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Transcatheter aortic valve implantation: predictors of procedural success—the Siegburg–Bern experience

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Aims The purpose of the present analysis was to identify predictors of procedural success of percutaneous transcatheter aortic valve implantation (TAVI).

Methods and results We prospectively assessed in-hospital outcome of patients undergoing TAVI at two institutions. We analysed clinical, morphological, and procedural parameters using univariate and multivariate regression models. Between 2005 and 2008, a total of 168 consecutive patients with symptomatic aortic valve stenosis underwent TAVI using the self-expanding CoreValve Revalving prosthesis. Patients (93%) were highly symptomatic with a New York Heart Association grade III/IV and a mean aortic valve area of 0.66 ± 0.21 cm^2. Acute and in-hospital procedural success rates were 90.5 and 83.9%, respectively, with an in-hospital mortality, myocardial infarction, and stroke rate of 11.9, 1.8, and 3.6%, respectively. Predictors of in-hospital procedural success were type of access (OR 0.33, 95% CI 0.13–0.82, $P = 0.017$), prior coronary intervention (OR 5.3, 95% CI 1.20–23.41, $P = 0.028$) and pre-procedural Karnofsky index using univariate regression. Pre-procedural Karnofsky index emerged as the only independent predictor (OR 1.04, 95% CI 1.00–1.08, $P = 0.032$) in the multivariate analysis.

Conclusion Pre-procedural functional performance status predicts the in-hospital outcome after TAVI. Patients with a good functional status are likely to benefit more from TAVI than previously reported high-risk patients.

Keywords Percutaneous aortic valve implantation • Aortic stenosis • Predictors

Introduction

Transcatheter aortic valve implantation (TAVI) has rapidly been implemented as a new and less-invasive treatment option for patients with severe symptomatic aortic valve stenosis at high surgical risk. Since the first-in-man experience in 2002,[1] the technology has significantly improved with the development of smaller profile delivery catheters and better prostheses with availability of various sizes. Presently, two different techniques are commercially available: the balloon-expandable Edwards SAPIEN prosthesis (Edwards Lifesciences, Irvine, CA, USA) and the self-expanding CoreValve Revalving system (Medtronic, Minneapolis, MN, USA; *Figures 1* and *2*). Both devices have been described in detail in previous publications,[1–10] and more than 4000 patients have now been treated worldwide with one of these techniques.

Data on procedural performance, safety, and efficacy are yet still limited. Using the latest devices in experienced centres, procedural success rates of up to 96% with a 30 day mortality rate of 7–12% have been reported,[8–10] in patients deemed at high surgical risk with numerous co-morbidities. However, predictors of procedural success are not well established. As with all new techniques, there is an operator learning curve, which influences early outcome. This holds true particularly for TAVI, a demanding procedure with several new features compared with standard interventional

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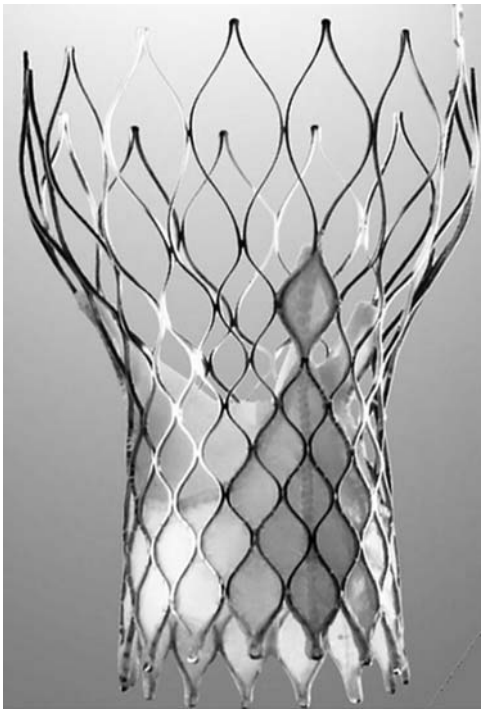


Figure 1 CoreValve prosthesis.

