ORIGINAL ARTICLE - CLINICAL SCIENCE

Concomitant percutaneous coronary intervention in patients undergoing transcatheter aortic valve implantation

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Abstract

Background: Patients undergoing transcatheter aortic valve implantation (TAVI) frequently have coronary artery disease requiring percutaneous coronary intervention (PCI). Usually, PCI and TAVI are performed in two separate procedures and current studies are investigating potential benefits regarding the order. However, the two interventions may also be performed simultaneously, thereby limiting the risk associated with repeated vascular access. Data evaluating benefit and harm of concomitant procedures are scarce.

Aims: Therefore, this study aimed to evaluate concomitant PCI (coPCI) in TAVI patients regarding Valve Academic Research Consortium 3 (VARC-3) endpoints and long-term mortality.

Methods: A total of 2233 consecutive TAVI patients from the EVERY-VALVE registry were analyzed according to the VARC-3 endpoint definitions. A total of 274 patients had undergone TAVI and concomitant PCI (coPCI group). They were compared to 226 TAVI patients who had received PCI within 60 days before TAVI in a stepwise approach (swPCI group) and to the remaining 1733 TAVI patients who had not undergone PCI recently (noPCI group).

Results: Overall median age was 81.4 years, median Society of Thoracic Surgeons score was 4.0%. Patients in the coPCI and in the swPCI group were predominantly male with reduced left-ventricular ejection fraction. Rates of VARC-3 composite endpoints technical success and 30-day device success were comparable between all three groups. Mortality rates at 3 years after TAVI were similar (coPCI, 34.2% vs. swPCI, 31.9% vs. noPCI, 34.0% $p = 0.84$).

Julius Fischer and Julius Steffen contributed equally to this study.

All authors take responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

Conclusions: coPCI during TAVI seems comparable in a retrospective analysis. Compared to a stepwise approach, it has similar rates of composite endpoints technical success and device success as well as long-term mortality.

KEYWORDS

AKI, aortic stenosis, bleeding, PCI, TAVI, VARC-3

1 | INTRODUCTION

Severe calcific aortic stenosis (AS) is often accompanied by obstructive coronary artery disease (CAD)[1,2] as the risk factors such as advanced age or arterial hypertension and pathophysiological pathways leading to calcification are similar. The prevalence of CAD among TAVI patients varies from 30% to 70% in different registry data[3–6] and randomized studies.[7,8]

European and American guidelines recommend a simultaneous treatment of both conditions, CAD and AS, if there is an indication for surgery or intervention of either one.[9,10] Transcatheter aortic valve implantation (TAVI) is the standard of care in elderly patients or patients with increased perioperative risk and is increasingly used in younger patients.[9,11–13] Accordingly, many patients undergoing TAVI also require percutaneous coronary intervention (PCI).[14–16]

There is a debate on what order of interventions would be beneficial.[17] Performing a combined procedure, however, may yield advantages as it limits the number of punctures for vascular access and is, presumably, more convenient for the patient and more economic in terms of material and equipment. Yet, longer procedure times, more anticoagulation and antithrombotic therapy, and higher contrast agent doses may increase risks of bleeding or acute kidney injury (AKI).

Detailed studies comparing concomitant PCI (coPCI) during TAVI to other approaches are lacking. Therefore, we aimed to investigate the efficacy and safety of TAVI and PCI performed in one procedure in terms of long-term mortality and procedural and clinical outcomes.

2 | METHODS

2.1 | Patients

This is a retrospective registry study conducted at LMU Munich University Hospital. All consecutive patients treated with transfemoral TAVI for symptomatic severe AS from January 2013 to December 2018 were screened for patients receiving TAVI and concomitant PCI (coPCI group). They were compared to either patients who had undergone PCI up to 60 days before TAVI in a stepwise treatment (swPCI group) or to patients without recent PCI and in which relevant stenoses were excluded by coronary angiography (noPCI group). Whether or not coronary angiography was performed before TAVI was decided by the physicians treating the patients before sending them for TAVI. If no coronary angiography had been performed yet, this was done at the beginning of the procedure at our center. Only symptomatic patients underwent PCI. Patients who had undergone PCI for acute coronary syndromes within 60 days before the TAVR procedure were excluded from the analysis (Supporting Information S1: Figure S1).

