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Valve: Research

Apical Access Management in Transapical Transcatheter Mitral Valve Replacement

Tillmann Kerbel, MD,[1] Mirjam G. Wild, MD,[2,3] Michaela M. Hell, MD,[4] Harald Herkner, MD, PhD,[5] Liliane Zillner, MA,[1] Elmar W. Kuhn, MD,[6] Tanja Rudolph, MD,[7] Thomas Walther, MD,[8] Lenard Conradi, MD,[9] Andreas Zierer, MD,[10] Francesco Maisano, MD,[11] Marco Russo, MD,[12] Fabrizio Rosati, MD,[13] Andrea Colli, MD, PhD,[14] Miguel Piñón, MD, PhD,[15] David Reineke, MD,[16] Gaby Aphram, MD,[17] Christophe Dubois, MD, PhD,[18] Jörg Hausleiter, MD,[3,19] Ralph Stephan von Bardeleben, MD,[4] and Martin Andreas, MD, PhD,[1] on behalf of the TENDER investigators*

ABSTRACT

BACKGROUND The role of the surgical technique and anatomy in transapical mitral valve replacement are scarcely investigated.

METHODS Computed tomography scans, surgical reports and planning slides of 127 patients undergoing transapical mitral valve replacement with the Tendyne valve system (Abbott Vascular) at 15 centers, participating in a European observational study, were retrospectively analyzed and compared between patients with (cohort A) and without (cohort B) apical access complications (AACs).

RESULTS A total of 8 (6.3%) AACs were recorded, of which 7 of 8 were observed in the first 10 patients of the respective center. Patients with AACs showed a trend to a thinner myocardium at the target access compared with those with regular access (median 4.4 vs 6.1 mm, $P = .086$). Technical difficulties along with AACs were reflected by a significant longer procedural time (median 180 vs 123 min, $P = .011$), higher rates of circulation support (50% vs 0%, $P < .001$), valve retrieval (38% vs 3%, $P = .005$), and bailout full sternotomy (13% vs 0%, $P = .063$). AACs were related with an intraprocedural mortality and in-hospital mortality rate of 25% (vs 0%, $P = .010$) and 50% (vs 7%, $P = .003$), respectively. In total, 8 of 12 in-hospital deaths were attributed to AACs and/or sepsis. AACs significantly increased the risk for 30-day (adjusted odds ratio, 19.5; 95% CI, 2.19–178.3; $P = .008$) and in-hospital mortality (adjusted hazard ratio, 9.00; 95% CI, 1.95–41.42; $P = .005$).

CONCLUSIONS Access complications in transapical mitral valve replacement are relatively rare but associated with poor short-term outcome. Focus on the apical myocardium within the screening process and specific surgical training might avoid AACs and improve outcome.

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Transapical (TA) transcatheter mitral valve replacement (TMVR) expanded the spectrum of interventional treatment options in

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*A complete list of the TENDER investigators is available in the Supplemental Material.

[1]Department of Cardiac Surgery, Medical University of Vienna, Austria; [2]Department of Cardiology and Angiology, University Heart Center Freiburg - Bad Krozingen, Medical Center - University of Freiburg and Faculty of Medicine, University of Freiburg, Freiburg, Germany; [3]Medizinische Klinik I, LMU University Hospital, Munich, Germany; [4]Department of Cardiology, University Medical Center Mainz, Mainz, Germany; [5]Department of Emergency Medicine, Medical University of Vienna, Austria; [6]Department of Cardiothoracic Surgery, Heart Center, University Hospital Cologne, Cologne, Germany; [7]Department of Cardiology, Heart and Diabetes Center Northrhine-Westfalia, Bad Oeynhausen, Ruhr-University Bochum and University of Bielefeld, Germany; [8]Department of Cardiac Surgery, University Hospital Frankfurt, Frankfurt, Germany; [9]University Heart and Vascular Center, Hamburg, Germany; [10]Department of Cardiac, Vascular, and Thoracic Surgery, Johannes Kepler University Linz, Kepler University Hospital, Linz, Austria; [11]Valve Center, IRCCS Ospedale San Raffaele and University Vita Salute, Milano, Italy; [12]Department of Cardiac Surgery and Heart Transplantation, Azienda Ospedaliera San Camillo Forlanini, Rome, Italy; [13]Division of Cardiac Surgery, Spedali Civili di Brescia, University of Brescia, Brescia, Italy; [14]Cardiothoracic and Vascular Department, University of Pisa, Pisa, Italy; [15]Department of Cardiac Surgery, Hospital Álvaro Cunqueiro, Vigo, Spain; [16]Department of Cardiac Surgery, Inselspital University Hospital Bern, Bern, Switzerland; [17]Department of Cardiovascular and Thoracic Surgery, Cliniques universitaires Saint Luc, Brussels, Belgium; [18]Department of Cardiovascular Medicine, University Hospital Leuven and Department of Cardiovascular Sciences, Leuven, Belgium; and [19]DZHK [German Center for Cardiovascular Research], partner site Munich Heart Alliance, Munich Germany

Address correspondence to Dr Andreas, Department of Cardiac Surgery, Medical University of Vienna, Waehringer Guertel 18-20, 1090 Vienna, Austria; email: martin.andreas@meduniwien.ac.at.

