group and 39 in the staged PCI group. The median age was 74.0 (70.0, 79.0) years in the concomitant group and 73.0 (68.0, 78.0) years in the staged group ($p = 0.308$). Male patients accounted for 58.9% of the concomitant group and 66.7% of the staged group ($p = 0.378$).

Comorbidities were prevalent in this cohort, indicating the typical clinical profile of the patients undergoing TAVR. The prevalence of major comorbidities was comparable between the two groups, including hypertension (68.8% vs 74.4%, $p = 0.502$), diabetes mellitus (31.9% vs 23.1%, $p = 0.286$), atrial fibrillation (9.9% vs 2.6%, $p = 0.197$), chronic obstructive pulmonary disease (7.1% vs 5.1%, $p = 1.000$), and peripheral artery disease (15.6% vs 12.8%, $p = 0.667$). The median number of diseased coronary vessels for the two groups was 2.0 (1.0, 3.0) and 3.0 (1.0, 3.0), respectively. The distribution of coronary lesion characteristics was broadly similar between the two groups. Significant left main coronary artery stenosis (≥50%) was identified in 10.6% of patients in the concomitant group and 5.1% in the staged group ($p = 0.372$). Proximal left anterior descending artery stenosis ≥70% was present in 51.1% and 51.3% of patients, respectively ($p = 0.981$).

In the concomitant group, two patients had undergone open-heart surgery, specifically coronary artery bypass grafting (CABG) and mitral valve replacement. Furthermore, a prior history of PCI was observed in 11 patients in the concomitant group and 4 patients in the staged group ($p = 0.743$). Overall, baseline demographic characteristics, comorbidities, coronary anatomy, and preoperative laboratory parameters were comparable between the two groups,

Table 2. Comparison of preoperative echocardiographic findings between the two groups.

Characteristics	Concomitant group (n = 141)	Staged group (n = 39)	χ^2/*Z*/*t value*	*p*-value
Severe AS, n (%)	125 (88.7%)	32 (82.1%)	1.194	0.274
Peak aortic pressure gradient, mmHg	81.7 (66.3, 99.6)	75.2 (63.2, 97.8)	0.504	0.616
LVEF, %	61.0 (52.0, 65.0)	60.0 (54.0, 62.0)	0.534	0.593
LVEDD, mm	48.0 (44.0, 53.0)	50.0 (45.0, 56.0)	–0.534	0.593
LVESD, mm	32.0 (28.0, 37.0)	32.0 (29.0, 38.0)	–0.472	0.637
≥Moderate MR, n (%)	25 (17.7%)	2 (5.1%)	3.805	0.051

Abbreviations: AS, aortic stenosis; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; MR, mitral regurgitation.

with no statistically significant differences observed (all $p > 0.05$).

Comparison of Preoperative Echocardiographic Characteristics Between the Two Groups

The preoperative echocardiographic findings of the study cohort are summarized in Table 2. Severe aortic stenosis was observed in 88.7% of patients in the concomitant group and 82.1% in the staged group ($p = 0.274$). The median preoperative peak aortic valve pressure gradient was comparable between the two groups (81.7 [66.3, 99.6] mmHg vs. 75.2 [63.2, 97.8] mmHg, $p = 0.616$). Likewise, left ventricular systolic function was similar between groups, with a median left ventricular ejection fraction (LVEF) of 61.0% (52.0, 65.0) in the concomitant group and 60.0% (54.0, 62.0) in the staged group ($p = 0.593$). No significant differences were observed in left ventricular end-diastolic diameter (LVEDD) (48.0 [44.0, 53.0] mm vs. 50.0 [45.0, 56.0] mm, $p = 0.593$) or left ventricular end-systolic diameter (LVESD) (32.0 [28.0, 37.0] mm vs. 32.0 [29.0, 38.0] mm, $p = 0.637$).

More than moderate mitral regurgitation was found more frequently in the concomitant group than in the staged group (17.7% vs. 5.1%); however, this difference did not reach statistical significance ($p = 0.051$). Overall, preoperative echocardiographic parameters were comparable between the concomitant and staged groups, indicating a similar baseline cardiac profile before intervention.