Demographics, clinical and procedural data, and clinical outcomes were collected prospectively as part of the EVERY-VALVE registry. Patient follow-up was performed 30 days after the procedure and yearly thereafter, as described before.[18] Informed consent was obtained from each patient, and the study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the local ethics committee (project number 19-840).

2.2 | TAVI procedure

The TAVI procedure was performed in conscious sedation. Transfemoral access was used in all patients. Concomitant coronary interventions were either done via femoral or radial arteries and were performed at the beginning of the TAVI procedure. Periprocedural anticoagulation was achieved with unfractionated heparin (50–70 IU/kg body weight). For access-site hemostasis, suture-mediated closure devices were used. Medication after TAVI consisted of antiplatelet therapy (acetylsalicylic acid + 3 months of clopidogrel). TAVI with concomitant PCI was followed by 100 mg aspirin lifelong and clopidogrel for 6 months. Patients with the need for oral anticoagulation were treated with oral anticoagulation and, if PCI was performed, in combination with antiplatelet therapy according to the guidelines.[19,20]

2.3 | Primary and secondary endpoints

The primary endpoint of this analysis was all-cause mortality at 3 years after TAVI. Secondary safety and efficacy endpoints included cardiovascular death and the recently updated Valve Academic Research Consortium 3 (VARC-3) composite endpoints technical success and device success.[21] Further secondary endpoints included AKI (any stage AKI and stage III or IV AKI) and bleeding after TAVI, as defined in the VARC-3 endpoint definitions with reference to the Kidney Disease: Improving Global Outcomes (KDIGO)[22] and the Bleeding Academic Research Consortium (BARC) guidelines,[23] respectively.

2.4 | Statistical analysis

Continuous variables are presented as mean and standard deviation or median and interquartile range depending on data distribution. Normal distribution was tested with Shapiro–Wilk test. Categorical variables are presented as numbers and percentages. For comparison of the groups, Student's t test, Wilcoxon-rank-sum test, Kruskal–Wallis test, or Fisher's exact test were used. A two-sided $p < 0.05$ was considered statistically significant. Linear regression analysis was performed to identify predictors for AKI as well as bleeding events. All variables with a $p < 0.1$ in the univariable analysis were entered into the multivariate analysis. Mortality analysis is based on the Kaplan–Meier method and Cox model calculations. For analysis of cardiovascular mortality, a competing risk model was used. Statistical analyses were conducted with R version 4.0.3 (R Foundation for Statistical Computing) with the use of the package "rms."[24]

3 | RESULTS

3.1 | Patients

In total, 2328 patients were treated with TAVI for severe AS and were part of the EVERY-VALVE registry at our center between January 2013 and December 2018 (Supporting Information S1: Figure S1). A total of 95 patients were excluded from the analysis because PCI had been performed in an ACS setting before TAVI. 274 patients were in the coPCI group. The two control groups, swPCI and noPCI, consisted of 226 and 1733 patients, respectively.

The median age of the overall population was 81.4 years (interquartile range, IQR, 77.1–85.6 years). The median Society of Thoracic Surgeons score was 4.0% (IQR, 2.4%–6.3%). Across the entire cohort, the overall prevalence of CAD was 61.7% (noPCI group, 50.7%). Baseline characteristics of the coPCI patients are shown and compared to the two control groups in Table 1. Patients in the coPCI group were

TABLE 1 Baseline characteristics at time of TAVI.