Abbreviations and Acronyms

AAC = apical access complication
HR = hazard ratio
LV = left ventricular
LVOT = left ventricular outflow tract
MDCT = multislice detector computed tomography
MR = mitral regurgitation
MV = mitral valve
OR = odds ratio
PROM = Predicted Risk of Mortality
STS = The Society of Thoracic Surgeons
TA = transapical
TAS = target access site
TEER = transcatheter edge-to-edge repair
TENDER = TENDyne European experience Registry
TMVR = transcatheter mitral valve replacement

high-risk patients with complex mitral valve (MV) pathology not suitable for interventional repair techniques.[1,2]

Clinical experience with the first CE-mark released self-expandable, D-shaped biologic prosthesis (Tendyne, Abbott Vascular) demonstrated a reliable and sustained abolishment of mitral regurgitation (MR) and good hemodynamic characteristics, resulting in a significant improvement in functional capacity and quality of life.[3-6] Nevertheless, a relevant portion of this multimorbid patient collective did not recover, reflected by an in-hospital and 30-day mortality ranging from 8% to 18%[4,5] and from 6% to 24%,[3-5] respectively. This might be related to a higher invasiveness and therefore an increased risk for surgical and postoperative adverse events, compared with transseptal devices.[7-9] As known from the experience from TA transcatheter aortic valve replacement, surgical complications are rare but associated with significant short-term mortality.[10]

Decision-making in multimorbid patients with severe MV disease rejected from conventional surgery is challenging and mainly driven by the MV pathology and the risk of left ventricular outflow tract (LVOT) obstruction. However, the morphology of the left ventricular (LV) apex and procedural-surgical patterns are not studied regarding impact on adverse events, thus we firstly investigate this field in a retrospective subanalysis of a multicenter observational registry.

PATIENTS AND METHODS

This is an exploratory subanalysis of the TENDyne European experience Registry study (TENDER, ClinicalTrials.gov Identifier: NCT04898335), including patients from 15 European heart centers after commercial TA-TMVR with the Tendyne valve system.[4] The study was approved by the respective ethics boards. The implantation period ranged from January 2020 to June 2022.

Preprocedural full cardiac cycle capturing (5%-10% R-R cycle steps) multislice detector computed tomography (MDCT) scans, procedural planning slides, as well as the surgical reports were provided by the participating centers in a pseudonymized fashion to the Department of Cardiac Surgery, Medical University of Vienna, for retrospective analysis.

The acquisition of the baseline and follow-up data was described before.[4] An impaired right ventricular systolic function was defined accordingly to current recommendations.[11] The procedural steps have been described in on- and off-label anatomies prior.[2,12]

COMPUTED TOMOGRAPHY ANALYSIS. From a total of 141 patients, 127 patients with acceptable imaging quality were included.[13] The mitral and direct access workflow of 3mensio (V10.3, Pie Medical Imaging BV, Maastricht, Netherlands) were used for data segmentation and final measurements. The MV annulus and true apex were defined, and standard transformation language files (available for all commercially available sizes and profiles) were utilized to identify the target access site (TAS). The TAS was located, where the simulated tether was crossing the apical myocardium. The end-diastolic thickness of the LV myocardium was measured at the TAS and at the thinnest part of the apical myocardium within 2 cm of the TAS (Figure 1).

Further calculations included the distance from the true apex and left anterior descending artery to the TAS, from the sternum to the TAS at the skin level, from the MV center to the epicardium (Steri-Strip [Solventum] location), the predicted implant angulations (transverse angle, off-table angle) and fluoroscopic angulations (intercommissural and en face view; Supplemental Figure 1).

ENDPOINT DEFINITION. The primary endpoint was the incidence of apical access complications (AACs), which were defined as major cardiac structural complication and/or reintervention at the access. Further endpoints were assessed accordingly to the current recommendations of the Mitral Valve Academic Research Consortium consensus statement.[14]

STATISTICAL ANALYSIS. We described continuous data as median and interquartile range, categorical data as absolute count and relative frequency. Baseline, MDCT-derived and outcome data of patients with AACs (cohort A) were compared to

