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ORIGINAL ARTICLE

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Surgery for infective endocarditis following low-intermediate risk transcatheter aortic valve replacement–a multicentre experience

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Key question

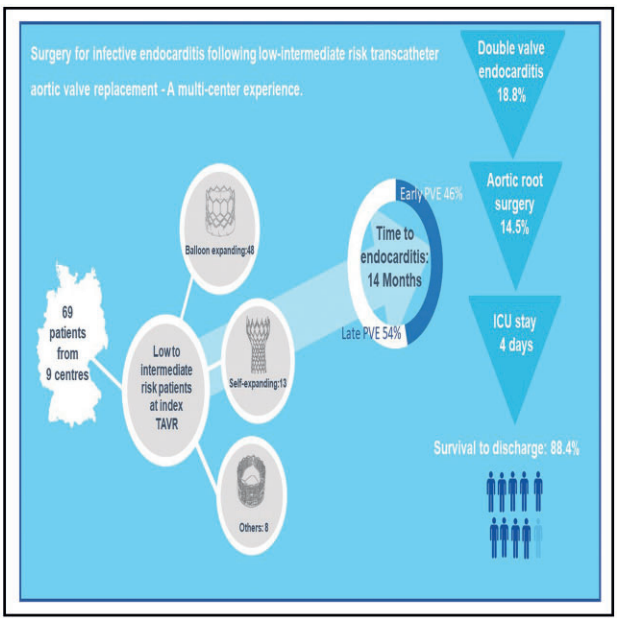
Should surgery be considered an option to treat infective endocarditis following TAVR?

Key finding(s)

All TAVR prostheses were explanted, with 14.5% requiring aortic root surgery. Survival to discharge was 88.4%.

Take-home message

Infective endocarditis following low-intermediate risk TAVR can be treated with early surgery and is associated with acceptable morbidity and mortality rates.



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Abstract

OBJECTIVES: With the expansion of transcatheter aortic valve replacement (TAVR) into intermediate and low risk, the number of TAVR procedures is bound to rise and along with it the number of cases of infective endocarditis following TAVR (TIE). The aim of this study was to review a multicentre experience of patients undergoing surgical intervention for TIE and to analyse the underlying indications and operative results.

METHODS: We retrospectively identified and analysed 69 patients who underwent cardiac surgery due to TIE at 9 cardiac surgical departments across Germany. The primary outcome was operative mortality, 6-month and 1-year survival.

RESULTS: Median age was 78 years (72–81) and 48(69.6%) were male. The median time to surgical aortic valve replacement was 14 months (5–24) after TAVR, with 32 patients (46.4%) being diagnosed with early TIE. Cardiac reoperations were performed in 17% of patients and 33% underwent concomitant mitral valve surgery. The main causative organisms were: *Enterococcus faecalis* (31.9%), coagulase-negative *Staphylococcus* spp. (26.1%), Methicillin-sensitive *Staphylococcus aureus* (15.9%) and viridians group streptococci (14.5%). Extracorporeal life support was required in 2 patients (2.9%) for a median duration of 3 days. Postoperative adverse cerebrovascular events were observed in 13 patients (18.9%). Postoperatively, 9 patients (13.0%) required a pacemaker and 33 patients (47.8%) needed temporary renal replacement therapy. Survival to discharge was 88.4% and survival at 6 months and 1 year was found to be 68% and 53%, respectively.

CONCLUSIONS: Our results suggest that TIE can be treated according to the guidelines for prosthetic valve endocarditis, namely with early surgery. Surgery for TIE is associated with acceptable morbidity and mortality rates. Surgery should be discussed liberally as a treatment option in patients with TIE by the 'endocarditis team' in referral centres.

