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Original article

Conventional aortic valve replacement or transcatheter aortic valve implantation in patients with previous cardiac surgery

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ABSTRACT

Background: Clinical outcomes were compared among patients with previous cardiac surgery undergoing transcatheter aortic valve implantation (TAVI) or surgical aortic valve replacement (AVR).
Methods: Between 2007 and 2014 a total of 142 consecutive patients with previous cardiac surgery were treated by TAVI either by the transfemoral ($n = 68$) or transapical access ($n = 74$), and 236 patients underwent a surgical redo-AVR. Of these patients, propensity analysis (m:n) matched 62 (group 1, TAVI) and 51 patients (group 2, redo-AVR). A multivariate logistic regression model was constructed. Moreover, mortality was compared between both groups by Cox regression.
Results: Both groups differed significantly ($p < 0.01$) in regard to age and preoperative risk scores (EuroSCORE and STS-Score). Thirty-day mortality was 14.5% (9/62) in group 1 and 5.8% (3/51) in group 2 ($p = 0.23$). Risk-adjusted multivariable analysis revealed only the logistic EuroSCORE to be strongly correlated with 30-day mortality ($p = 0.01$). Multivariate analysis showed no difference in 30-day mortality between both groups ($p = 0.21$). Multivariate Cox regression revealed New York Heart Association functional class ($p = 0.001$), logistic EuroSCORE ($p = 0.01$), and STS-Score ($p = 0.03$) to be strongly associated with overall mortality. Moreover, evaluating overall mortality, Cox regression showed no difference between both groups ($p = 0.36$).
Conclusions: The present study shows that in patients with cardiac reoperation, TAVI comes with similar outcomes when compared to surgical AVR. On the other hand, conventional redo-AVR is still a valuable and safe treatment option.

Introduction

Surgical aortic valve replacement (AVR) is a highly standardized, well-established procedure and is currently the therapeutic gold standard for symptomatic aortic stenosis [1]. Recently, the German Aortic Valve Registry (GARY) confirmed excellent results of conventional surgical AVR [2]. Within this registry, 30-day mortality for primary isolated AVR in Germany has been reported as a percentage of 2.4% [3]. As patients are getting older and live longer, due to their primary heart operation, reoperative cardiac surgery is an increasing and integrative part of the cardio-surgical daily practice. Although increased experience and technical evolution lead to considerably improved outcomes, prior cardiac surgery still represents a significant risk factor influencing morbidity and mortality. Especially in high-risk patients, cardiac reoperation might be challenging.

The purpose of the present study was therefore to compare the outcomes of high-risk patients presenting with symptomatic degenerative aortic stenosis with prior cardiac surgery undergoing

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transcatheter aortic valve implantation (TAVI) to those who were treated with conventional surgical AVR.

Materials and methods

Study design

The present study was a non-randomized, single-center study including 378 patients who underwent either transcatheter aortic valve implantation ($n = 142$) or surgical AVR ($n = 236$) at the West-German Heart and Vascular Center Essen between 2007 and 2014. Propensity score matching (m:n) resulted in a total of 62 patients (group 1) with previous cardiac surgery who were treated by TAVI either by the transfemoral ($n = 68$) or transapical access ($n = 74$), and 51 patients underwent a surgical redo-AVR (group 2). The present study obtained IRB approval according to the Declaration of Helsinki. An individual patient consent was waived. TAVI was only considered in high-risk patients with a logistic EuroSCORE-I greater than 20%, or if patients were deemed to be at high risk due to the presence of other coexisting illnesses not reflected by the EuroSCORE. Moreover, the indication for TAVI in the individual patient was discussed for each patient in an interdisciplinary consensus conference (“heart-team”) of cardiologists and cardiac surgeons (D.W., P.K., F.A., and M.T.), and the patient’s or physician’s preference alone was not considered adequate for decision-making. Both, the transfemoral and transapical route were considered as potential access sites for TAVI, depending on suitability.