Comparison of Surgical Outcomes Between the Two Groups

Table 3 summarizes the surgical outcomes across the study cohort. All procedures were completed without the need for conversion to open surgery, and PCI was successfully performed in all patients. Technical success was achieved in 139 of 141 patients (98.6%) in the concomitant group and in 38 of 39 patients (97.4%) in the staged group ($p = 0.522$). In the concomitant group, technical failure occurred in 2 patients. In 1 patient, premature released valve resulted in coronary obstruction, ultimately preventing the successful implantation of the transcatheter valve. In the other case, moderate paravalvular leak (PVL) occurred immediately after implantation and was successfully managed with PVL closure. In the staged group, one patient experienced suboptimal valve positioning after implantation of a 25-mm valve and was subsequently re-implanted with a 27-mm valve to reduce the risk of prosthesis-patient mismatch. Procedural success was achieved in 130 of 141 patients (92.2%) in the concomitant group and in 38 of 39 patients (97.4%) in the staged group ($p = 0.467$). In the concomitant group, failure to achieve procedural success was mainly attributable to 2 technical failures, 6 perioperative deaths, 1 major bleeding event requiring repeat surgical hemostasis, and 2 cases of moderate PVL detected before discharge. The median postprocedural peak aortic pressure gradient was 20.0 (12.7, 24.8) mmHg in the concomitant group and 14.9 (8.4, 27.3) mmHg in the staged group ($p = 0.184$). Within-group paired comparisons showed that the peak transvalvular pressure gradient decreased significantly after TAVR in both the concomitant group (Tables 2,3), from 81.7 (66.3, 99.6) to 20.0 (12.7, 24.8) mmHg, and the staged group, from 75.2 (63.2, 97.8) to 14.9 (8.4, 27.3) mmHg (both $p < 0.001$). These findings demonstrated effective hemodynamic improvement after TAVR with both procedural strategies.

Regarding in-hospital complications, PPI was required in 2 patients in the concomitant group, whereas no cases were found in the staged group ($p = 1.000$). Perioperative myocardial infarction occurred in one patient in each group ($p = 0.387$). Six perioperative deaths were documented in the concomitant group, primarily due to low cardiac output syndrome (n = 4) and severe gastrointestinal bleeding (n = 2). Major bleeding events occurred in 3 patients (2.1%) in the concomitant group and in none of the staged group ($p = 1.000$). Stroke was observed in 7 patients (5.0%) in the concomitant group and in none of the staged group ($p = 0.349$). The incidence of AKI was comparable between the concomitant and staged groups (13.5% vs. 12.8%), with no statistically significant difference observed ($p = 0.915$). No cases of repeat revascularization or valve thrombosis were observed in either group. The median length of hospital stay was shorter in the concomitant group than in the staged group (11.9 [8.9, 17.1] days vs. 15.1 [12.0, 20.0] days, $p = 0.010$).

Table 3. Comparison of surgical outcomes between groups before discharge.

Variables	Concomitant group (n = 141)	Staged group (n = 39)	χ^2/*Z*/*t value*	*p*-value
Technical success rate, %	139 (98.6%)	38 (97.4%)	-	0.522
Procedural success rate, %	130 (92.2%)	38 (97.4%)	-	0.467
Peak aortic pressure gradient, mmHg	20.0 (12.7, 24.8)	14.9 (8.4, 27.3)	1.328	0.184
Moderate PVL, n (%)	2 (1.4%)	0	-	1.000
Perioperative mortality, n (%)	6 (4.3%)	0	-	0.343
PPI, n (%)	2 (1.4%)	0	-	1.000
Periprocedural MI, n (%)	1 (0.7%)	1 (2.6%)	-	0.387
Major bleeding, n (%)	3 (2.1%)	0	-	1.000
Stroke, n (%)	7 (5.0%)	0	-	0.349
AKI, n (%)	19 (13.5%)	5 (12.8%)	0.011	0.915
Repeat revascularization, n (%)	0	0	-	-
Length of hospital stay, days	11.9 (8.9, 17.1)	15.1 (12.0, 20.0)	–2.568	0.010

Abbreviations: PVL, paravalvular leak; PPI, permanent pacemaker implantation; AKI, acute kidney injury.
-, indicates that Fisher's exact test was used.