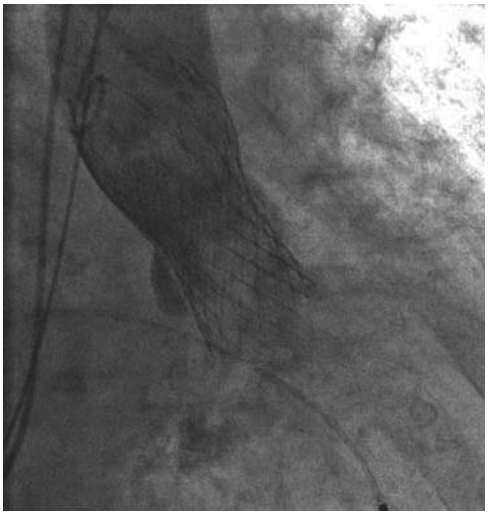


Figure 2 CoreValve prosthesis after successful implantation.

techniques, such as dealing with a large arterial access, manoeuvring a large-profile device retrogradely through the aorta as well as the implantation steps of the prosthesis itself within the native, diseased aortic valve. Even if the operator is familiar with the technique, procedural success still varies over a wide range between 70 and 96%,[7–10] indicating additional obstacles. Therefore, we aimed at identifying predictors of in-hospital procedural success, defined as successful device implantation without in-hospital major adverse cardiac and cerebral adverse events (MACCE).

Methods

Patient population

Between February 2005 and June 2008, 168 consecutive patients underwent TAVI using the CoreValve Revalving device (*Figures 1* and *2*) at two institutions with TAVI expertise, HELIOS Klinikum Siegburg, Siegburg, Germany (138 patients), and Bern University Hospital, Bern, Switzerland (30 patients). As the CoreValve Revalving prosthesis received European market approval in 2007, the present patient population encompasses patients included during the early safety and efficacy studies as well as post-approval registry patients.

Patient screening and eligibility

All patients underwent a pre-interventional screening process to determine eligibility. Coronary anatomy and haemodynamic status were evaluated by coronary angiography and complete left and right heart catheterization. The valvular anatomy was assessed using transthoracic and transoesophageal echocardiography, contrast angiography of the aortic root and multi-slice computer tomography (MSCT) of the thoracic aorta as the key screening methods. Annulus dimensions were obtained from three-dimensional multi-planar MSCT reformation due only to its accuracy and robustness in visualizing the region of interest with minimized artificial effects as opposed to echocardiography. Vascular access was assessed using MSCT of the abdominal aorta, and the iliac and femoral vessels. The baseline surgical risk was estimated by use of the logistic EuroSCORE. Eligibility of patients included into the safety and efficacy studies was dependent on the study-specific inclusion and exclusion criteria described elsewhere.[5,7,9] Patient eligibility of the post-approval series was similar to the safety and efficacy studies. Patients were considered suitable if they (i) fulfilled the anatomical requirements (*Figure 3*) and (ii) were considered at high surgical risk as confirmed by a senior cardiologist and cardiac surgeon.

Device and procedure

Design characteristics of the self-expanding CoreValve Revalving prosthesis (*Figure 1*) as well as the procedural characteristics have been described previously.[4,5,7,9] Briefly, the CoreValve prosthesis consists of a tri-leaflet bioprosthetic porcine pericardial tissue valve, which is sutured into a self-expanding nitinol frame. The sizes of three subsequently developed delivery systems have been gradually reduced from 25 French (Generation 1) and 21 French (Generation 2) to 18 French (Generation 3) over time which facilitated vascular access and deployment of the device. For the current Generation 3 device, two different sizes are available accommodating annulus dimensions from 19 to 27 mm.