	coPCI (n = 274)	swPCI (n = 226)	noPCI (n = 1733)	p Value
Male sex	167 (60.9%)	132 (58.4%)	809 (46.7%)	**<0.01**
Age (years)	81.8 [77.4–86.8]	82.1 [78.2–85.6]	81.2 [77.0–85.4]	0.06
Body mass index (kg/m^2)	25.8 [23.4–28.6]	25.8 [23.1–28.1]	25.9 [23.4–29.3]	0.37
STS score	4.0 [2.3–6.3]	4.2 [3.0–6.0]	4.0 [2.3–6.3]	0.18
Diabetes mellitus	94 (34.3%)	71 (31.4%)	540 (31.2%)	0.58
Arterial hypertension	256 (93.4%)	210 (92.9%)	1567 (90.4%)	0.16
Smoking (active or past)	65 (23.7%)	41 (18.1%)	371 (21.4%)	0.32
Hypercholesterolemia	141 (51.5%)	118 (52.2%)	789 (45.5%)	0.05
Positive family history	25 (9.1%)	27 (11.9%)	200 (11.5%)	0.47
GFR at baseline [ml/min]	45.1 [34.3–55.9]	44.0 [34.5–54.5]	45.4 [34.0–57.9]	0.74
Dialysis before TAVI	10 (3.6%)	8 (3.5%)	73 (4.2%)	0.83
Atrial fibrillation	69 (25.2%)	62 (27.4%)	548 (31.6%)	0.06
CAD	274 (100.0%)	226 (100.0%)	878 (50.7%)	**<0.01**
Prior MI	43 (15.7%)	32 (14.2%)	215 (12.4%)	0.28
Prior PCI	72 (26.4%)	226 (100.0%)	428 (25.4%)	**<0.01**
COPD	49 (17.9%)	35 (15.5%)	308 (17.8%)	0.69
LVEF [%]	55.0 [45.0–55.0]	55.0 [45.0–56.0]	55.0 [47.0–56.0]	**0.03**
Impaired LVEF	45 (19.7%)	32 (18.4%)	241 (17.3%)	0.65
Aortic valve opening area (cm^2)	0.8 (0.6–0.9)	0.8 (0.6–0.9)	0.7 [0.6–0.9]	0.89
Mean valvular gradient (mmHg)	35.0 [26.0–44.0]	36.0 [27.0–45.5]	37.0 [27.0–46.0]	0.13
Aortic regurgitation >grade 1	34 (13.7%)	21 (11.0%)	201 (13.2%)	0.66
Mitral regurgitation grade 3–4/4	19 (7.6%)	6 (3.1%)	88 (5.7%)	0.13
Tricuspid regurgitation >grade 1	37 (17.3%)	20 (12.1%)	219 (16.9%)	0.28

Note: Data shown as n (%) or median (IQR).

Abbreviations: CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; GFR, glomerular filtration rate; IQR, interquartile range; LVEF, left ventricular ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; STS score, Society of Thoracic Surgeons score; TAVI, transcatheter aortic valve implantation.

predominately male with a reduced left-ventricular function. The other characteristics including the rate of diabetes mellitus or the glomerular filtration rate (GFR) at baseline did not differ between groups.

3.2 | Procedural data

Balloon-expandable prostheses were used in the majority of patients (85.6%), with no differences between the groups. The median amount of contrast agent used during TAVI was 200 mL (IQR, 151–250) in the coPCI group. This was significantly more compared to patients in the swPCI group (120 mL [IQR 82–159]) or in the noPCI group (120 mL [IQR, 85–157], p overall <0.01). Duration of the combined procedure was significantly longer than TAVI alone (coPCI, 56 [IQR, 42–71] min vs. swPCI, 43 [IQR, 35–55] min vs. noPCI 40 [33–55] min, $p < 0.01$). Further information on procedural characteristics can be found in Supporting Information S1: Table S1.

Concerning the PCI, a significantly higher total number of stents were implanted in the coPCI group compared to the swPCI group (1.9 ± 1.2 vs. 1.6 ± 1.2, $p < 0.01$). The rate of PCI in the left main coronary artery was higher in the coPCI compared to the swPCI group (14% vs. 7%, $p < 0.01$, Supporting Information S1: Table S2). Patients in the coPCI group had a significantly longer mean length of hospital stay after the procedure than patients in the swPCI group (10.7 ± 6.5 vs. 9.7 ± 7.0 days, $p = 0.04$). The length of stay on the intensive care unit was comparable (3.1 ± 3.3 vs. 2.8 (± 2.4) days, $p = 0.94$).