Logistic Regression Analysis for AKI

To account for potential confounding due to the non-randomized study design, logistic regression analyses were performed to evaluate the association between PCI strategy and AKI. In univariable analysis, PCI strategy (OR 1.00, 95% CI 0.37–3.21, $p = 0.995$), age (OR 1.04, 95% CI 0.98–1.11, $p = 0.223$), and baseline serum creatinine (OR 1.003, 95% CI 0.998–1.008, $p = 0.195$) were not significantly associated with AKI. Given that only 24 AKI events were observed, the number of covariates incorporated in the multivariable model was intentionally restricted to reduce the risk of overfitting. Selection of variables was guided by clinical relevance rather than purely statistical thresholds, ensuring that clinically essential covariates were retained. In the multivariable logistic regression analysis, PCI strategy (concomitant vs. staged) was not independently associated with AKI (adjusted OR 0.93, 95% CI 0.33–2.99, $p = 0.887$). Neither age (adjusted OR 1.05, 95% CI 0.99–1.13, $p = 0.144$) nor baseline serum creatinine (adjusted OR 1.00, 95% CI 1.00–1.01, $p = 0.105$) demonstrated a significant association with AKI.

Follow-up Outcomes Across the Study Participants

The follow-up outcomes are shown in Table 4. Survival analysis included 174 hospital survivors, including 135 in the concomitant group and 39 in the staged group. Over a median follow-up of 12.0 (6.6, 25.7) months, 13 deaths were documented, including 11 in the concomitant group and 2 in the staged group (8.1% vs. 5.1%, $p = 0.735$). Reported causes of death included heart failure (n = 5), lung cancer (n = 1), COVID-19 infection (n = 2), stroke (n = 2) and unknown causes (n = 3). Kaplan–Meier analysis showed no significant difference in 1-year survival between the two groups (log-rank $p = 0.22$; **Supplementary Fig. 1**). The estimated 1-year survival rates were 96.0% (95% CI, 92.1%–100.0%) in the concomitant group and 94.2% (95% CI, 86.6%–100.0%) in the staged group (**Supplementary Fig. 2**).

At follow-up, the median LVEF was 64.0% (60.0, 67.0) in the concomitant group and 61.5% (42.5, 65.8) in the staged group ($p = 0.082$). The median LVEDD was 45.5 (43.0, 48.0) mm in the concomitant group and 48.0 (45.3, 52.5) mm in the staged group ($p = 0.298$). The median LVESD was 29.0 (27.0, 32.0) mm in the concomitant group and 34.5 (31.3, 42.5) mm in the staged group, showing a significant between-group difference ($p < 0.001$). During follow-up, one patient in the staged group received repeat PCI. TTE confirmed satisfactory prosthetic aortic valve function in all patients, although 4 patients in the concomitant group developed mild-to-moderate PVL one year postoperatively. Overall, clinical symptoms improved compared with baseline among surviving patients. No recurrent acute coronary syndrome, stroke events, or additional CABG procedures were observed. Furthermore, PPI was not required for any patients during follow-up.

Discussion

CAD is a common comorbidity in patients undergoing TAVR, with a reported incidence of 15% to 80%. Aortic valve disease and CAD share multiple overlapping risk factors, such as advanced age, dyslipidemia, hypertension, and diabetes [11]. CAD may have an adverse impact on the long-term prognosis of patients treated with TAVR. However, the clinical value of coronary revascularization in asymptomatic CAD patients with concomitant severe aortic valve disease remains unclear. Lønborg et al. [12] suggested that PCI in patients with CAD undergoing TAVR offers favorable outcomes, including a reduced risk of all-cause mortality, myocardial infarction, and urgent revascularization compared with conservative treatment.

Table 4. Comparison of follow-up outcomes between the two groups.