Inclusion and exclusion criteria

Surgical AVR

Patients with prior cardiac surgery and severe symptomatic aortic stenosis (aortic valve area $<1.0\ cm^2$) were considered for surgical AVR, if only the calcified aortic valve had to be treated, except additional myectomy, aortic root enlargement, or simple wrapping of the ascending aorta. Patients with endocarditis were excluded.

Study endpoints and definitions

The primary study endpoint was in-hospital mortality, defined as all causes of death within 30 days, including all patients. A follow-up was also performed. Patient and operative demographics were recorded in a prospective institutional database and retrospectively evaluated. Echocardiographic data were stored in an institutional parallel workflow platform (Horizon Cardiology™, Medcon/McKESSON, San Francisco, CA, USA). Chronic obstructive pulmonary disease (COPD) was defined as per the EuroSCORE definition. Survival was obtained by active follow-up. All outcomes were reported according to the standardized VARC-2 criteria (Valve Academic Research Consortium).

TAVI procedure

Transapical

All transapical TAVIs were performed under general anesthesia in a dedicated hybrid operation room offering full functionality for cardiac catheterization, anaesthesiology, and cardiac surgery and a cardiopulmonary bypass circuit and clinical perfusion team were kept on stand-by. Competences of the interdisciplinary heart-team, consisting of cardiac surgeons, cardiologists, anesthesiologists, and perfusionists, complemented in optimal support during the TAVI procedure. The transapical access was performed as previously described by our group [4]. Either the pericardium was opened and adhesiolysis was performed or the pericardium was unaltered, and the correct apical position was then detected by transesophageal echocardiography. For the transapical access, only the balloon-expandable Edwards Sapien or Sapien XT valve was used (Edwards Lifesciences, Irvine, CA, USA).

Transfemoral

All transfemoral transcatheter aortic valve implantations were performed within the same setting as described above, but under conscious sedation as previously described by our group [5]. For transfemoral implantation, both, the Edwards and the self-expandable Medtronic CoreValve (Medtronic, Minneapolis, MN, USA) systems were used. All TAVI patients received a lifetime standard therapy of 100 mg acetylsalicylic acid and 75 mg clopidogrel for 6 months.

Surgical AVR

All patients underwent computed tomography to evaluate the distance between heart and sternum. In case of cardiosternal contact, a femoro-femoral extracorporeal bypass was performed. All operations were carried out through a standard median repeated sternotomy followed by adhesiotomy and identification of the cardiac structures. All bypass grafts were identified. In case of no cardiosternal contact, cardiopulmonary bypass was performed (CPB) with ascending aorta cannulation. The cardiopulmonary bypass was established with a single atrial cannula. Moderate hypothermia (28–32 °C) was obtained. Myocardial protection was achieved by antegrade and optional retrograde crystalloid cardioplegic arrest (Custodiol®, Dr. Köhler Chemie, Bensheim, Germany) and additional topic cooling. According to our institutional protocol, a patent left internal in mammary bypass graft would also be dissected and clamped during aortic cross-clamping.

A hockeystick aortotomy with subsequent removal of the native aortic valve and debridement of the native annulus and aortic root was performed. After sizing the annulus with a respective industry-labeled sizer, the prosthesis was carefully chosen. When an effective orifice area index (EOAI) $>0.85\ cm^2/m^2$ would not be achieved because of small annulus, a Manougian procedure was performed to avoid prosthesis-patients mismatch. Patients received either a mechanical or a biological prosthesis depending on the patients’ preference.

Risk calculation

The EuroSCORE-I and -II calculator available online (http://www.euroscore.org) was used for both additive (AES) and logistic EuroSCORE (LES) and EuroSCORE-II calculations. The Society of Thoracic Surgeons (STS)-Score was performed by the online available STS-Score calculator (http://riskcalc.sts.org/de.aspx). The age, creatinine, and ejection fraction (ACEF) score were calculated as published by Ranucci and coworkers (age divided by ejection fraction, with 1 point added if the preoperative creatinine is ≥ 2.0 mg/dL) [6].