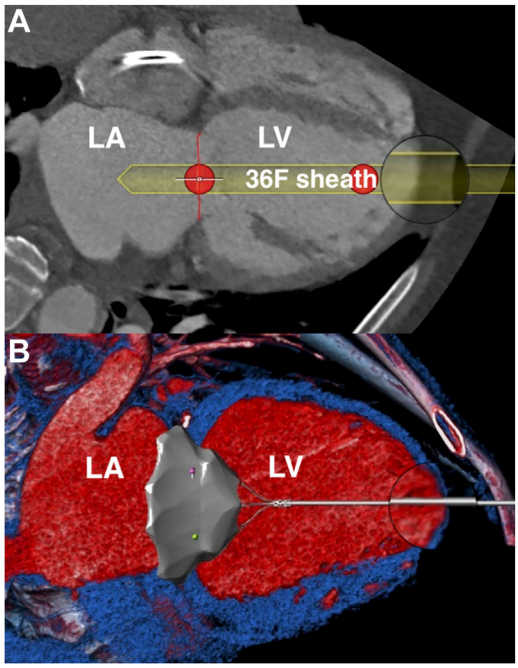

FIGURE 1 Apex-specific measurement. Exemplary multislice detector computed tomography scan of a patient (thinned apex, 1.6 mm) and lethal ventricular rupture during Tendyne TMVR (Abbott Vascular). (A) Identification of the end-diastolic thickness of the apical myocardium using standard transformation language transformed 36F Tendyne valve implantation sheath. (B) Setting of the final myocardial borders was supported by using different rendering options, here in an intercommissural view. (LA, left atrium; LV, left ventricle.)

those without AACs (cohort B). Mann-Whitney U test for continuous variables and Fisher's exact test for categorical data were used.

Logistic regression and Cox proportional hazard regression were applied to estimate the effect of AACs on 30-day mortality and survival up to the time of hospital discharge, respectively. The influence on the main effect was investigated by introducing additional covariables into the models separately. The influences of potential confounders were analyzed following considerations on the counterfactual theory based directed acyclic graphs (Supplemental Figures 2A, 2B). Where standard logistic models did not converge (limited sample size), we used exact logistic regression instead. Potential interactions were tested using the Wald test for the interaction terms. Further, logistic regression was performed to investigate potential predictors for AACs.

For data analysis we used Microsoft Excel 16.74, SPSS 29.0 (IBM) and Stata 17 (StataCorp) for Macintosh. Generally, a 2-sided P value $<.05$ was considered statistically significant. Odds ratios (ORs) and hazard ratios (HRs) are reported with 95% CI.

RESULTS

A total of 127 patients after TMVR with the Tendyne valve system were included in this surgical subanalysis of the TENDER registry. The demographic data indicate multimorbidity and were comparable between the cohorts (Table 1). Five patients underwent off-label valve-in-ring TMVR due to MR recurrence after surgical annuloplasty (all cohort B). Nine patients underwent TMVR after unsuccessful transcatheter edge-to-edge repair (TEER) (no device implanted: n = 6). In those with implanted TEER device, electrosurgical cutting prior to TMVR was necessary in 2 patients (all cohort B).

BASELINE ECHOCARDIOGRAPHIC AND MDCT-DERIVED CHARACTERISTICS. Patients with AAC were more frequently treated for primary MR (primary MR 75% vs 37%, $P = .057$). Further baseline echocardiographic characteristics did not differ significantly.

The enddiastolic diameter of the TAS and thinnest part of the LV apex within 2 cm of the TAS ranged from 1.6 to 12.5 mm and 0.6 to 8.7 mm, respectively. The myocardium at the TAS tended to be thinner in patients with AAC (4.4 vs 6.1 mm, $P = .086$). There was no difference in the prevalence of apex aneurysm, the proximity of the left anterior descending artery to TAS, the simulated implantation angulation, the Steri-Strip location, and the calculated fluoroscopic angulation between the cohorts (Table 2).

PROCEDURAL DETAILS AND OUTCOME. The sample size of Tendyne-TMVR per center ranged from 2 to 18 (7 centers with n $\geq$ 10). Technical success was achieved in 92% of the overall cohort (Figure 2A). AACs were observed in 8 (6.3%) patients and were associated with an in-hospital mortality of 50% (Table 3). Seven of 8 AAC occurred in the centers' first 10 Tendyne TMVR cases. AACs were observed in 4 of 15 centers and the incidence of AAC per center ranged from 0% to 33% (AAC per center, $P = .065$). In 2 centers, $\geq$2 AACs were recorded (center 1, 4 of 16; center 2, 2 of 10).