Variables	Concomitant group (n = 135)	Staged group (n = 39)	χ^2/Z/t value	p-value
Death, n (%)	11 (8.1%)	2 (5.1%)	-	0.735
LVEF, %	64.0 (60.0, 67.0)	61.5 (42.5, 65.8)	1.738	0.082
LVEDD, mm	45.5 (43.0, 48.0)	48.0 (45.3, 52.5)	–1.037	0.298
LVESD, mm	29.0 (27.0, 32.0)	34.5 (31.3, 42.5)	–3.644	<0.001
Mild-to-moderate PVL, n (%)	4 (3.0%)	0	-	0.576
PPI, n (%)	0	0	-	-

-, indicates that Fisher's exact test was used.

The NOTION-3 trial enrolled 455 TAVR patients diagnosed with severe aortic stenosis (AS) (median age 82 years) who had at least one coronary artery stenosis characterized either by a fractional flow reserve of ≤0.80 or diameter stenosis of ≥90%. This is the largest prospective study to date involving such a patient population. Participants were randomly allocated to PCI or conservative management. After a median follow-up period of two years, major adverse cardiac events were observed 26% of patients receiving PCI compared with 36% in those receiving conservative treatment (HR 0.71, 95% CI 0.51–0.99). However, bleeding events occurred at a higher incidence in the PCI group (28% vs. 20%, HR 1.51, 95% CI 1.03–2.22). Notably, the NOTION-3 trial primarily evaluated the benefit of coronary revascularization itself rather than the optimal timing of PCI relative to TAVR. In that study, PCI was performed either before, during, or shortly after TAVR, and only approximately 26% of cases were treated concomitantly with or shortly after the valve procedure. Therefore, the trial was not specifically designed to address whether PCI should be performed concomitantly with TAVR or as a staged procedure.

Performing PCI and TAVR simultaneously during the same session offers practical advantages, reduced vascular procedures, shorter hospitalization, and potentially lower cost. Simultaneous procedures increase the use of contrast agents and require dual antiplatelet therapy, thereby increasing the risks of AKI and bleeding events. Most available evidence indicates that outcomes of simultaneous and staged procedures are broadly comparable [13,14,15]. Data from the EVERYVALVE registry [16] confirmed an acceptable technical success rate and favorable three-year survival with simultaneous PCI and TAVR, although stage methods may be useful in certain patient groups, such as those with a history of myocardial infarction. Staged PCI procedures can be categorized into two types: pre-TAVR PCI and post-TAVR. Some centers prefer PCI before TAVR to address ischemia-induced hemodynamic instability, while also allowing clearer visualization of coronary anatomy. On the contrary, post-TAVR PCI may be technically more challenging because of altered coronary access caused by the presence of the transcatheter prosthesis stent and the need to avoid prosthesis displacement [17,18].

Our study provides real-world evidence from the largest Asian cohort assessing PCI timing approaches performed within the same hospitalization period. Our findings propose that both TAVR and PCI are often necessary in patients with severe aortic valve disease and CAD, as combined treatments can alleviate clinical symptoms and improve long-term prognosis. Regardless of whether a PCI was performed concomitantly or in a staged manner, we advocate adopting a PCI priority strategy in patients who meet the indications for PCI and TAVR. On one hand, the success rate of prior PCI is high, with a technical success rate of 100% in our study. On the other hand, addressing coronary ischemia helps reduce the risk of intraoperative circulatory collapse. Both approaches were associated with increased procedural success rates, favorable valve hemodynamics, and low complication rates, without a statistically significant difference between groups. The absence of significant differences in post-TAVR valve hemodynamics suggests that performing PCI during the same hospitalization does not appear to compromise valve deployment or early valve function. These findings support the concept that PCI timing can be flexibly selected in contemporary practice, provided that careful patient selection and standardized periprocedural management are applied in experienced centers [15].

Previous studies have shown an in-hospital incidence of AKI following combined TAVR and PCI ranges from 2.5% to 19.7% [19,20,21]. We observed that the incidence of AKI was slightly more frequent in the concomitant group compared to the staged group, likely indicating increased contrast exposure during concomitant procedures. With treatment, all cases of AKI were reversible and were not associated with worsening of cardiac function. This observation highlights the significance of careful patient selection, particularly in cases with impaired baseline renal function. Interestingly, not all studies suggest a higher incidence of AKI with concomitant TAVR and PCI. A national analysis by Tran et al. [22] found that PCI performed before TAVR during the same hospitalization was associated with a higher risk of AKI. It might be attributed to the earlier initiation of dual antiplatelet therapy, which increases the risk of bleeding and contrast-induced nephrotoxicity. Although staged procedures involve a lower contrast volume per session, the cumulative contrast exposure from two separate interventions may be higher, potentially exerting a greater adverse impact on renal function. Moreover, patients un-

dergoing early staged procedures may experience transient hemodynamic instability following PCI, potentially heightening the risk of AKI.