Statistics

Descriptive statistics are summarized for categorical variables as frequencies and proportions (%). Continuous variables were reported as mean ± standard deviation. New York Heart Association (NYHA) class is presented as a median. A stratified analysis based on the propensity score (using 5 strata) was performed based on 12 patients’ major risk factors. The following factors were used for the propensity score calculation: age, gender, left ventricular ejection fraction, renal disease, peripheral vascular disease, EuroSCORE-I, EuroSCORE-II, STS-Score, COPD, pulmonary hypertension, diabetes mellitus, and NYHA-functional class. Groups were compared using

Student's *t*-test or Fisher's exact tests. Univariate and multivariable logistic regression analyses were performed to identify preoperative independent risk factors for in-hospital mortality. For the analysis of mortality, those variables identified by the univariate analysis with a *p*-value <0.1 were added to the multivariable model, including group membership (belonging to one of both groups). Survival curves were generated with the Kaplan–Meier method followed by a log-rank test. In addition, uni- and multivariate Cox's proportional hazards models were applied to analyze the survival times and their relationship to the other variables. The proportional hazards assumption was furthermore verified with log–log survival plots. For those risk factors, which have been identified to significantly affect 30-day mortality, receiver operating curves (ROCs) were calculated. Sensitivity and specificity of expected vs. observed mortality were summarized by ROCs and the area under the resulting curve (AUC). A decreasing value of this statistic from 1.0 toward 0.5 indicates decreasing distinctiveness or discrimination between patients living and dead. Results were given as AUC accompanied by 95% confidence intervals.

A *p*-value less than 0.05 was considered to indicate statistical significance. All statistical analyses were performed using SAS®, version 9.2 (SAS Inc., Cary, NC, USA).

Statement of responsibility

The authors had full access to the data and take full responsibility for its integrity. All authors have read and agreed to the manuscript as written.

Results

Preoperative characteristics of both groups are summarized in Table 1. Both groups were similar for all listed characteristics, except for age, peripheral vascular disease, and the calculated risk scores. Patients in group 1 were significantly older (78.1 ± 5.9 years vs. 71.1 ± 10.8 years, $p < 0.01$), and showed more peripheral vascular disease than patients in group 2 (52.4% vs. 29.4%, $p = 0.02$). Furthermore, preoperative risk assessment showed higher estimated risk scores for group 1 (logistic EuroSCORE-I 36.4 ± 17.4% vs. 22.2 ± 17.5%, $p < 0.01$, additive EuroSCORE-I 12.9 ± 2.9% vs. 10.1 ± 2.9%, $p < 0.01$, EuroSCORE-II 13.0 ± 9.2% vs. 9.2 ± 7.2%, $p < 0.01$, ACEF-Score 1.9 ± 0.8% vs. 1.6 ± 0.6%, $p < 0.01$, and STS-Score 12.1 ± 10.0% vs. 7.1 ± 5.2%, $p < 0.01$). Patients in group 1 had significantly more isolated coronary artery bypass graft (CABG) surgery as previous cardiac surgery, whereas patients in group 2 had significantly more isolated aortic valve surgery ($p < 0.01$). A detailed summary of all underlying types of previous cardiac surgery is presented in Table 1.

Table 1
Patient baseline characteristics.