The overall intraprocedural mortality rate was 1.6%. Both intraprocedural deaths were related to AACs (case 1, LV rupture; case 2, tear in the right ventricle) not controllable after conversion to full sternotomy. In 2 further patients, severe bleeding complications (LV rupture, apical suture

TABLE 1 Baseline Characteristics

Characteristics	Cohort A (Apical Access Complication) (n = 8)	Cohort B (No Apical Access Complication) (n = 119)	*P* Value
Age, y	80.5 (74.3–84.5)	77 (71, 81)	.247
Female	3 (37.5)	51 (42.9)	1.000
Body mass index, kg/m^2	27.8 (25.2–28.6)	25.5 (22.7–28.4)	.293
EuroSCORE II, %	8.2 (6.2–11.1)	6.3 (3.2–10.3)	.238
STS PROM, %	7.8 (4.1–17.3)	6.0 (3.3–9.6)	.364
NYHA			
NYHA <III	1 (12.5)	18 (15.1)	1.000
NYHA III	5 (62.5)	94 (79)	.373
NYHA IV	2 (25)	7 (5.9)	.100
Previous HFH	3 (37.5)	84 (70.6)	.195
NT-proBNP, ng/dL	3852 (3282–10221)	3435 (1702–7206)	.325
Atrial fibrillation or flutter	4 (50.0)	77 (64.7)	.459
Glomerular filtration rate, mL/min[1]	38 (25–65)	42 (30–59)	.850
COPD	1 (12.5)	21 (17.6)	1.000
Stroke	0 (0)	16 (13.2)	.595
Coronary artery disease	4 (50)	74 (62.2)	.710
Previous myocardial infarction	0 (0)	23 (19.3)	.349
Previous PCI	0 (0)	46 (38.7)	.050
Previous CABG	3 (37.5)	32 (26.9)	.683
Previous TAVR	1 (12.5)	16 (13.4)	1.000
Previous SAVR	3 (37.5)	27 (22.7)	.392
Previous MV intervention	1 (12.5)	8 (6.7)	.454
Previous MV surgery	0 (0)	5 (4.2)	1.000
Echocardiographic characteristics			
MV disease etiology			
Primary	6 (75)	44 (37)	.057
Secondary	2 (25)	48 (40.3)	.479
Mixed	0 (0)	27 (22.7)	.201
Mitral annular calcification[a]			
None	5 (62.5)	69 (58)	1.000
Mild	0 (0)	15 (12.6)	.595
Moderate	2 (25)	16 (13.5)	.316
Severe	1 (12.5)	19 (16)	1.000
Mitral regurgitation ≥3+	8 (100)	113 (94.8)	1.000
Mitral stenosis			
MPG > 5 mm Hg	3 (37.5)	18 (15.2)	.126
MPG > 10 mm Hg	0 (0)	4 (3.4)	1.000
LV-EF, %	58 (40–64)	50 (37–56)	.102
LVEDD, mm	50 (45–61)	57 (49–62)	.178
Indexed LVEDD, mm/m^2	27.5 (22.4–31.6)	30.6 (26.5–33.6)	.081
Impaired RV function	3 (37.5)	38 (31.9)	.689
Tricuspid regurgitation ≥III	4 (50)	26 (21.8)	.091
sPAP, mm Hg	60 (42–81)	54 (40–61)	.320

[a]According to Guerrero et al.[21] Values are presented as n (%) or median (interquartile range). CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; EuroSCORE, European System for Cardiac Operative Risk Evaluation; HFH, heart failure hospitalization; LVEDD, left ventricular end-diastolic diameter; LV-EF, left ventricular ejection fraction; MPG, mean pressure gradient; MV, mitral valve; NT-proBNP, N-terminal brain natriuretic peptide; NYHA, New York Heart Association class; PCI, percutaneous coronary intervention; SAVR, surgical aortic valve replacement; sPAP, systolic pulmonary artery pressure; STS PROM, The Society of Thoracic Surgeons predicted risk of mortality; TAVR, transcatheter aortic valve replacement; RV, right ventricle.

dislodgement) were surgically controllable by additional stitches under on-pump condition. Nevertheless, both patients died due to unsuccessful weaning from extracorporeal membrane oxygenation (day 13) and sepsis (day 7), respectively. Another 4 AACs were related to hemothorax requiring revision causing prolonged post-interventional hospitalization (discharge at post-operative day 13, 20 [n = 2], and 34). Technical difficulties in patients with AAC were reflected by a significant longer procedural time (180 vs 123 min, $P = .011$).

TABLE 2 Computed Tomography

Variable	Cohort A (Apical Access Complication) (n = 8)	Cohort B (No Apical Access Complication) (n = 119)	*P* Value
Thickness of the apical myocardium			
Target access, mm	4.4 (3.3–6.3)	6.1 (4.5–7.2)	.086
Thinnest part within 2 cm radius of the target access, mm	2.4 (1.5–3.6)	2.8 (1.8–4.7)	.279
Apex aneurysm, n (%)	1 (12.5)	11 (9.2)	.559
Target access to true apex, mm	9.6 (5.9–18.5)	12.9 (8.3–20.0)	.355
Target access to LAD, mm	13.6 (6.4–20.8)	16.4 (10.7–24.2)	.256
Steri-Strip[a] location, mm	105 (102–114)	105 (100–110)	.534
Target access to sternum, mm	143 (107–159)	133 (116–151)	.601
Implant angulations			
Transverse angle, °	23 (11–30)	22 (16–28)	.823
Off-table angle, °	43 (33–45)	40 (32–48)	.793
Fluoroscopic angulations			
S/L view RAO, °	29 (27–37)	34 (26–42)	.456
S/L view CRA, °	32 (26–45)	30 (21–36)	.450
En face view LAO, °	48 (45–52)	48 (42–56)	.904
En face view CAU, °	19 (9–23)	17 (12–22)	.940