Antiplatelet and anticoagulation therapeutic regimes prescribed after concomitant TAVI are presented in Supporting Information S1: Table S3. Two-thirds of these patients received dual antiplatelet therapy with acetylsalicylic acid + clopidogrel and 29% received a triple therapy consisting of direct oral anticoagulation, acetylsalicylic acid, and clopidogrel.

3.3 | Primary outcome: Long-term mortality

Follow-up data were available for 99.6% of the patients at 1 year, 99.3% at 2 years, and 94.6% at 3 years. Estimated mortality rates 3 years after the TAVI procedure were comparable, with 34.2% (95% confidence interval, CI, 28.3%–39.6%) in the coPCI group, 31.9% (95% CI 25.6%–37.8%) in the swPCI group, and 34.0% (95% CI, 31.7%–36.2%) in the noPCI group (log-rank overall $p = 0.84$, Figure 1A). There was also no difference in cardiovascular death among the three groups (19.6% in the coPCI group, 14.8% in the swPCI group, and 18.9% in the noPCI group, $p = 0.40$ Figure 1B).

3.4 | Procedural outcomes

Within the entire study cohort, successful device implementation according to VARC-3 was achieved in 2116 (94.8%) patients without significant differences between the groups ($p = 0.66$). The composite endpoint of device success at 30 days was achieved in 1941 (86.9%)

patients, again without a between-group difference ($p = 0.31$). Supporting Information S1: Table S4 presents the rates of device success and technical success in more detail. For additional comparison of the coPCI and swPCI groups, odds ratios (ORs) for the VARC-3 composite endpoints and their components are shown in Figure 2 and Supporting Information S1: Table S5, indicating no relevant difference between these two groups.

Concerning postprocedural bleeding and AKI as defined in the VARC-3 guidelines, results indicate slightly higher risks in the coPCI group compared to the control groups: BARC type 3 or higher bleeding events occurred significantly more often in the coPCI group compared to the swPCI group (24.8% vs. 17.3%, $p = 0.04$) or the noPCI group (15.6%, $p < 0.01$, Figure 3A). High bleeding rates were mainly due to periprocedural blood losses measured by hemoglobin levels; blood transfusion rates were equally low in all three groups (coPCI, 1.8%, vs. swPCI, 1.8%, vs. noPCI, 1.6%, $p = 0.93$).

The rate of any type of AKI after TAVI was significantly higher in the coPCI group (17.8%) than in the control groups (swPCI group, 11.0%, noPCI group 9.9%, $p < 0.01$, Figure 3B). Rates of stage 3 or 4 AKI after TAVI were numerically higher in the coPCI group without reaching statistical significance (coPCI, nine patients, 3.4% vs. swPCI, three patients, 1.4%, $p = 0.26$).

3.5 | Relevance of AKI or bleeding complications

A more detailed comparison of patients in the coPCI and swPCI groups was performed focusing on bleeding complications and AKI.

Bleeding events BARC type 3 or higher were associated with an increased 3-year mortality (hazard ratio 1.20 [95% CI, 1.00–1.45], $p = 0.048$). Univariable and multivariable analyses were performed to identify predictors for BARC type 3 or higher bleeding complications. All variables with $p < 0.1$ were included in a multivariable model. In the univariable analysis, coPCI, female sex, and increasing eGFR values were associated with higher bleeding risks (Supporting Information S1: Table S6). In the multivariable model, only coPCI (OR 1.60 [95% CI, 1.03–2.52], $p = 0.04$) and female sex (OR 1.57 [95% CI, 1.01–2.44], $p = 0.05$) prevailed as a significant bleeding predictor.

AKI stage 1 or above complicating TAVI was associated with a significantly increased 3-year mortality, too (hazard ratio 1.67 [95% CI, 1.35–2.06], $p < 0.01$). coPCI compared to swPCI as well as a history of myocardial infarction were associated with higher rates of AKI, which prevailed in the multivariable model (Supporting Information S1: Table S7).