Variable	Group 1 (*n* = 62)	Group 2 (*n* = 51)	*p*-Value
Demographics			
Age, years	78.7 ± 5.9	71.1 ± 10.8	<0.001
Gender, female	19 (30.6)	13 (25.5)	0.67
BMI, kg/m^2	27.1 ± 4.1	26.6 ± 3.7	0.53
Risk factors and comorbidities			
NYHA class (range)	3 (2–4)	3 (2–4)	–
Peripheral vascular disease	32 (52.4)	15 (29.4)	0.02
Systemic hypertension	57 (91.9)	45 (88.2)	0.54
COPD	16 (25.8)	17 (33.3)	0.42
Renal disease (serum creatinine >200 μmol/L)	12 (23.5)	13 (21.0)	0.82
Diabetes mellitus	24 (38.7)	22 (43.1)	0.71
Cardiac history			
LV-EF, %	48.1 ± 13.0	49.9 ± 12.3	0.44
LV-EF, <35%	14 (22.6)	6 (11.8)	0.15
Pulmonary hypertension	14 (22.6)	7 (13.7)	0.33
Atrial fibrillation	14 (22.6)	13 (25.5)	0.82
Previous cardiac surgery	62 (100.0)	51 (100.0)	1.00
Isolated CABG surgery	54 (87.1)	33 (64.7)	<0.01
CABG + mitral valve surgery	1 (1.6)	1 (1.9)	1.00
Isolated mitral valve surgery	1 (1.6)	5 (9.8)	0.09
Isolated aortic valve surgery	2 (3.2)	10 (19.6)	<0.01
Aortic valve + CABG	4 (6.5)	2 (3.9)	0.69
Patent IMA-graft	58 (93.5)	51 (100.0)	0.13
Risk scores			
STS-Score, %	12.1 ± 10.0	7.1 ± 5.2	<0.01
Logistic EuroSCORE-I, %	36.4 ± 17.4	22.2 ± 17.5	<0.01
Additive EuroSCORE-I, %	12.9 ± 2.9	10.1 ± 2.9	<0.01
EuroSCORE-II, %	13.0 ± 9.2	9.2 ± 7.2	<0.01
ACEF-Score, %	1.9 ± 0.8	1.6 ± 0.6	<0.01

Data are presented as mean ± SD or number (%), NYHA class presented as median; BMI, body mass index; NYHA, New York Heart Association; COPD, chronic obstructive pulmonary disease; LV, left ventricle; EF, ejection fraction; STS, Society of Thoracic Surgeons; EuroSCORE, European System for Cardiac Operative Risk Evaluation.

Postoperative outcomes

There was no difference in 30-day mortality between the two groups. 30-Day mortality was 14.5% (9/62) in group 1 compared to 5.8% (3/51) in group 2 ($p = 0.23$). Outcomes according to VARC-2 are given in Table 2.

Survival

Freedom from all-cause death in group 1 was 77.4% at 1 year, 72.5% at 2 years, 59.5% at 3 years, 54.3% at 4 years, and 30.1% at 5 years. In group 2, freedom from all-cause death was 86.3% at 1 year, 80.0% at 2 years, 73.8% at 3 years, 71.5% at 4 years, and 68.9% at 5 years. Kaplan–Meier survival curves are given in Fig. 1.

Regression analysis

In order to evaluate independent predictors for 30-day mortality, a logistic regression model was constructed, based on 12 major risk factors. Several univariate indicators were found to predict for 30-day mortality. In the univariate model, the following variables were found to be strongly associated with 30-day mortality: logistic EuroSCORE-I, EuroSCORE-II, and STS-Score (Table 3). The multivariable regression model showed that only the logistic EuroSCORE-I [odds ratio (OR) 1.054; 95% confidence interval (CI), 1.007–1.104; $p = 0.02$] was significantly associated with 30-day mortality. Most notably, group membership was not associated with 30-day mortality ($p = 0.21$) (Table 3). In a next step, a Cox's proportional hazards regression model of survival was constructed. The univariate model found the following variables to be strongly associated with survival: ejection fraction, logistic EuroSCORE-I, EuroSCORE-II, STS-Score, and NYHA-functional class (Table 4). The multivariable model showed that the logistic

Table 2
VARC-2 criteria.

Variable	Group 1 (*n* = 62)	Group 2 (*n* = 51)
Mortality		
30-Day all cause	9 (14.5)	3 (5.8)
30-Day cardiovascular	1 (1.6)	(1.6)
12-Month all cause	14 (22.6)	7 (13.7)
Stroke 30-day	0 (0)	1 (2.0)
Major bleeding	5 (8.0)	2 (3.9)
Life-threatening bleeding	2 (3.2)	1 (2.0)
Pacemaker implantation	11 (17.7)	1 (2.0)
Dialysis	7 (11.3)	3 (5.9)

Data are presented as number (%); VARC, Valve Academic Research Consortium.