[a]Steri-Strip, Solventum. Variables are presented as median (interquartile range) unless otherwise marked. CAU, caudal; CRA, cranial; LAD, left anterior descending artery; LAO, left anterior oblique; S/L, septal to lateral; RAO, right anterior oblique.

Valve retrieval with the 36F dedicated capturing device was necessary in 7 patients after acute LVOT obstruction (n = 3) or valve migration into the LV (n = 4), and was significantly more frequently performed in patients with AACs (38% vs 3%, P = .005). LVOT obstruction after valve expansion was present in 9 patients (in total, 7%; 25% [cohort A] vs 6% [cohort B], P = .102), and was treated either conservatively (n = 4) or by rescue tip-to-base electrosurgical laceration of the anterior mitral leaflet to prevent outflow tract (n = 1) or valve retrieval (reclocking, n = 1; no valve implanted, n = 3). In patients with aborted TMVR, either no MV treatment (n = 2) or intraprocedural switch to TEER (n = 1) was performed (in-hospital mortality, 2 of 3).

The 30-day and in-hospital all-cause mortality rate was 7.4% and 9.5%, respectively, and was significantly higher in patients with AACs (30-day mortality, 50% vs 4%; P < .001; in-hospital mortality, 50% vs 7%; P = .003). Overall, AAC and sepsis were the main causes for in-hospital mortality (Figure 2B). The incidence of bleeding complications was 19%.

Prior to discharge, 82.9% of the patients were set on coumarin derivatives (treatment goal for at least 3 months: 2.5-3.5 international normalized ratio). The residuals were off-label-treated by oral anticoagulants (15.3%) and antiplatelet therapy only (1.8%; P = .375 between cohort A and B).

Echocardiographic assessment within the index hospitalization demonstrated complete MR abolishment and paravalvular leakage grade <2 in 96.8% and 98.4% of the overall cohort, respectively, with a median transprosthetic MV mean pressure gradient of 4 (interquartile range, 3-5) mm Hg.

LOGISTIC REGRESSION MODEL: 30-DAY MORTALITY. The unadjusted OR of AACs associated with 30-day mortality was 21.80 (95% CI, 4.18-113.57, P < .001; Supplemental Figure 3). Adjusted for the covariables "vascular frailty" (definition: coronary artery disease and/or previous percutaneous coronary intervention and/or previous coronary artery bypass graft and/or stroke; adjusted OR, 10.91; 95% CI, 0.52-227.3; P = .123), indexed LV end-diastolic diameter (adjusted OR, 0.81; 95% CI, 0.66-1.00; P = .052), The Society of Thoracic Surgeons (STS) Predicted Risk of Mortality (PROM) (adjusted OR, 1.10; 95% CI, 0.98-1.23; P = .110), and myocardial thickness at the TAS (adjusted OR, 0.79; 95% CI, 0.51-1.23; P = .293), AACs were still associated with an almost 20-fold increased risk for 30-day mortality (adjusted OR, 19.5; 95% CI, 2.19-178.3; P = .008; Figure 3A).

COX REGRESSION MODEL: IN-HOSPITAL MORTALITY. The unadjusted HR for AACs causing in-hospital mortality was 13.46 (95% CI, 3.32-54.59; P < .001; Supplemental Figure 4). The hazard of AAC leading to in-hospital mortality (adjusted HR 9.00; 95% CI, 1.95-41.42; P = .005; Figure 3B) was partially confounded by STS PROM

(adjusted HR, 1.07; 95% CI, 0.98-1.18; $P = .13$) and myocardial thickness at the TAS (adjusted HR, 0.77; 95% CI, 0.50-1.19; $P = .239$).

LOGISTIC REGRESSION MODEL: ACCESS COMPLICATION. In patients with AACs, myocardial thickness at the TAS was lower compared with patients without AAC (median, 4.4 vs 6.1 mm). With each millimeter increase in myocardial thickness at the TAS, the odds of AAC decreased by 30% univariable (OR, 0.70; 95% CI, 0.46-1.05; $P = .082$, Supplemental Figure 5) and multivariable (OR, 0.70; 95% CI, 0.46-1.08; $P = .104$, Figure 4).

COMMENT

We report the first MDCT-based investigation on apical LV myocardial morphology in relation to surgical complications in TA-TMVR.