Keywords: Infective endocarditis • transcather aortic valve replacement

ABBREVIATIONS

EuroSCORE II	European System for Cardiac Operative Risk Evaluation II
IE	Infective endocarditis
PVE	Prosthetic valve endocarditis
STS PROM	Society of Thoracic Surgeons Predicted Risk of Mortality
TAVR	Transcatheter aortic valve replacement
TIE	Infective endocarditis following TAVR

INTRODUCTION

Infective endocarditis following transcatheter aortic valve replacement (TIE) is the most common indication for surgery following transcatheter aortic valve replacement (TAVR) [1]. Despite clear indications for surgery in more than 80% of patients suffering from TIE, only 2–14% of the cases have been reported to undergo surgery [2]. To date, this has been attributed to advanced age, high rate of comorbidities and elevated surgical risk [2, 3]. The rapid growth of TAVR procedures following expansion of its indications to intermediate- and low-risk patients is likely to change this situation [4, 5]. In 2019, TAVR accounted for almost two-thirds of the isolated aortic valve procedures in Germany [6].

Prosthetic valve endocarditis (PVE) has been reported in 1–6% of patients with valve prostheses, with an incidence of 0.3–1.2% per patient-year [7]. The incidence of TIE within the first year has been reported to be between 0.1% and 3.4%, with a 5-year incidence of up to 5.8%, which is comparable to that of PVE following surgical aortic valve replacement [3, 8–13]. Autopsy case series have reported the incidence rate of TIE to be as high as 12.5% in patients following TAVR [3].

To date, the majority of cases of TIE reported in the literature have been treated conservatively with some patients entering palliative care on diagnosis [2, 3, 9]. To gain further insight on patient characteristics as well as surgical outcomes, a retrospective analysis of a surgically treated cohort of TIE patients was examined in a multicentre approach.

METHODS

Ethics statement

This study was approved by the ethics board of the Ludwig Maximilian University (No. 20-821) and since all institutions contributed cases after obtaining local institutional review board approvals, the requirement to obtain patient consent was waived for this retrospective study. Postoperative treatment and data acquisition were performed as part of routine patient care. Data acquisition was based on institutional databases and then de-identified. All procedures described in this study were in accordance with the institutional ethics boards and national data safety regulations.

Study design

In 2020, a survey on surgically treated TIE patients was conducted in Germany. Between June 2013 and December 2019, 69 consecutive patients were identified in 9 cardiac surgery departments. Patients included in the study were retrospectively reviewed in accordance with national data safety regulations. All patients were discussed in the respective local Endocarditis-Team and all patients were evaluated individually. Patient details were collected from institutional databases and surgeon notes, and de-identified for further analysis. Follow-up was achieved by routine check-ups and patient interviews. The European System for Cardiac Operative Risk Evaluation II (EuroSCORE II) and Society of Thoracic Surgeons Predicted Risk of Mortality (STS PROM) were used to predict the risk of perioperative mortality at the time of TAVR and conventional cardiac surgery. All patients were discharged to either cardiac rehabilitation centres or to transferred to secondary care centres. Antibiotic treatment

was carried out in-hospital up to 6 weeks, as per the current guidelines [7].

Definition of parameters

1. PVE was diagnosed according to the modified Duke's criteria and 2015 ESC guidelines on infective endocarditis (IE) [7].
2. Early PVE was defined as IE occurring within 1 year of surgery and late PVE as IE occurring beyond 1 year [7].
3. Reoperations were defined as one or more previous major cardiac operation involving opening the pericardium [14].
4. Adverse cerebrovascular events were defined as new-onset postoperative neurological symptoms that were accompanied by a new computed tomography–confirmed central nervous system lesion [15].
5. Re-explorative surgery was performed in cases of pericardial tamponade or surgical bleeding.

Statistical analysis

Data were analysed using the IBM SPSS Statistics Data Editor® version 25 (IBM Corp. Released 2017. IBM SPSS Statistics, Version 25.0. Armonk, NY: IBM Corp.). Survival analysis was performed with the Kaplan–Meier curve. Illustrations were prepared using GraphPad Prism (GraphPad Software Inc., San Diego, CA, USA). Data are presented as medians (25–75th quartiles) or as absolute numbers (percentages) unless otherwise specified.