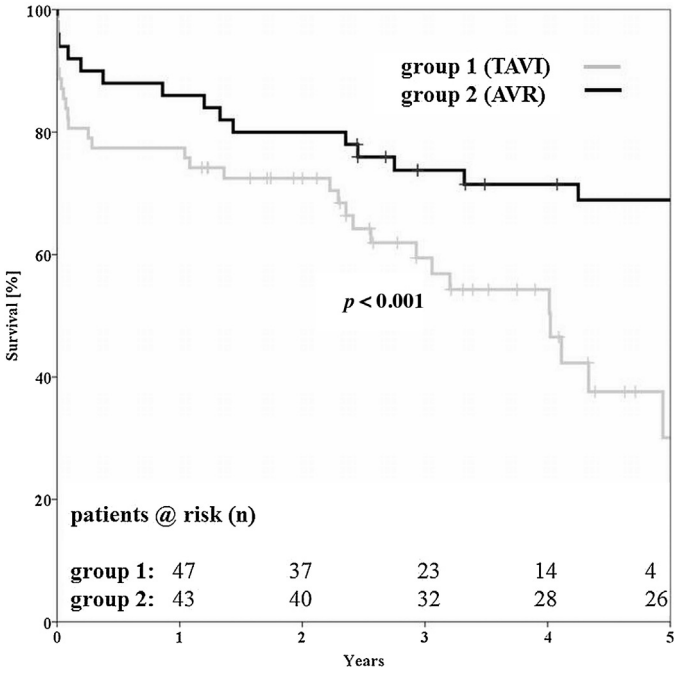

Fig. 1. Kaplan–Meier survival curves; gray line: group 1; black line: group 2. TAVI, transcatheter aortic valve implantation; AVR, aortic valve replacement.

EuroSCORE-I [hazard ratio (HR) 1.031; 95% CI 1.006–1.057; $p = 0.01$], the STS-Score (HR 1.039; 95% CI 1.003–1.077; $p = 0.03$), and NYHA-functional class (HR 6.531; 95% CI 2.109–20.220; $p = 0.001$) were significantly associated with survival (Table 4). Importantly, after final adjustment of the Cox's proportional hazards regression model for the propensity score, group membership remained not significant (HR, 0.651; 95% CI, 0.257–1.651, $p = 0.36$).

ROC analysis

As the logistic EuroSCORE-I was identified to significantly influence 30-day mortality, a ROC analysis was performed for the logistic EuroSCORE-I. The AUC was 80.1 for the logistic EuroSCORE-I (CI 66.3–93.9) for all patients ($n = 113$) and 87.9 for group 2 (CI 70.7–100.0), whereas group 1 showed an AUC of 73.6 (CI 53.5–93.6). The ROC analysis of the EuroSCORE-I for all patients is shown in Fig. 2.

Discussion

The present study compared high-risk patients with previous cardiac surgery and new symptomatic aortic stenosis undergoing either TAVI or a surgical reoperation strategy. This study provides a number of interesting findings:

1. Although TAVI patients were older and showed higher risk scores, we observed no statistically significant difference concerning 30-day mortality.

Table 3
Univariate and multivariate regression analysis of variables associated with 30-day mortality.

Variable	Univariate analysis			Multivariate analysis		
	OR	CI	*p*-Value	OR	CI	*p*-Value
Group membership	0.332	0.086–1.279	0.109	0.314	0.052–1.889	0.21
Gender	1.314	0.337–5.133	0.694	–	–	–
Age	1.079	0.978–1.190	0.128	–	–	–
Ejection fraction	0.960	0.978–1.005	0.078	0.992	0.934–1.053	0.786
Renal insufficiency	1.871	0.521–6.728	0.337	–	–	–
Peripheral artery disease	2.462	0.750–8.074	0.1372	–	–	–
Logistic EuroSCORE-I	1.062	1.028–1.097	<0.001	1.054	1.007–1.104	0.02
EuroSCORE-II	1.088	1.024–1.157	<0.001	0.975	0.889–1.069	0.588
STS-Score	1.064	1.016–1.115	<0.001	1.062	0.995–1.132	0.068
COPD	1.585	0.477–5.261	0.452	–	–	–
Pulmonary hypertension	2.144	0.591–7.776	0.246	–	–	–
Diabetes mellitus	1.795	0.561–5.740	0.324	–	–	–
NYHA	0.948	0.109–8.255	0.961	–	–	–

OR, odds ratio; CI, confidence interval.