In the initial TA-TMVR period, AACs were suspected to be higher compared with transcatheter aortic valve replacement because of a larger delivery sheath (Tendyne, 36F; transcatheter aortic valve replacement, 18-26F), and suspected lack of hypertrophic myocardium at the TAS. However, the incidence of AAC after TA-TMVR (6.3%) is comparable to TA-transcatheter aortic valve replacement,[10,15] which may be attributed to the hemostatic effect of the apical pad. Contrarily to assumptions, we found comparable apical myocardial thickness in patients with and without prior aortic valve surgery or intervention (TAS, 6.1 vs 5.7 mm; $P = .330$; thinnest part within 2 cm of the TAS, 2.8 vs 2.7 mm; $P = .658$).

There is a limiting amount of tissue for stitching the purse string sutures securing the apical access (TAS thickness <3 mm, 6.3%; <5mm, 33.9%; <7mm, 70.9%). Surgical-interventional experience might be a crucial factor for safely performing the apical access, as 7 of 8 cases of AAC in our analysis were observed in the centers' first 10 cases (cases 1-3/center, n = 3; cases 1-5/center, n = 4; case 6, n = 1; case 9, n = 2; case 16, n = 1). This might partially explain the high variability in AACs per center (from 0% to 33%; $P = .065$), and elevated risk for AAC for the center variable (adjusted OR, 1.12; 95% CI, 0.91-1.39; $P = .295$).

The applied purse-string stitching technique is retrospectively—despite insights in the surgical reports—hardly examinable. Potentially, surgeons not routinely used to the TA access may tend to perform the TA access with (1) too superficial, and not complete transmural stitches, and (2) too small TA tissue incisions, which both may delimit the safeguarding of the apical access and increase the friction during insertion, tilting and retraction of the device system and, if required, of the retrieval device. Further, the identification of the intercostal space for the TA access and TAS comprises potential pitfalls. Importantly, the intercostal space for the TA access should be identified by transthoracic echocardiography, as planning MDCT is performed with upward stretched arms. Fundamental echocardiographic skills are necessary for correctly positioning the TAS because it relies solely on transesophageal-echocardiographic x-plane view of the left ventricle; this procedural step is decisive for a coaxial valve deployment and especially avoiding shift of the purse-string suture too anteriorly, as these might cause an increased LVOT obstruction risk. We observed LVOT obstruction in almost every 14th patient (7.1%)—a serious adverse event associated with increased mortality (in-hospital mortality in LVOT-obstruction, 33.3% vs no LVOT-obstruction, 6%, $P = .040$), also after valve retrieval (in-hospital

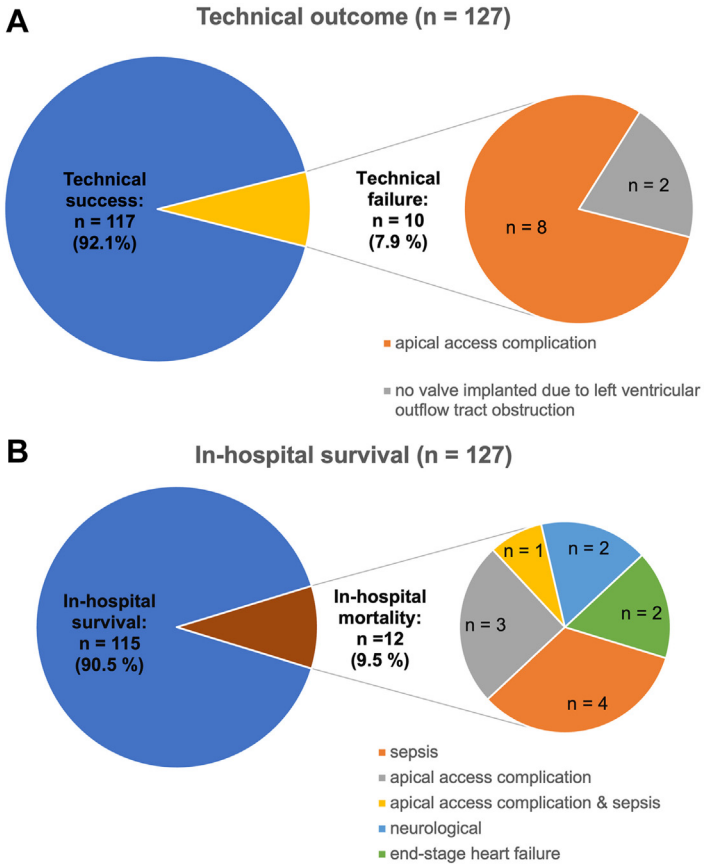

FIGURE 2 Short-term outcome in Tendyne transcatheter mitral valve replacement. (A) Technical success (Mitral Valve Academic Research Consortium criteria); (B) in-hospital survival.