RESULTS

Patient population

Most patients in this cohort underwent primary TAVR due to severe aortic stenosis (97.1%). The median EuroSCORE II and STS PROM of patients presented for surgery for TIE, at the time of TAVR were 5.3% (3.4–9.1%) and 1.8% (1.2–2.4%), respectively. Twelve patients (17.4%) had a history of previous conventional cardiac surgery prior to TAVR and 6 patients (8.7%) underwent valve-in-valve TAVR. In this cohort, 13 patients (18.8%) underwent elective surgery, 40 patients (58.0%) underwent urgent surgery, 13 (18.8%) patients underwent emergency surgery and 3 (4.3%) patients underwent salvage operations.

The implanted TAVR prostheses were as follows: Sapien 3 ($n = 39$; 56.5%), Sapien XT ($n = 9$; 13.0%), CoreValve ($n = 10$; 14.5%), Direct Flow ($n = 5$; 7.2%), JenaValve ($n = 1$; 1.4%), Acurate NEO ($n = 1$; 1.4%), Portico ($n = 1$; 1.4%) and Lotus ($n = 1$; 14%). Transvascular access was used in 66 patients [transfemoral $n = 65$ (94.2%), transaortic $n = 1$ (1.4%)] and transapical access was utilized in 1 patient (1.4%). No records on the technique of the TAVR implantation were found in 2 patients (2.9%; Figs. 1 and 2).

The median time between TAVR and surgical revision was 14 months (5–24), with 32 patients (46.4%) being diagnosed with early PVE. At the time of surgery for IE, the median age was 78 years (72–81 years) and 48 patients (69.6%) were male. Median EuroSCORE II and STS PROM were 17% (10.1–31.0%) and 3.1% (2.2–4.9%), respectively, which was significantly higher compared to pre-TAVR implantation risk scores ($P < 0.001$ and $P < 0.001$, respectively). Preoperative adverse cerebrovascular events were diagnosed in 18 patients (26.1%), whereas other preoperative septoembolic events were diagnosed in 17 patients (24.6%). Demographic characteristics are detailed in Table 1.

Preoperative echocardiographic data

Echocardiographic data are depicted in Table 2. Paravalvular leakage was observed in 30 patients (43.5%) and moderate to severe aortic regurgitation was observed in 13 patients (18.8%). With regards to the mitral and tricuspid valves, moderate to