4 | DISCUSSION

This is a comprehensive retrospective analysis on mortality and procedural outcomes including bleeding and AKI of TAVI patients undergoing concomitant PCI. Main findings of the study are: (i) concomitant PCI is not associated with an increased mortality, and there was (ii) no relevant difference for the VARC-3 composite
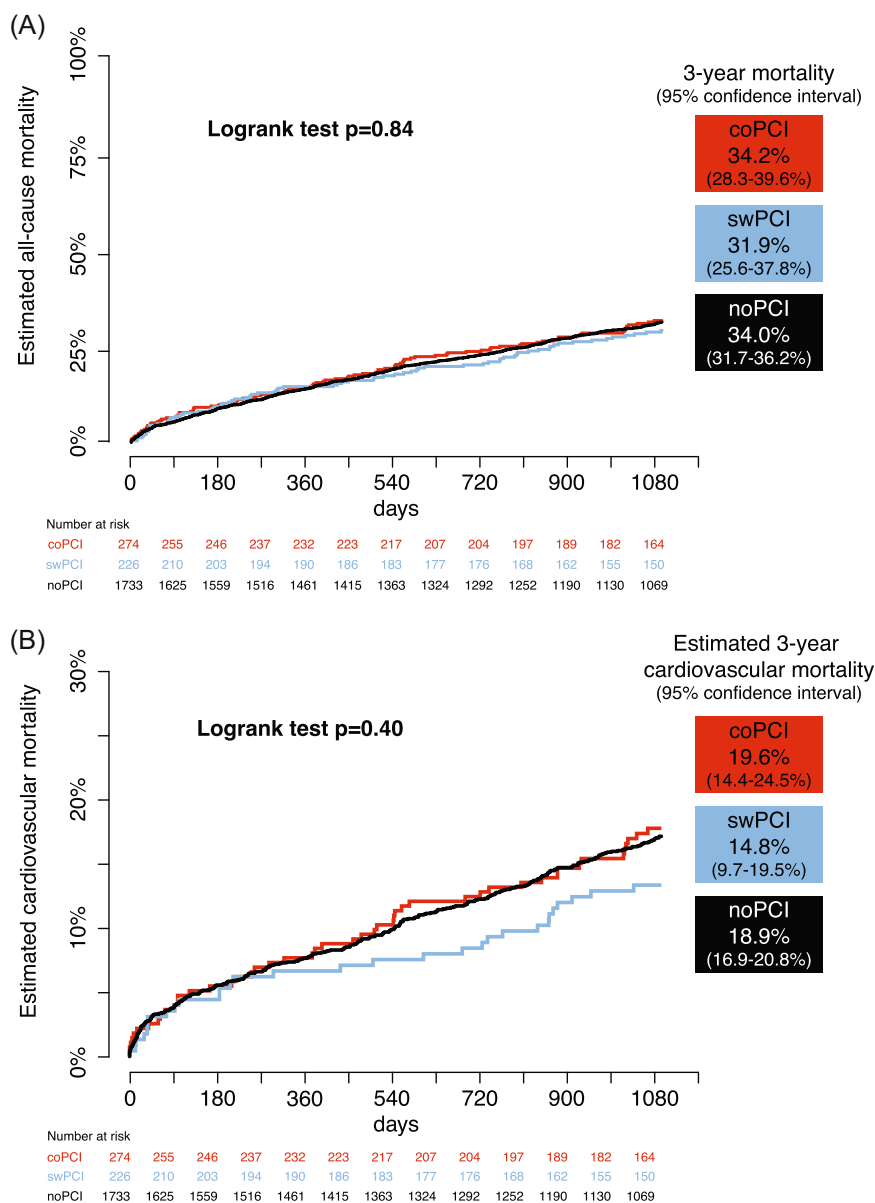
(A)

(B)