TABLE 3 Interventional Outcomes

Variable	Cohort A (Apical Access Complication) (n = 8)	Cohort B (No Apical Access Complication) (n = 119)	*P* Value
Procedural time, min	180 (125–264)	123 (100–151)	.011[a]
Procedure			
Technical success	0 (0)	117 (98.3)	<.001[a]
Predilatation	2 (25)	15 (12.6)	.291
Valve implanted	7 (87.5)	117 (98.3)	.179
Valve retrieval	3 (37.5)	4 (3.4)	.005[a]
Intraprocedural ECMO/HLM	4 (50)	0 (0)	<.001[a]
Full sternotomy	1 (12.5)	0 (0)	.063
LVOT obstruction	2 (25)	7 (5.9)	.102
Survival			
Intraprocedural death	2 (25)	0 (0)	.010[a]
Immediate procedural mortality[b]	2 (25)	1 (0.8)	.010[a]
In-hospital mortality	4 (50)	8 (6.7)	.003[a]
Time to in-hospital death, d	4 (0–12)	25 (20–46)	.016[a]
30-d mortality	4 (50)	5 (4.4)	<.001[a]
In-hospital course			
Days at intensive care unit	1 (0–7)	2 (1–3)	.506
Days to discharge	13 (2–20)	11 (8–17)	.807
Reintervention	4 (50)	0 (0)	<.001[a]
Hemothorax	4 (50)	0 (0)	<.001[a]
Bleeding			
Red blood cell transfusion, n	6 (4–12)	0 (0–1)	<.001[a]
Fatal	3 (37.5)	0 (0)	<.001[a]
Life-threatening bleeding	8 (100)	0 (0)	<.001[a]
Bleeding BARC 2/3/5	8 (100)	16 (13.7)	<.001[a]
Kidney injury	2 (25)	21 (18.1)	.316
Dialysis	0 (0)	2 (1.7)	1.000
Stroke	0 (0)	3 (2.7)	1.000
Disabling stroke	0 (0)	1 (0.9)	1.000
Myocardial infarction	0 (0)	1 (0.9)	1.000
Sepsis	1 (12.5)	12 (10.2)	.593
Anticoagulation			.375
Coumarin derivative	4/5 (80)	88/106 (83)	
Oral anticoagulant	1/5 (20)	16/106 (15.1)	
Only antiplatelet therapy	0/5 (0)	2/106 (0.2)	
Echo within index hospitalization			
Residual mitral regurgitation			
None	6/7 (85.7)	114/117 (95.8)	.210
Mild	0/7 (0)	2/117 (1.7)	1.000
More than mild	1/7 (12.5)	1/117 (0.8)	.110
Paravalvular leakage			
None	5/7 (71.4)	104/116 (89.7)	.181
Mild	1/7 (14.3)	11/116 (9.2)	.522
More than mild	1/7 (14.3)	1/116 (0.8)	.111
Trans-prosthetic MV MPG	5 (4–8)	4 (3–5)	.094
MV MPG ≥ 5 mm Hg	2/5 (40)	32/99 (32.3)	.661
Discharge location			
Home	1 (12.5)	75 (63.6)	.007[a]
Rehabilitation	3 (37.5)	26 (22.0)	.382
Other hospital	0 (0)	9 (7.6)	1.000

[a]*P* < .05; [b]mortality within 72 hours. Values are presented as n (%) or median (interquartile range). BARC, Bleeding Academic Research Consortium; ECMO, extracorporeal membrane oxygenation; HLM, heart lung machine; LVOT, left ventricular outflow tract; MPG, mean pressure gradient; MV, mitral valve.

mortality,: 2 of 3). A LVOT-risk underestimation by a neo-LVOT cutoff of 250 mm^2 alone (neo-LVOT > 250 mm^2 in all included patients) is conceivable, which can be addressed by more widespread performance of LVOT-obstruction preventive techniques in Tendyne TMVR.[16-19]

Moreover, anatomic factors might be considered as risk factors for short-term mortality: We found a trend to a thinner myocardium at the TAS tended in patients with AAC (P = .086). The regression models are limited due to the low number of ACCs; however, a 1-mm decrease in the TAS thickness was, even if nonsignificantly, associated with an increased adjusted risk for AAC by 30% (P = .104), for 30-day mortality by 21% (P = .293), and for in-hospital mortality by 23% (P = .239), respectively. Remarkably, 2 of 4 patients with lethal AAC (both ventricular rupture) underwent prior (hormone- or radio-) chemotherapy, and showed extremely thinned apical myocardium (thinnest apical part: 0.7 mm, 1.6 mm). These AACs might be avoided by (1) focusing on the apex within the screening process, (2) performing cardiac magnetic resonance imaging in patients after chemotherapy to screen for myocardial fibrosis and necrosis to assess the risk for a fragile apex,[20] and (3) using a large apical pad in presence of a thin apex to increase the compression on the apex.