While the implants of Generation 1 and majority of Generation 2 required surgical access to the iliac arteries requiring general anaesthesia, the Generation 3 device can be implanted percutaneously under sedoanalgesia. Vascular access can be obtained with standard percutaneous access techniques and percutaneous closure using a pre-loaded suture device (e.g. Prostar XL suture device, Abbott Vascular, Abbott Park, IL, USA).

After mandatory pre-dilation of the native aortic valve, the prosthesis is advanced retrogradely and deployed within the aortic annulus.

Anatomy	Preferred	Borderline
Atrial or ventricular thrombus	Not present	
Mitral regurgitation	≤Grade 1	Grade 2
LV ejection fraction	>50%	30–50%
LV hypertrophy (wall thickness)	Normal to mild (0.6–1.3 cm)	Moderate (1.4–1.6 cm)
Sub-aortic stenosis	Not present	
Annulus (width)	20–23 mm → 26 mm device 24–27 mm → 29 mm device	
Annulus-to-aorta (angle) †	<30°	30–45°
AO root (width)	≥30 mm	27–29 mm
Sinuses of valsalva (height)	≥15 mm	10–14 mm
Coronary ostia position (take-off)	High	Mid-sinus level
Coronary disease	None	Mid or distal stenosis <70%
Ascend aorta (width)	≤40 → 26 mm device ≤43 → 29 mm device	

Figure 3 Anatomical requirements for CoreValve implantation.

Statistical analysis

Potential predictors for in-hospital procedural success were divided into clinical, quantitative morphological, and procedural variables. *Clinical variables* included the parameters presence of congestive heart failure, diabetes, renal insufficiency (creatinine >1.2 mg/dL), smoking, arterial hypertension, pulmonary hypertension (mean pulmonary artery pressure at rest >25 mmHg), coronary artery disease, prior stroke, prior myocardial infarction, prior percutaneous coronary intervention (PCI), prior coronary artery bypass grafting, pre-procedural New York Heart Association (NYHA) class, pre-procedural Karnofsky index (see Appendix),[11] and logistic EuroSCORE. *Quantitative morphological variables* included pre-procedural aortic regurgitation, pre-procedural peak aortic valve gradient, pre-procedural mean aortic valve gradient, pre-procedural mean aortic valve area, left ventricular ejection fraction, and annulus diameter by MSCT. *Procedural variables* included use of a large prosthesis, pre-dilation balloon diameter, post-dilation performed, post-dilation balloon diameter, access (femoral, iliac, subclavian artery). Details on parameter characteristics are listed in Appendix 1.

Categorical variables are presented as frequencies and were compared by chi-square test or Fisher's exact test. Continuous variables are presented as mean ± standard deviation and were compared by unpaired Student's *t*-test. Univariate logistic regression was performed on all variables to identify determinants for in-hospital procedural success, in-hospital major adverse cardiac and cerebrovascular events (MACCE), and death. A *P*-value of <0.20 at the univariate stage was the method of selection of potential predictive factors in the comparison of incidence rates. Next, relationships of event incidence to selected covariates were investigated with multivariate logistic regression models. All statistical tests were bilateral and a *P*-value of <0.05 was considered significant in the final modelling.

Statistical analyses were conducted by Medpass International, Paris, France. The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agreed to the manuscript as written. All patients provided written informed consent prior to the procedure. The study as well as informed consent procedures were approved by the local ethics committees at each institution.

Outcome definitions

In-hospital procedural success was defined as device success with the absence of MACCE during the in-hospital period. Acute procedural success was defined as device success with the absence of peri-procedural MACCE during the first 24 h after device implantation. Device success was defined as stable device placement and adequate function without severe aortic regurgitation during the first attempt as assessed by angiography and echocardiography. MACCE consisted of death from any cause, myocardial infarction (creatine kinase-myocardial band more than two times the upper limit of normal; measured routinely post procedure and on Day 1 as well as in case of clinical need), and stroke (as assessed by routine neurological assessment before and after procedure and before hospital discharge). Clinical adverse events were adjudicated by an independent clinical events committee.