FIGURE 1 (A) Kaplan–Meier curves show the estimated 3-year all-cause mortality. Estimated 3-year mortality rates were 34.2% (95% CI 28.3%–39.6%) in the coPCI group, 31.9% (95% CI 25.6%–37.8%) in swPCI group, and 34.0% (95% CI 31.7%–36.2%) in noPCI group. There was no significant difference between the coPCI, swPCI, and noPCI groups ($p = 0.84$). Mortality rates at 1 year were 25.9% (95% CI 20.5%–30.9%), 22.6 (95% CI 16.9%–27.8%), and 24.9% (95% CI 22.8%–26.9%), respectively ($p = 0.70$). Mortality rates at 2 years were 15.3% (95% CI 11.0%–19.5%), 15.9 (95% CI 11.0%–20.6%), and 15.3% (95% CI 13.6%–17.0%), respectively ($p = 1.0$). (B) Cardiovascular mortality was analyzed in a competing risk model. There was no statistical difference between the three groups (coPCI, 19.6% [95% CI, 14.4%–24.5%], swPCI, 14.8% [95% CI, 9.7%–19.5%], and noPCI, 18.9% [95% CI, 16.9%–20.8%], $p = 0.40$). CI, confidence interval; coPCI, concomitant PCI and TAVI group; PCI, percutaneous coronary intervention; swPCI, stepwise PCI and TAVI group, noPCI, TAVI only group; TAVI, transcatheter aortic valve implantation. [Color figure can be viewed at wileyonlinelibrary.com]

endpoints, but (iii) an increased risk for BARC type 3 bleeding and AKI in TAVI patients with concomitant PCI compared to controls.

CAD is common in patients with AS, as certain patient characteristics, such as arterial hypertension, age, or impaired renal function are associated with both diseases. Furthermore, symptoms of AS and CAD are similar and cannot always be distinguished from one another. Given the increasing use of TAVI, the question of timing of PCI is of high clinical relevance.

There are several prospective trials underway evaluating coronary revascularization and aortic valve replacement. This includes the NOTION-3 trial (NCT03058627) comparing TAVI and PCI versus TAVI alone in 452 patients, the TAVI-PCI trial (NCT04310046) comparing PCI before or after TAVI in two separate procedures in 986 patients, and the PRO-TAVI trial (NCT05078619) evaluating the omission of PCI of significant CAD in patients planned to undergo TAVI.

4.1 | Literature is scarce, results are comparable

So far, evidence in this field is rather scarce. Most available studies are small, have short follow-up periods, or do not directly compare both approaches.[25–27] The recently published prospective ACTIVA-TION trial[28] was stopped early due to slow recruitment. In that trial, patients were randomized to PCI or no PCI before TAVI. Although the primary endpoint (death or rehospitalization) was not significantly different, bleeding rates in the PCI group were higher (up to 45% at 1 year). These observations fit to our data and are in line with a larger meta-analysis from 2018 and a more recent retrospective study from 2020, where the hazard ratio for 2-year major adverse cardiac events in coPCI compared to pre-TAVI PCI was 0.92 (0.5–1.7).[26,27] Albeit being very small, another retrospective analysis evaluating the different approaches also found comparable mortality rates between the groups.[25] The rate of AKI in the present study was comparable
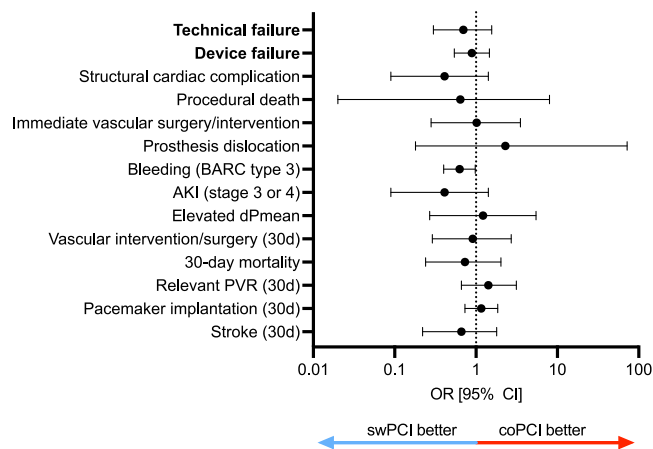
FIGURE 2 Procedural and clinical outcomes were analyzed according to the Valve Academic Research Consortium 3 (VARC-3) endpoint definitions. Odds ratios and confidence intervals for these endpoints are depicted in this figure. Two composite endpoints were analyzed: technical failure (consisting of procedural death, cardiac or vascular complications, prosthesis dislocation, the use of a second valve prosthesis, conversion to open surgery, or the need for immediate vascular intervention or surgery) and device failure (consisting of technical failure, 30-day mortality, elevated transvalvular pressure gradients [dPmean], or relevant paravalvular regurgitation on echocardiography, stroke, or vascular surgery or intervention at 30 days). Numbers are given in Supporting Information S1: Table S5. AKI, acute kidney injury; BARC, Bleeding Academic Research Consortium; coPCI, concomitant PCI and TAVI group; PCI, percutaneous coronary intervention; swPCI, stepwise PCI and TAVI group; TAVI, transcatheter aortic valve implantation. [Color figure can be viewed at wileyonlinelibrary.com]