Stenotic mitral valve disease and balloon valvuloplasty were associated with an OR of 2.61 (P = .481) and 1.38 (P = .771) for overall AAC, respectively. However, there was no difference in the short-term survival between patients with and without balloon valvuloplasty (in-hospital mortality: 11.8% vs 9.1%: P = .663; 30-day mortality: 11.8% vs 6.7%: P = .611) and mitral stenosis (in-hospital mortality: 10.5% vs 9.4%: P = 1.000; 30-day mortality: 10.5% vs 6.9 %: P = .652).

Following our multivariable model, the indexed LV end-diastolic diameter may be considered as a predictor for 30-day mortality (adjusted OR, 0.81; 95% CI, 0.66-1.00; P = .052), whose impact should be evaluated in future, large-volume studies.

Patient comorbidities have a high impact on procedural recovery and survival: The vascular frailty was linked to a notorious, even if not nonsignificant adjusted OR of 10.91 (P = .123) for 30-day mortality. Moreover, multimorbidity, reflected by high STS PROM, increases proneness for lethal post-operative sepsis (STS score 8.7% [lethal sepsis] vs 6.0% [no lethal sepsis], P = .087). Perhaps these patients might profit, as transseptal TEER was considered anatomically not feasible in 11 of 12 nonsurvivors, from less-invasive, transseptal TMVR in the future.

In summary, specific surgical (simulator) training, focusing on the apical myocardium while screening,

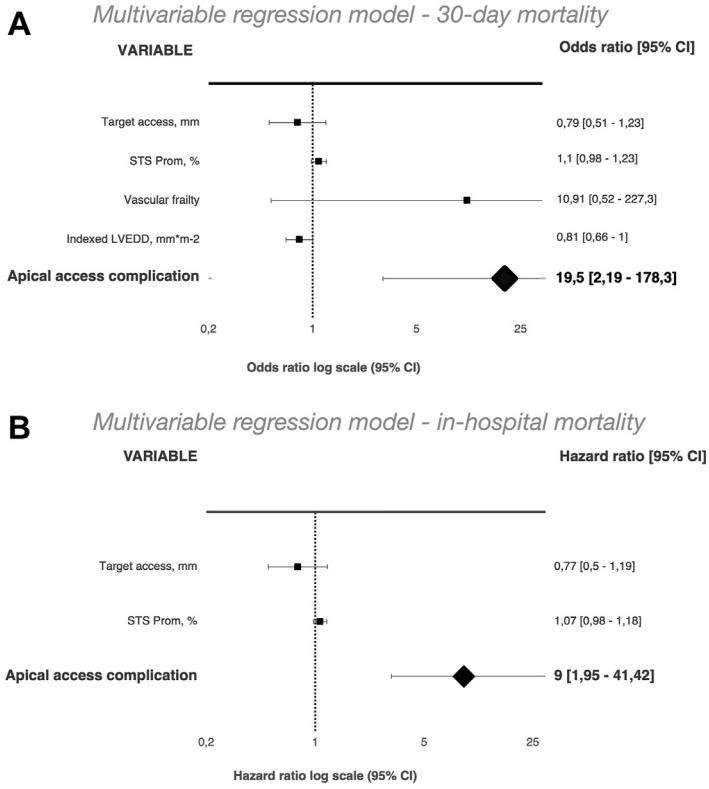

FIGURE 3 Multivariable regression models – 30-day and in-hospital mortality. Final models illustrated by forest plot indicating the impact of the co-variables on 30-day mortality (A) and in-hospital mortality (B). CI, confidence interval; LVEDD, left ventricular end-diastolic diameter; STS Prom, The Society of Thoracic Surgeons Predicted Risk of Mortality.

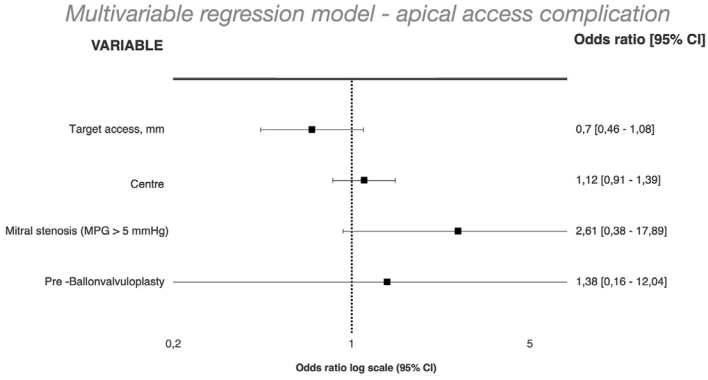

FIGURE 4 Multivariable logistic regression model, access complication. Considered risk factors within the final model for apical access complications (all P > .05). (MPG, mean pressure gradient.)

avoiding LVOT obstruction and valve retrieval, and careful patient selection might improve future outcomes in TA-Tendyne TMVR.

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