Results

Patient population

Patient baseline and procedural characteristics are listed in *Table 1*. A total of 168 patients out of 380 patients with aortic valve stenosis and high surgical risk entering the MSCT screening process underwent TAVI at two institutions and were included in this analysis. In 14.2% of screened patients, eligibility criteria were fulfilled and TAVI procedure was intended, but not yet performed, during the study period. Patients were not eligible for the TAVI procedure due to inadequate annulus sizes (27.2%, with annulus range inclusion criterion of '20–23 mm', early one device size generation; 4.2%, with annulus range inclusion criterion of '20–27 mm', current two device size generations), peripheral artery disease (19.8%), excessive valve calcifications (2.4%), and aneurysms of the ascending aorta (1.4%). Surgical valve replacement was performed in 12.3% of patients without TAVI exclusion criteria based on the interdisciplinary clinical judgment, and in 21.2% of patients, the TAVI procedure was not performed due to lack of clinical indication (including reduced life expectancy for other reasons, bleeding risk) or patient preferences.

The mean patient age of patients undergoing TAVI was 81.9 ± 6.7 years. Pre-procedural functional status as assessed by the Karnofsky index (functional performance scale, see Appendix) was 10–40 (severely reduced) in 48% of these patients, mean 44.8, median 50, range 20–80. Patients were severely symptomatic (NYHA class III/IV: 93% of patients) with a mean aortic valve area of 0.66 ± 0.21 cm^2, mean pressure gradient was 43.2 ± 16.9 mmHg. None or mild pre-procedural aortic regurgitation was present in 80.8% of patients.

Acute and in-hospital outcome

The acute and in-hospital procedural success rates in the study population were 90.5 and 83.9%, respectively (*Table 2*). The in-hospital MACCE rate was 16.7%, with an in-hospital mortality,

Table 1 Patient baseline and procedural characteristics

Number of patients	168
Age, years	81.9 ± 6.7
Male gender	73 (43.5%)
Clinical characteristics	
Hypertension	127 (75.6%)
Renal insufficiency	44 (26.2%)
Coronary heart disease	99 (58.9%)
Pulmonary hypertension	36 (21.4%)
Congestive heart failure	55 (32.7%)
Smoker	22 (13.1%)
Diabetes	47 (28.0%)
Prior stroke	15 (8.9%)
Prior myocardial infarction	41 (24.4%)
Prior PCI	44 (26.2%)
Prior CABG	49 (29.2%)
Pre-procedural NYHA grade	
III	112 (67.1%)
IV	43 (25.7%)
Pre-procedural Karnofsky index	
10–40	81 (48.2%)
50–70	85 (50.6%)
80–100	2 (1.2%)
Logistic EuroSCORE	23.8 ± 15.4%
STS score: mortality	9.0 ± 6.0%
Quantitative morphological characeristics	
Pre-procedural aortic valve area	0.66 ± 0.21 cm^2
Pre-procedural peak valve gradient	69.9 ± 24.0 mmHg
Pre-procedural mean valve gradient	43.2 ± 16.9 mmHg
Pre-procedural aortic regurgitation grade	
None/mild	135 (80.8%)
Moderate	29 (17.4%)
Severe	3 (1.8%)
Annulus diameter by CT-Scan	23.6 ± 1.5 mm
Ejection fraction	51.3 ± 16.3%
Procedural characteristics	
Access	
Femoral	155 (92.3%)
Iliac	10 (6.0%)
Subclavian	3 (1.8%)
Pre-dilation balloon diameter	22.5 ± 1.5 mm
Post-dilation performed	92 (55.4%)
Post-dilation balloon diameter	25.4 ± 2.5 mm
Use of large prosthesis	53 (31.9%)
Length of Hospital Stay, median	9 days

myocardial infarction, and stroke rate of 11.9, 1.8, and 3.6%, respectively. In-hospital mortality was primarily related to progressive heart failure, dominantly right heart failure, as well as pneumonia, sepsis, and mesenterial infarction. Acute device success was observed in 93.5%.