We observed the bleeding events, which also warrant consideration. However, the overall incidence of major bleeding events in this study was low. Data in the real-world registry have suggested higher in-hospital bleeding rates with concomitant PCI compared with staged PCI before TAVR (e.g., 9.9% vs 3.4% in REVASC-TAVI), highlighting that bleeding risk is multifactorial and may reflect procedural complexity, contrast load, periprocedural antithrombotic exposure, and access-site vulnerability rather than timing alone [23]. Taken together, bleeding and AKI remain clinically relevant concerns during concomitant PCI and TAVR and should therefore be considered alongside procedural and patient-specific factors when selecting concomitant and staged strategies. In clinical practice, the choice of strategy should be individualized according to patient characteristics, coronary anatomy, and procedural complexity. A concomitant strategy may be preferred in patients with relatively simple coronary lesions (e.g., focal proximal stenosis amenable to straightforward PCI), stable renal function, and circumstances where minimizing repeated vascular access or hospitalization is desirable, such as in frail or elderly patients. In contrast, a staged strategy may be more appropriate in patients with complex coronary anatomy requiring prolonged PCI, high contrast burden, pre-existing renal dysfunction, or elevated bleeding risk, where separating the procedures may help reduce cumulative physiological stress and allow closer monitoring between interventions. Therefore, the timing of PCI relative to TAVR should be guided by a comprehensive assessment of procedural risk and patient-specific factors.

This study has several limitations. First, there was a substantial imbalance in sample size between the concomitant and staged PCI groups, reflecting the real-world practice pattern at our high-volume TAVR center. This group imbalance may have reduced the statistical power of between-group comparisons, particularly for infrequent clinical events in this study, such as perioperative mortality, stroke, major bleeding, and PPI. As a result, the absence of statistically significant differences in some outcomes should not be interpreted as definitive evidence of equivalence between strategies, because a type II error cannot be excluded, and potentially clinically meaningful differences may have remained undetected due to the limited sample size of the staged group (n = 39). Owing to the relatively small number of patients in the staged group, advanced adjustment strategies such as propensity score matching or inverse probability weighting were not applied, as these approaches would have further reduced the effective sample size. Therefore, residual confounding cannot be excluded. Second, as a retrospective non-randomized study, the findings are subjected to potential selection bias. For example, the strategy decision was influenced by multiple clinical and procedural factors, including lesion severity, operator experience and institutional preference. This study design also meant that certain clinically significant data, such as contrast load, lesion complexity, detailed lesion characteristics, number of lesions treated and SYNTAX score, could not be retrieved. The absence of these variables limits the ability to fully adjust for differences in coronary disease burden and PCI complexity between groups.

Therefore, the findings regarding AKI and bleeding outcomes should be interpreted with caution, as these events may have been influenced not only by PCI timing itself but also by procedural complexity, contrast exposure, and lesion-related factors that could not be comprehensively assessed in the present analysis. Besides, we are currently unable to provide long-term follow-up data beyond 5 years for all patients. Finally, this was a single-center retrospective study conducted in a high-volume TAVR center. Therefore, the procedural experience and clinical management in our center may differ from those in lower-volume or less-experienced institutions, which may limit the generalizability of our findings. Further studies with larger sample sizes and extended follow-up periods are needed to compare concomitant and staged groups more comprehensively.

Conclusions

In this selected cohort of patients undergoing TAVR, both concomitant and staged PCI procedures demonstrated high procedural success rates and comparable early clinical outcomes. No statistically significant differences in major complications were observed between the two approaches. Further studies with larger cohorts and extended follow-up are needed to clarify the optimal timing of PCI in patients undergoing TAVR.

Availability of Data and Materials

The data analyzed are available from the corresponding authors upon reasonable request.