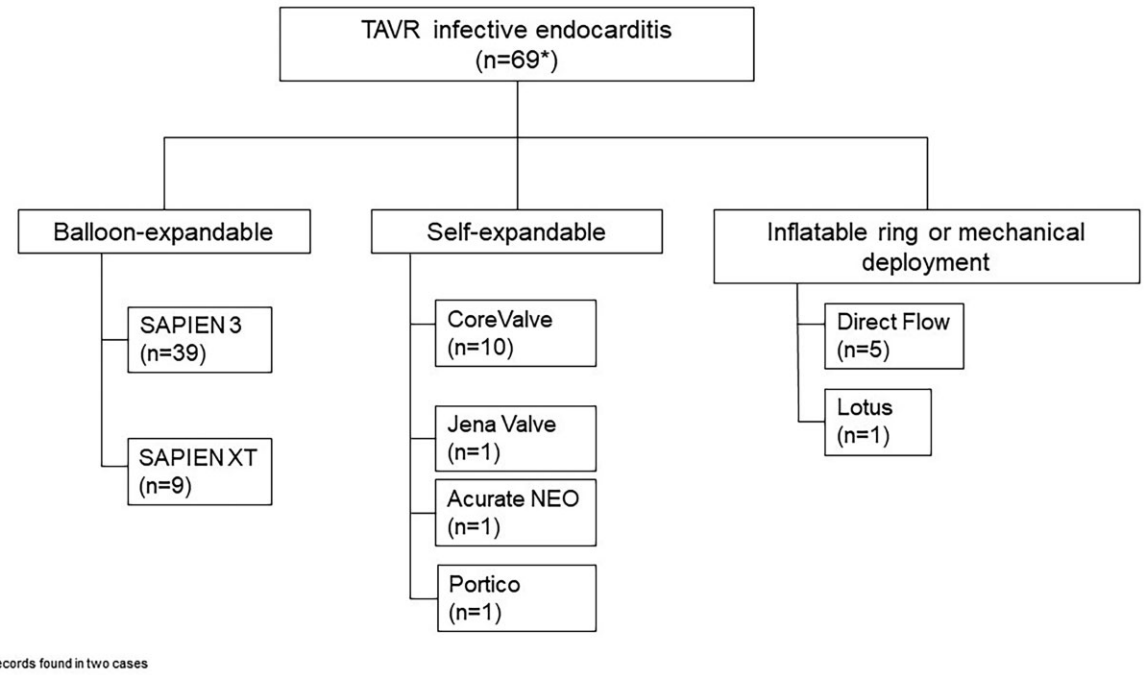

Figure 1: Edwards SAPIEN XT (Edwards Lifesciences Inc.); Edwards SAPIEN 3 (Edwards Lifesciences Inc.); CoreValve (Medtronic Inc); Jena Valve (JenaValve Technology GmbH); Acurate NEO (Boston, Marlborough); Portico (Abbott); Direct Flow (Direct Flow Medical Inc.); Lotus (Boston). TAVR: transcatheter aortic valve replacement.

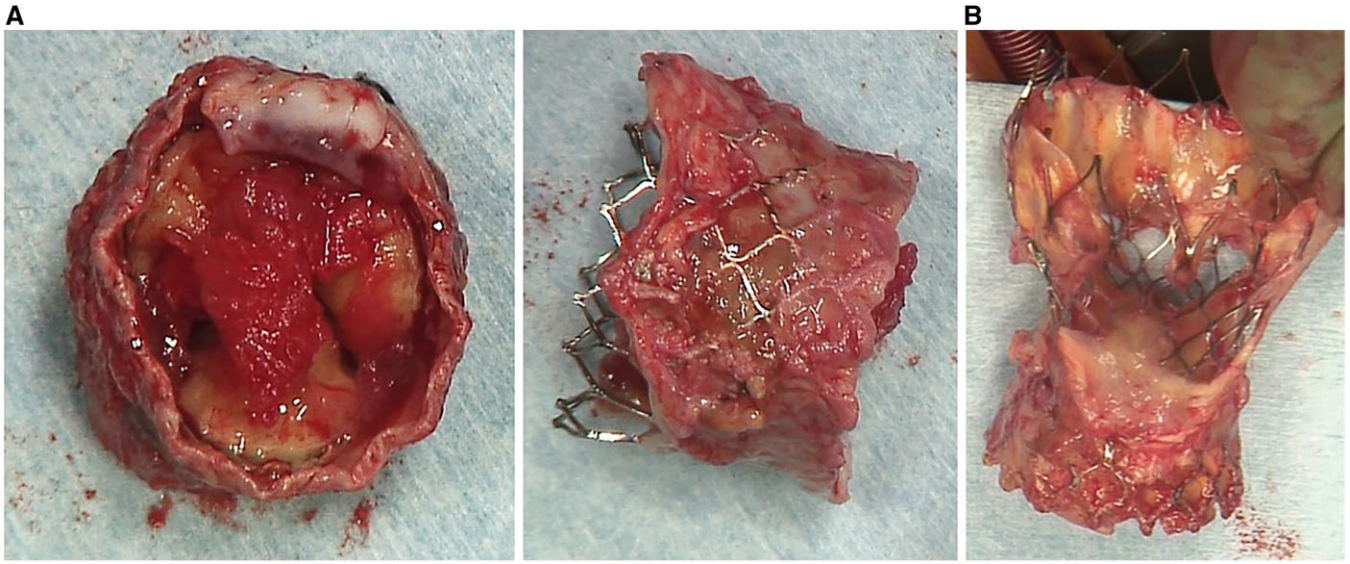

Figure 2: (**A**) An explanted balloon-expandable prosthesis with vegetations. (**B**) An explanted self-expanding prosthesis.

severe regurgitation was found in 5 (7.2%) and 9 (13.0%) patients, respectively. A left ventricular ejection fraction ≤30% was found in 8 patients (11.6%) and pulmonary hypertension was diagnosed in 19 (27.5%) patients. Abscesses were detected in 12 patients (17.4%). Vegetations were detected in three-fourths of the patients.