Table 2 Procedural success and in-hospital outcome

Procedural success, acute	152 (90.5%)
Device success, acute	157 (93.5%)
Death, in-hospital	20 (11.9%)
Stroke, in-hospital	6 (3.6%)
Myocardial infarction, in-hospital	3 (1.8%)
Procedural success, in-hospital	141 (83.9%)

Univariate and multivariate analyses

Results of the univariate and multivariate analyses are presented in *Tables 3–8*. Univariate analysis identified two potential clinical predictors [pre-procedural Karnofsky index, odds ratio (OR) 1.04, 95% confidence interval (CI) 1.01–1.08, $P = 0.01$; prior PCI, OR 5.3, 95% CI 1.20–23.41, $P = 0.028$; *Table 3*] and one procedural predictor (access site, OR 0.33, 95% CI 0.13–0.82, $P = 0.017$; *Table 5*) for in-hospital procedural success. In the multivariate analysis, pre-procedural Karnofsky index emerged as the only independent predictor for in-hospital procedural success (OR 1.04, 95% CI 1.00–1.08, $P = 0.032$; *Table 6*). There was a trend for the variable access site (OR 0.48, 95% CI 0.18–1.27, $P = 0.139$), but this did not reach significance in the multivariate analysis. The multivariate predictor analysis for any major adverse event including death, stroke, and myocardial infarction—as part of in-hospital success—as well as mortality alone revealed a predictive impact of the pre-procedural Karnofsky index (any MACCE: OR 0.98, 95% CI 0.93–1.00, $P = 0.025$; death alone: OR 0.97, 95% CI 0.93–1.00, $P = 0.051$; *Tables 7* and *8*).

Discussion

Transcatheter aortic valve implantation success is influenced by numerous factors, including operator experience and patient selection. Particularly, the operator learning curve affects the outcome in the first cases of each centre. However, even beyond this learning period, procedural outcome varies, with procedural failure rates of approximately 5–25%.[7–9] Therefore, it is of importance to identify factors which predict the outcome of TAVI in clinical practice.

We have analysed various clinical, quantitative morphological, and procedural parameters potentially affecting procedural outcome based on the combined TAVI experience of two institutions. In-hospital procedural success was chosen as the principal outcome parameter, as it reflects a combination of feasibility, safety, and efficacy in a clinically relevant way, indicating the amount of patients discharged after TAVI without major complications including death, stroke, or myocardial infarction.

The in-hospital procedural success rate amounted to 83.9% in the present report, with an acute device and procedural success rate of 93.5 and 90.5%, respectively, which is in line with previous publications.[8–10]

The only independent predictive parameter of in-hospital procedural success was the pre-procedural functional performance status of the patient, as expressed in our study by the Karnofsky

Table 3 Univariate predictor analysis for in-hospital procedural success of transcatheter aortic valve implantation—clinical predictors

Clinical variables	Odds ratio	Confidence limits for odds ratio 95%	Probability value
Pre-procedural Karnofsky index	1.04	[1.01, 1.08]	0.01
Prior PCI	5.3	[1.20, 23.41]	0.028
Prior CABG	2.7	[0.88, 8.25]	0.083
Coronary heart disease	2.01	[0.88, 4.63]	0.099
Pulmonary hypertension	2.44	[0.69, 8.63]	0.165
Renal insufficiency	0.54	[0.23, 1.29]	0.166
Congestive heart failure	0.66	[0.28, 1.54]	0.335
Smoker	2.07	[0.45, 9.41]	0.348
Pre-procedural NYHA grade	0.74	[0.35, 1.55]	0.421
Prior myocardial infarction	1.51	[0.53, 4.28]	0.439
Diabetes	1.46	[0.56, 3.79]	0.441
Gender	0.73	[0.31, 1.70]	0.464
Prior stroke	0.74	[0.20, 2.84]	0.665
Hypertension	1.1	[0.43, 2.83]	0.841
Logistic EuroSCORE	1	[0.97, 1.03]	0.981