Author Contributions

Conceptualization, TT, ZL and EZ. Methodology, ZL and YL. Formal analysis, TT. Data curation, ZL. Writing—original draft preparation, TT and ZL. Writing—review and editing, EZ and YL. All authors have been involved in revising the manuscript critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

This study conforms to the Declaration of Helsinki and was approved by the Ethics Committee of Beijing Anzhen Hos-

pital (2024255x). Given the retrospective design of the study and the use of anonymized clinical data, the requirement for informed consent was waived by the Ethics Committee of Beijing Anzhen Hospital.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.4593.

References

[1] Writing Committee Members, Jneid H, Chikwe J, Arnold SV, Bonow RO, Bradley SM, et al. 2024 ACC/AHA Clinical Performance and Quality Measures for Adults With Valvular and Structural Heart Disease: A Report of the American Heart Association/American College of Cardiology Joint Committee on Performance Measures. Journal of the American College of Cardiology. 2024; 83: 1579–1613. https://doi.org/10.1016/j.jacc.2023.12.006

[2] Yerasi C, Rogers T, Forrestal BJ, Case BC, Khan JM, Ben-Dor I, et al. Transcatheter Versus Surgical Aortic Valve Replacement in Young, Low-Risk Patients With Severe Aortic Stenosis. JACC. Cardiovascular Interventions. 2021; 14: 1169–1180. https://doi.org/10.1016/j.jcin.2021.03.058

[3] Khawaja MZ, Redwood SR, Thomas M. Coronary artery disease in patients undergoing TAVI–why not to treat. EuroIntervention : Journal of EuroPCR in Collaboration with the Working Group on Interventional Cardiology of the European Society of Cardiology. 2014; 10 Suppl U: U76–83. https://doi.org/10.4244/EIJV10SUA11

[4] Praz F, Borger MA, Lanz J, Marin-Cuartas M, Abreu A, Adamo M, et al. 2025 ESC/EACTS Guidelines for the management of valvular heart disease: Developed by the task force for the management of valvular heart disease of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). European Heart Journal. 2025; 46: 4635–4736. https://doi.org/10.1093/eurheartj/ehaf194

[5] Lim GB. Combining TAVI with PCI in patients with aortic stenosis and CAD. Nature Reviews. Cardiology. 2024; 21: 742. https://doi.org/10.1038/s41569-024-01080-4

[6] Alharbi MA, Isouard G, Tolchard B. Historical development of the statistical classification of causes of death and diseases. Cogent Medicine. 2021; 8: 1893422. https://doi.org/10.1080/2331205X.2021.1893422

[7] VARC-3 WRITING COMMITTEE:, Généreux P, Piazza N, Alu MC, Nazif T, Hahn RT, et al. Valve Academic Research Consortium 3: Updated Endpoint Definitions for Aortic Valve Clinical Research. Journal of the American College of Cardiology. 2021; 77: 2717–2746. https://doi.org/10.1016/j.jacc.2021.02.038

[8] Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, Cercek B, et al. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. Circulation. 2011; 124: e574–651. https://doi.org/10.1161/CIR.0b013e31823ba622

[9] Kellum JA, Lameire N, KDIGO AKI Guideline Work Group. Diagnosis, evaluation, and management of acute kidney injury: a KDIGO summary (Part 1). Critical Care (London, England). 2013; 17: 204. https://doi.org/10.1186/cc11454

[10] Tan T, Zhu E, Cui H, Lai Y. Managing Cardiogenic Shock With Concurrent Transcatheter Aortic Valve Replacement and Percutaneous Coronary Intervention. JACC. Case Reports. 2025; 30: 103918. https://doi.org/10.1016/j.jaccas.2025.103918

[11] Ljungberg J, Johansson B, Engström KG, Albertsson E, Holmer P, Norberg M, et al. Traditional Cardiovascular Risk Factors and Their Relation to Future Surgery for Valvular Heart Disease or Ascending Aortic Disease: A Case-Referent Study. Journal of the American Heart Association. 2017; 6: e005133. https://doi.org/10.1161/JAHA.116.005133