Table 4
Univariate and multivariate Cox's proportional hazards regression model of survival times.

Variable	Univariate analysis			Multivariate analysis		
	HR	CI	*p*-Value	HR	CI	*p*-Value
Group membership	0.621	0.322–1.201	0.157	1.164	0.510–2.659	0.718
Gender	0.984	0.517–1.873	0.961	–	–	–
Age	1.032	0.996–1.068	0.079	1.019	0.981–1.059	0.321
Ejection fraction	0.975	0.953–0.998	0.031	0.996	0.968–1.024	0.767
Renal insufficiency	1.248	0.632–2.465	0.523	–	–	–
Peripheral artery disease	1.639	0.897–2.995	0.108	–	–	–
Logistic EuroSCORE-I	1.036	1.020–1.052	<0.001	1.031	1.006–1.057	0.01
EuroSCORE-II	1.044	1.016–1.072	<0.001	0.979	0.933–1.027	0.389
STS-Score	1.034	1.010–1.059	0.01	1.039	1.003–1.077	0.03
COPD	1.094	0.583–2.053	0.779	–	–	–
Pulmonary hypertension	1.140	0.548–2.369	0.726	–	–	–
Diabetes mellitus	1.795	0.646–2.072	0.624	–	–	–
NYHA	4.566	1.625–12.831	0.004	6.531	2.109–20.220	0.001

HR, hazard ratio; CI, confidence interval.

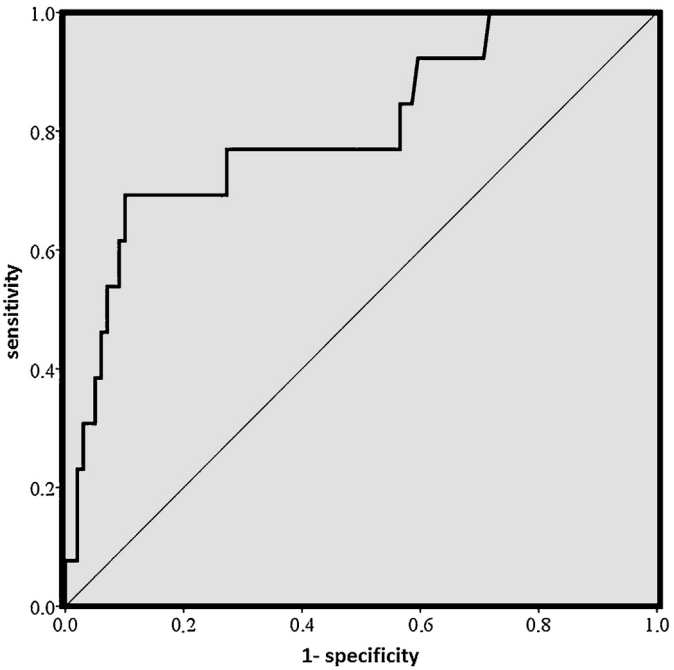

Fig. 2. ROC curves for the logistic EuroSCORE-I for all patients (n = 113) in regard to 30-day mortality.

2. Multivariate regression analysis showed the logistic EuroSCORE-I to significantly affect 30-day mortality in patients with previous cardiac surgery.
3. The logistic EuroSCORE-I showed a good performance in our overall cohort of redo patients with an AUC of 80.1.
4. Surgical AVR showed excellent long-term results in patients with previous cardiac surgery.