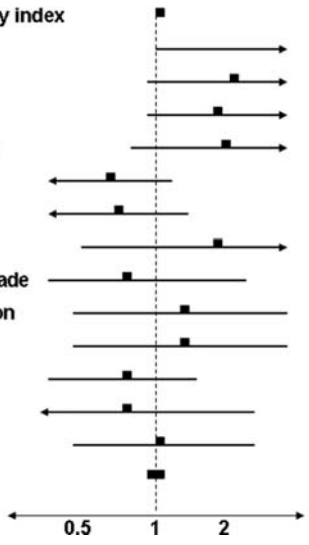
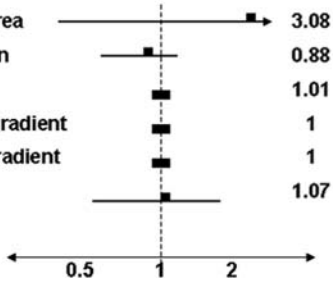


Table 4 Univariate predictor analysis for in-hospital procedural success of transcatheter aortic valve implantation—morphological predictors

Morphological variables	Odds ratio	Confidence limits for odds ratio 95%	Probability value
Preprocedural aortic valve area	3.08	[0.31, 30.21]	0.334
Annulus diameter by CT scan	0.88	[0.68, 1.14]	0.334
Ejection fraction	1.01	[0.99, 1.04]	0.378
Pre-procedural mean valve gradient	1	[0.98, 1.03]	0.755
Pre-procedural peak valve gradient	1	[0.98, 1.02]	0.796
Pre-procedural aortic regurgitation grade	1.07	[0.61, 1.87]	0.809



index—though the effect was mild just reaching significance. This observation is primarily driven by a significant influence of the pre-procedural Karnofsky index on the incidence of MACCE, namely the rate of death. The univariate analysis identified the access site as another potential predictor for in-hospital procedural success without significance in the multivariate analysis. In other words, the in-hospital outcome might have been partially affected by the selection of the access site, favouring the femoral over the iliac and subclavian access. However, the number of patients with non-femoral access is comparatively low, limiting the ability to draw meaningful conclusions from this finding.

This observation of a predictive effect of the Karnofsky index is of importance for future TAVI studies, as it might shift the clinical relevance of scoring systems from the historically used, more co-morbidity-based EuroScore or Society of Thoracic Surgeons (STS) score towards functional assessment scales (frailty indices). Accordingly, it is not the sum of various individual co-morbidities that predicts the procedural risk, but rather their consequences on the functional and clinical status of the patient. This finding is not surprising—a frail patient usually has a slower and more complicated recovery than a physically healthy one—but its impact on procedural success and in-hospital mortality has not previously been validated in the field of TAVI.

In this study, we have chosen the Karnofsky index as functional performance scale, which originates from the field of oncology owing to its simplicity. However, there are multiple functional

Table 5 Univariate predictor analysis for in-hospital procedural success of transcatheter aortic valve implantation—procedural predictors

Procedural variables	Odds ratio	Confidence limits for odds ratio 95%	Probability value
Access	0.33	[0.13, 0.82]	0.017
Post-dilation balloon diameter	0.86	[0.67, 1.10]	0.22
Use of large prosthesis	1.58	[0.59, 4.23]	0.359
Pre-dilation balloon diameter	1.08	[0.81, 1.46]	0.597
Post-dilation performed	1.25	[0.52, 2.96]	0.618