[12] Lønborg J, Jabbari R, Sabbah M, Veien KT, Niemelä M, Freeman P, et al. PCI in Patients Undergoing Transcatheter Aortic-Valve Implantation. The New England Journal of Medicine. 2024; 391: 2189–2200. https://doi.org/10.1056/NEJMoa2401513

[13] Bajaj A, Pancholy S, Sethi A, Rathor P. Safety and feasibility of PCI in patients undergoing TAVR: A systematic review and meta-analysis. Heart & Lung : the Journal of Critical Care. 2017; 46: 92–99. https://doi.org/10.1016/j.hrtlng.2016.12.003

[14] Wen Q, Yang J, Xu G, Wang D. Comparison of different timings of percutaneous coronary intervention in patients with transcatheter aortic valve implantation: a network meta-analysis. Frontiers in Cardiovascular Medicine. 2025; 12: 1596208. https://doi.org/10.3389/fcvm.2025.1596208

[15] Zhang X, Geng W, Yan S, Zhang K, Liu Q, Li M. Comparison of the outcomes of concurrent versus staged TAVR combined with PCI in patients with severe aortic stenosis and coronary artery disease: a systematic review and meta-analysis. Coronary Artery Disease. 2024; 35: 481–489. https://doi.org/10.1097/MCA.0000000000001373

[16] Fischer J, Steffen J, Arlart T, Haum M, Gschwendtner S, Doldi PM, et al. Concomitant percutaneous coronary intervention in patients undergoing transcatheter aortic valve implantation. Catheterization and Cardiovascular Interventions : Official Journal of the Society for Cardiac Angiography & Interventions. 2024; 103: 186–193. https://doi.org/10.1002/ccd.30927

[17] Nai Fovino L, Scotti A, Massussi M, Fabris T, Cardaioli F, Rodinò G, et al. Incidence and feasibility of coronary access after transcatheter aortic valve replacement. Catheterization and Cardiovascular Interventions : Official Journal of the Society for Cardiac Angiography & Interventions. 2020; 96: E535–E541. https://doi.org/10.1002/ccd.28720

[18] Kleiman NS. Monster Under the Bed?: Coronary Access After TAVR. JACC. Cardiovascular Interventions. 2021; 14: 1591–1593. https://doi.org/10.1016/j.jcin.2021.06.001

[19] Abugroun A, Osman M, Awadalla S, Klein LW. Outcomes of Transcatheter Aortic Valve Replacement With Percutaneous Coronary Intervention versus Surgical Aortic Valve Replacement With Coronary Artery Bypass Grafting. The American Journal of Cardiology. 2020; 137: 83–88. https://doi.org/10.1016/j.amjcard.2020.09.040

[20] Barbanti M, Buccheri S, Capodanno D, D'Errigo P, Ranucci M, Rosato S, et al. Transcatheter or surgical treatment of severe aortic

stenosis and coronary artery disease: a comparative analysis from the Italian OBSERVANT study. International journal of cardiology. 2018; 270: 102–106. https://doi.org/10.1016/j.ijcard.2018.06.011

[21] Søndergaard L, Popma JJ, Reardon MJ, Van Mieghem NM, Deeb GM, Kodali S, et al. Comparison of a Complete Percutaneous Versus Surgical Approach to Aortic Valve Replacement and Revascularization in Patients at Intermediate Surgical Risk: Results From the Randomized SURTAVI Trial. Circulation. 2019; 140: 1296–1305. https://doi.org/10.1161/CIRCULATIONAHA.118.039564

[22] Tran Z, Hadaya J, Downey P, Sanaiha Y, Verma A, Shemin RJ, et al. Staged versus concomitant transcatheter aortic valve replacement and percutaneous coronary intervention: A national analysis. JTCVS Open. 2022; 10: 148–161. https://doi.org/10.1016/j.xjon.2022.02.019

[23] Rheude T, Costa G, Ribichini FL, Pilgrim T, Amat Santos IJ, De Backer O, et al. Comparison of different percutaneous revascularisation timing strategies in patients undergoing transcatheter aortic valve implantation. EuroIntervention : Journal of EuroPCR in Collaboration with the Working Group on Interventional Cardiology of the European Society of Cardiology. 2023; 19: 589–599. https://doi.org/10.4244/EIJ-D-23-00186