Surgical AVR still represents the therapeutic golden standard in the treatment of aortic stenosis with excellent long-term outcomes, which have been proven by the recently published GARY data [2,3]. Within this registry, 30-day mortality for isolated surgical AVR has been reported to be as low as 2.4%, and 6.7% at 1 year, respectively, and one should bear in mind, that a total of 9.4% of these patients had undergone previous cardiac surgery [2]. In conventional surgical AVR, it is well-known that previous cardiac surgery represents an independent risk factor, which is associated with increased morbidity and mortality compared with first-time surgery. One surgical series reported a 11-fold increase for 30-day mortality in patients with previous CABG undergoing redo-AVR [7]. In a previous evaluation, we published an OR of 3.3 (95% CI 1.1–10.2) for repeat cardiac surgery in our institution [8]. Cardiac re-exploration in cases of patent internal mammary artery (IMA) might increase surgical risk. In the present study, all IMA-grafts in the surgically treated group and 93.5% in the TAVI-treated group were patent. In our institution, the operative standard is to dissect and free the patent IMA-graft in order to clamp it during cardiac arrest, thereby preventing both regional myocardial warming and cardioplegia-"washout" during clamping. If the IMA-graft could not be clearly identified, a sterile ultrasound probe was used (Medistim, Oslo, Norway).

As a minimally invasive alternative, TAVI has evolved to become the new standard of care for inoperable patients with severe, symptomatic aortic valve stenosis [9] and to be a viable treatment option for high-risk, but operable patients [10], as recently demonstrated in the Placement of Aortic Transcatheter Valves (PARTNER) trial, and also in patients with previous renal transplantation [11]. In contrast to large aortic valve registries, cohort A of the randomized PARTNER trial presented a somewhat huge number of patients with previous cardiac surgery (42.6% of the TAVI group and 44.2% in the surgical AVR group). Greason et al. recently published a PARTNER trial subgroup analysis including only patients (n = 288) with prior CABG operation, who were treated either by TAVI (51%) or surgical AVR (49%). There was no difference in 30-day mortality (16.7% vs. 16.3%, p = 0.95), but a trend toward greater 2-year all-cause mortality in the TAVI-treated patients (36% vs. 25%; p = 0.052). Interestingly, they described no association of paravalvular regurgitation in the TAVI group (9%) with the 2-year outcome (p = 0.011) [12].

Despite these publications, there are limited data evaluating the impact of previous cardiac surgery on long-term outcomes. For exactly that reason, it appears reasonable to evaluate the outcomes of patients with previous cardiac surgery undergoing either surgical AVR or percutaneous TAVI.

In a recent publication, Wilbring et al. evaluated transapical TAVI vs. surgical AVR in high-risk patients with previous cardiac surgery by propensity score analysis. A total of 53 patients per group were matched, and in regard to 30-day mortality, they observed no difference between both groups (5.7% in the surgical control group and 9.4% in the TAVI group) [13], similar to our results (5.8% in surgical redo-AVR vs. 14.5% in the TAVI group). It must be emphasized, however, that our institutional TAVI program started in 2005 with the transfemoral, and in 2007 with the transapical approach. Therefore, within the present study some patients were matched, who reflect our early experience with TAVI, which might explain the relatively high 30-day mortality in group 1.

Although we performed a profound m:n matching of both groups, the results showed a statistical significance of preoperative risk scores and age between both groups. On the other side, however, we could show by detailed multivariate analysis, that group membership had no influence on 30-day mortality, despite such different preoperative risk scores.

Of note, in the absence of data evaluating the long-term outcomes of TAVI patients, the present study provides comprehensive follow-up data up to 5 years after TAVI/surgical AVR in patients with repeated cardiac surgery as we have been one of the pioneering centers in Germany starting with TAVI. In the surgical group, we observed excellent outcomes, despite the independent risk of previous cardiac surgery with 1-year survival rates of 86.3% and 68.9% at 5 years. This is in line with previous published data, showing survival rates of 93.4% at 1 year and 75.8% at 5 years in isolated surgical AVR [1]. For comparison, the 1-year survival rates of the PARTNER cohort A for surgical AVR were 73.2% [10]. On the other hand, TAVI-treated patients of cohort A within the PARTNER trial showed a 1-year survival rate of 75.8%, which could be reflected by our results with 1-year survival rates of 77.4%. However, evaluating our long-term results, we observed a statistically significant difference between both groups with better survival in the conventional AVR group ($p < 0.001$), which can be attributed to the fact that in our series, TAVI patients were significantly older.