FIGURE 3 Bar graph comparing the occurrence of bleeding (A) and any AKI stage 1 or above (B) between the coPCI, the swPCI, and the noPCI groups. Bleeding rates differed significantly between all three groups (coPCI, 24.8%, vs. swPCI, 17.3%, vs. noPCI, 15.6%) (coPCI vs. swPCI, $p = 0.04$, coPCI vs. noPCI, $p < 0.01$, swPCI vs. noPCI, $p = 0.52$). Also, the rates of any stage of AKI differed significantly between all three groups (coPCI, 17.8%, vs. swPCI 11.0%, vs. noPCI, 9.9%, $p < 0.01$), again with a significant difference between the two PCI groups ($p = 0.04$). AKI, acute kidney injury; coPCI, concomitant PCI and TAVI group; PCI, percutaneous coronary intervention swPCI, stepwise PCI and TAVI group; noPCI, TAVI only group; TAVI, transcatheter aortic valve implantation. [Color figure can be viewed at wileyonlinelibrary.com]

(18%) to an analysis of a combined surgical and interventional approach (17%).[29]

More recent studies of PCI and TAVI also included a group with post-TAVI PCI.[30,31] Rheude et al. evaluated a stepwise, a concomitant and a post-TAVI PCI approach and found a lower all-cause mortality when PCI was performed after TAVI but no difference between a prior or concomitant approach, similar to the results of the present study.[31] Likewise, Lunardi et al. compared PCI before or after TAVI in two separate procedures and found an advantage of a TAVI first approach, too.[30] Moreover, a large multicenter registry evaluating complete or incomplete coronary revascularisation in patients with stable CAD found no difference in short-term outcomes when comparing different PCI timing strategies.[32]

The present study is one of the largest analyses[33] with the longest follow-up time and the only one so far, evaluating coPCI in TAVI patients according to the VARC-3 endpoints.

4.2 | Clinical implications of study results

Long-term mortality and the VARC-3 composite endpoints technical failure and device failure at 30 days after TAVI were comparable in the coPCI and the control groups. Although periprocedural data of
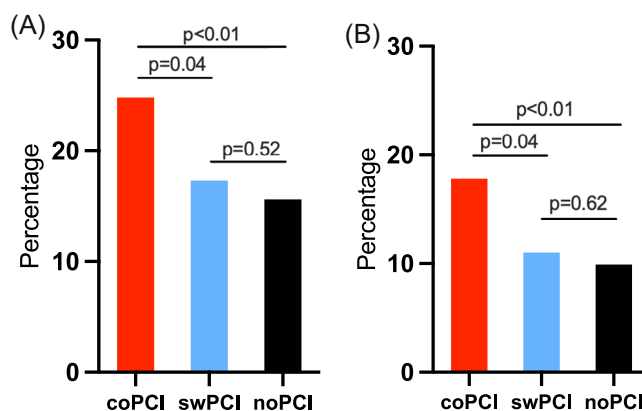
the PCI from the swPCI group were not available in much detail, the results indicate that both approaches, coPCI and swPCI, can be justified. From a patient's perspective, it might seem beneficial to have to undergo only one single procedure and, as part of this, to limit the number of punctures for vascular access. Also, one single procedure can be preferable in terms of material use and organizational aspects. On the other hand, length of hospital stay was found to be slightly longer in the coPCI group than in the swPCI group.