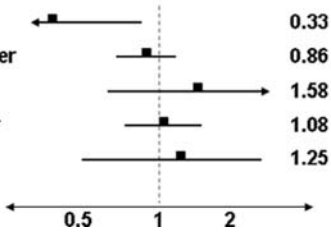


Table 6 Multivariate predictor analysis for in-hospital procedural success of transcatheter aortic valve implantation

Variables	Odds ratio	Confidence limits for odds ratio 95%	Probability value
Pre-procedural Karnofsky index	1.04	[1.00, 1.08]	0.032
Access	0.48	[0.18, 1.27]	0.139

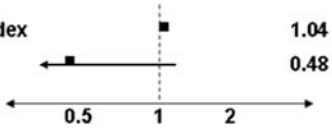
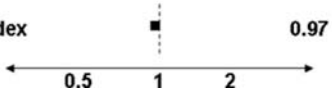


Table 7 Multivariate predictor analysis for any in-hospital major adverse cardiac and cerebral adverse events after transcatheter aortic valve implantation

Variables	Odds ratio	Confidence limits for odds ratio 95%	Probability value
Pre-procedural Karnofsky index	0.96	[0.93, 1.00]	0.025
Renal Insufficiency	2.10	[0.86, 5.11]	0.102

Table 8 Multivariate predictor analysis for in-hospital death after transcatheter aortic valve implantation

Variables	Odds ratio	Confidence limits for odds ratio 95%	Probability value
Pre-procedural Karnofsky index	0.97	[0.93, 1.00]	0.051



performance scales available, which might be valuable as well. Additional studies on larger patient populations focusing on this important aspect are certainly needed to confirm this finding.

The result of the univariate analysis with a predictive value of the type of access site, favouring femoral access over iliac and subclavian access, helps to understand the improvement of published outcome rates over the past few years. The main benefit of the profile size reduction of the CoreValve prosthesis from Generation 1 (25 French) over Generation 2 (21 French) to the Generation 3 (18 French) was to allow the shift of access site from a more central location—iliac—to a more peripheral—femoral—position. This resulted in the ability to perform the procedure in a truly percutaneous fashion, without the risk of complications associated with the access surgery—which was required to open as well as close the iliac artery—or the accompanying general anaesthesia. However, these technical changes did not affect the predictive importance of the patient's functional condition as shown above.

If confirmed in larger studies, the finding of a correlation of pre-procedural frailty and post-procedural outcome might be important for future studies in the field of TAVI as it may open the door towards inclusion of lower-risk patients as presently enrolled. Up to now, it has been uncertain whether a complication after TAVI was procedure-related or mainly related to the patient's pre-procedural functional status and co-morbidities. The present data support the notion that the healthier the patient is before the procedure the better is his outcome after TAVI. Accordingly, complication and success rates of TAVI as currently reported in patients at high surgical risk cannot be translated to lower risk patients with a good functional performance status. TAVI in patients at low surgical risk might yield better feasibility and safety results than the presently reported ones.

Limitations

The present analysis is based on consecutive cohorts of two centres with considerable TAVI experience. Notwithstanding, the overall number of patients is small, which might affect the validity of the predictor analysis due to lack of sufficient power particularly with respect to the detection of confounding factors. Larger studies are needed to confirm these findings. To expand the overall patient population, the entire TAVI cohort has been included in both centres, also comprising the patients of the learning phase as well as the patients included during the evaluation of first- and second-generation devices at HELIOS Heart Center Siegburg. Exclusion of these patients would have limited the event numbers and hence the ability to perform the predictor analysis. Only the self-expanding CoreValve Revalving prosthesis has been studied in this analysis. Separate studies are needed to confirm these findings for patients treated with a balloon-expandable aortic valve prosthesis. The Karnofsky index has been chosen for assessment of the functional patient status which has not been validated in patients undergoing TAVI. Other frailty scores might be more suitable to assess the patient performance. However, none of the presently available scoring systems are validated in this new field of interventional cardiology. The STS score was calculated retrospectively in the study patient population and added for descriptive purposes in the patient characteristic table, but was not considered as a parameter in the present analysis. Since the focus of this analysis was prediction of MACCE with relevant clinical sequelae, namely death, stroke, and myocardial infarction, we did not include complications such as need for pacemaker or bleeding in our success definition.