Furthermore, as we identified the logistic EuroSCORE-I to significantly impact 30-day mortality in patients with previous cardiac surgery undergoing either TAVI or surgical AVR, we performed a ROC analysis evaluating the logistic EuroSCORE-I. Our group has previously shown that in conventional surgical AVR the STS-Score appears to be more appropriate for risk prediction, which could be proven in a future study evaluating also TAVI patients [14]. In the present study, however, as all patients were redo patients, the logistic EuroSCORE-I showed a good performance with an AUC of 80.1 (CI 66.3–93.9). Moreover, in the subgroup of patients treated by surgical AVR, the AUC was even better with 87.9 (CI 70.7–100.0). It is well known that the logistic

EuroSCORE-I greatly overestimated the risk for 30-day mortality. Improvements in cardio-surgical techniques since then may mean that EuroSCORE-I is currently inappropriately calibrated. It is also important to note that some risk scoring systems include mainly data of CABG patients, rather than those undergoing AVR. In the present study, we observed a good c-statistics for the logistic EuroSCORE-I in redo patients. This might be related to the fact that in redo cases, of course, the operative risk is higher, and therefore the logistic EuroSCORE-I might predict better.

In cardiac surgery, high-risk patients presenting with symptomatic aortic stenosis and with previous cardiac surgery represent a challenging patient cohort. In particular, patients with previous CABG surgery are at risk for graft injury during re-exploration. On the one hand, despite the potential risk of reoperation, the surgical approach comes with excellent long-term outcomes as supported by the results of the present evaluation. On the other hand, however, TAVI represents a minimally invasive alternative without the need for complete re-exploration and extracorporeal circulation or even myocardial arrest. Therefore, TAVI might be particularly helpful in elderly high-risk redo patients. To this extent, it remains to discuss a broadened indication of TAVI in the future in the reoperative situation.

Limitations

The present study was performed at a single tertiary care medical center starting with TAVI in 2005, and the matching resulted in a relatively small sample size. Therefore, the generalization of our findings may not extend to all centers worldwide. In addition, as patients of our early experience have also been included, results might be mixed due to the learning curve of the new technique of TAVI and of note, recent results of TAVI are nearly comparable to conventional AVR. In addition, our model of propensity matching might have missed some relevant factors.

Conclusion

In conclusion, our study showed no difference in regard to 30-day mortality in patients with previous cardiac surgery undergoing either TAVI or surgical AVR. However, it should be kept in mind, that despite best matching, the TAVI group was still significantly older and had higher risk scores. Against this background, one must consider these differences between both groups with a nearly doubled logistic EuroSCORE-I in the percutaneous-treated group. In our study, we showed that multivariate regression analysis revealed the logistic EuroSCORE-I to significantly affect 30-day mortality, and a high AUC was observed for the logistic EuroSCORE-I especially in conventional reoperative AVR patients. Moreover, and most interestingly, one treatment strategy (TAVI) evolved simultaneously while the other has been used for decades as the standard of care. As a result, as short-term mortality shows no difference, TAVI might be particularly helpful in elderly high-risk redo patients, although we showed a significant difference in "mid-term" results up to 5 years. However, surgical redo-AVR is still a good option, except in very high-risk patients. To this extent, it remains to discuss a broadened indication of TAVI in the future in the reoperative situation. Therefore, further studies with larger patient numbers as well as randomized clinical trials with longer follow-up are warranted since we were able to present only "mid-term" results.

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Conflict of interest

The authors declare that there is no conflict of interest.

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