The present analysis also focused on BARC type 3 bleeding and AKI following TAVI. Both secondary endpoints were associated with an increased 3-year mortality. Importantly, bleeding was mainly due to larger drops in hemoglobin during the procedure rather than actual vascular complications. Furthermore, although the majority of patients in the swPCI group was on dual antiplatelet therapy before TAVI, relevant vascular complication rates did not increase in this group.

In multivariable logistic regression analyses among the coPCI and swPCI group, coPCI prevailed as a predictor for bleeding and AKI, together with female sex (bleeding) and prior myocardial infarction (AKI). Therefore, while direct comparison of the two approaches, coPCI and swPCI, is not possible with this retrospective analysis, the results seem to favor a stepwise approach in certain subpopulations.

The incidence of AKI was higher in the coPCI group than in the control groups although the rate of pre-existing CKD was similar between all groups at baseline. AKI may be triggered by a higher contrast agent dose applied in combined procedures. A contrast-enhanced CT was performed in preparation for TAVI shortly before. This, again, involved contrast agent, which, in sum, might provoke AKI. However, there is data questioning a dose-dependency for contrast agent-induced renal failure,

as emphasized in the current consensus statement of the American College of Radiology and the National Kidney Foundation.[34] This assumption is underlined by several studies in the literature comparing concomitant and stepwise revascularization approaches without significant differences for AKI or the need for hemodialysis.[25,35,36]

Taken together, our findings suggest that concomitant TAVI and PCI is usually feasible and not associated with an increased long-term mortality, a staged approach might be beneficial in certain patient subsets (i.e., women or patients with prior myocardial infarction). However, due to the inherent limitations of retrospective analyses, this requires confirmation from a prospective randomized trial.

4.3 | Limitations

This is a retrospective analysis with all its inherent limitations. The main limitation is the missing information on the secondary endpoints bleeding and AKI after PCI in the swPCI group. According to recent publications, rates of puncture site bleeding after PCI range between 0.5% and 3%.[37,38] Rates of AKI range around 4%, as recently found in a large registry.[39] Thus, compared to the bleeding and AKI rates found after TAVI in the swPCI group in this study (17.3% and 11.0%, respectively), the additional risk associated with a separate PCI before TAVI can be presumed to have only limited impact on the overall complication rate.

Furthermore, we must assume some degree of selection bias as there was a high number of complex PCI in the concomitant group. Being a tertiary care hospital, complex PCI procedures are often referred to our center. If patients had a complex coronary lesion in the preprocedural workup at a local cardiologist, PCI might have been postponed for it to be completed during TAVI at our center. However, despite more complex coronary interventions in the coPCI group, 3-year mortality was not affected.

5 | CONCLUSIONS

In conclusion, in this large retrospective analysis, concomitant PCI had no impact on long-term mortality, technical success or device success according to the VARC-3 endpoint definitions. However, if patients are at risk for bleeding (e.g., women) and AKI a priori, a stepwise approach for PCI and TAVI seems favorable to avoid bleeding complications or AKI. More randomized trials addressing different PCI strategies in TAVI patients would be desirable.

CONFLICTS OF INTEREST STATEMENT
J. S. received speaker honoraria from AstraZeneca and travel grants from the German Center for Cardiovascular Research (DZHK). D. B. received speaker honoraria from Abbott Vascular. M. O. received speaker honoraria and travel compensations from Abbott Medical, AstraZeneca, Abiomed, Bayer vital, BIOTRONIK, Bristol-Myers Squibb, CytoSorbents, Daiichi Sankyo Germany, Edwards Lifesciences Services, and Sedana Medical. S. P. received speaker honoraria from AstraZeneca and travel grants from Edwards Lifesciences. J. H. received research support from Abbott Vascular and Edwards Lifesciences. S. D. received speaker honoraria from AstraZeneca. The remaining authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.