Acknowledgement

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Conflict of interest: E.G. is consultant to CoreValve. U.G., P.W., and S.W. are clinical proctors for CoreValve. CoreValve, Inc., recently acquired by Medtronic, provided study devices for the safety and efficacy study. There was no other involvement of the study sponsor. The other authors have nothing to disclose in relation to this article.

Appendix 1: parameter characteristics

Parameter	Type of data	Data source or method of assessment
Presence of		
Congestive heart failure	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Diabetes	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Renal insufficiency	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Smoker	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Hypertension	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Pulmonary hypertension	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Coronary artery disease	Dichotomous nominal (yes/no)	Medical history and pre-procedural on-site exam
Prior stroke	Dichotomous nominal (yes/no)	Medical history
Prior myocardial infarction	Dichotomous nominal (yes/no)	Medical history
Prior PCI	Dichotomous nominal (yes/no)	Medical history
Prior coronary artery bypass grafting	Dichotomous nominal (yes/no)	Medical history

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Parameter	Type of data	Data source or method of assessment
Pre-procedural NYHA	Ordinal (I, II, III, IV)	Pre-procedural on-site examination
Pre-procedural Karnofsky index	Ordinal (0,10, . . . ,90, 100)	Pre-procedural on-site examination
Logistic EuroScore	Continuous	Pre-procedural on-site calculation
Pre-procedural aortic regurgitation	Ordinal (0, 1+, 2+, 3+, 4+)	Pre-procedural echo screening
Pre-procedural peak aortic valve gradient	Continuous	Pre-procedural echo screening
Pre-procedural mean aortic valve gradient	Continuous	Pre-procedural echo screening
Left ventricular ejection fraction	Continuous	Pre-procedural echo screening
Annulus diameter	Continuous	Pre-procedural MSCT screening
Use of a large prosthesis	Dichotomous nominal (yes/no)	Procedural data
Pre-dilation balloon diameter	Continuous	Procedural data
Post-dilation performed	Dichotomous nominal (yes/no)	Procedural data
Post-dilation balloon diameter	Continuous	Procedural data
Access	Nominal (femoral, iliac, subclavian)	Procedural data
In-hospital procedural success	Dichotomous nominal (yes/no)	Post-procedural clinical follow-up
In-hospital MACCE	Dichotomous nominal (yes/no)	Post-procedural clinical follow-up
In-hospital death	Dichotomous nominal (yes/no)	Post-procedural clinical follow-up

PCI, percutaneous coronary intervention; NYHA, New York Heart Association; MACCE, major adverse cardiac and cerebral events.

Appendix 2: Karnofsky performance status scale: definitions

100	Normal no complaints; no evidence of disease.	Able to carry on normal activity and to work; no special care needed.
90	Able to carry on normal activity; minor signs or symptoms of disease.	
80	Normal activity with effort; some signs or symptoms of disease.	
70	Cares for self; unable to carry on normal activity or to do active work.	Unable to work; able to live at home and care for most personal needs; varying amount of assistance needed.
60	Requires occasional assistance, but is able to care for most of his personal needs.	
50	Requires considerable assistance and frequent medical care.	
40	Disabled; requires special care and assistance.	Unable to care for self; requires equivalent of institutional or hospital care; disease may be progressing rapidly.
30	Severely disabled; hospital admission is indicated although death not imminent.	
20	Very sick; hospital admission necessary; active supportive treatment necessary.	
10	Moribund; fatal processes progressing rapidly.	
0	Dead	

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