Causative organisms

Blood culture-negative IE was diagnosed in 3 cases (4.3%). The causative organisms in our cohort were exclusively gram-positive and are outlined in Table 3. The main causative organisms were as follows: *Enterococcus faecalis* (31.9%), coagulase-negative *Staphylococcus* spp. (26.1%), Methicillin-sensitive *Staphylococcus aureus* (15.9%) and viridans group streptococci (14.5%).

Surgical data

Details of surgery are presented in Table 4. In all cases, the TAVR prostheses were explanted and replaced with stented bioprostheses in 64 (92.8%) patients and a root replacement in 4 (5.8%) patients. Mechanical prostheses were implanted in 5 (7.2%) patients. Concomitantly, mitral valve surgery was carried out in 23 patients (33.3%), tricuspid valve repair in 6 patients (8.7%) and 6 patients (8.7%) underwent coronary artery bypass grafting. The median cardiopulmonary bypass time was 108 min (84–152 min) and cross-clamp time was 77 min (58–101 min). Abscess debridement was performed in 10 patients (14.5%), whereas repair of the aortomitral continuity was required only in 3 patients (4.3%).

Postoperative outcomes and long-term mortality

Postoperative outcomes and morbidities are listed in Table 5. Postoperative adverse cerebrovascular events were observed in 13 patients (18.8%) and 9 patients (13.0%) required implantation of a pacemaker. Temporary renal replacement therapy was necessary in 33 patients (47.8%), and extracorporeal life support was required in 2 patients (2.9%) with a median duration of 3 days (3–3 days). Paravalvular leakage was observed in only 1 patient (1.4%). The predominant cause of mortality was multiorgan failure.

Median hospital stay was 19 days (12–30 days) and median intensive care unit stay was 4 days (2–13 days). The median duration of postoperative mechanical ventilation was 13 h (5–43 h). Sixty-one patients (88.4%) were successfully discharged from the hospital, with an observed operative mortality of 11.6%. All patients were contacted 1-year after surgery. Survival at 6 months and 1 year was found to be 77% and 68%, respectively (Fig. 3).

DISCUSSION

The principal findings of the present study investigating TIE maybe summarized as follows:

- Endocarditis was diagnosed early in 46.4% of the patients with TIE.
- The TAVR prostheses were successfully explanted in all cases with aortic root surgery being required in 14.5% of the cases.
- Survival to discharge was 88.4% and survival 1 year was found to be 68%.

Current literature reports a surgical reluctancy in cases of TIE. This has been attributed to the high-risk profile of these patients. However, with younger and healthier patients undergoing TAVR, this indisposition towards surgery may be disastrous. The study at hand describes a multicentre surgical experience of TIE in intermediate-risk patients.

Procedural-, device- and patient-related risk factors

In a recent study by Stortecky *et al.* [11], it has been shown that TAVR implantation in catheterization laboratories, rather than hybrid operating rooms, has been an independent risk factor for the development of TIE [11]. Transfemoral access for the index

Table 1: Patient characteristics and comorbidities at surgical revision

Patient characteristics	(*n* = 69)
Age (years)	78 (72–81)
Male (%)	48 (69.6)
Body mass index (kg/m^2)	26.7 (24.2–30.5)
Indication for TAVR	
Aortic stenosis	67 (97.1)
Aortic regurgitation	2 (2.9)
Valve-in-valve procedures (%)	6 (8.7)
Time to surgical revision (months)	14 (5–24)
Early PVE (%)	32 (46.4)
EuroSCORE II (%)	17 (10.1–31.0)
STS PROM (%)	3.1 (2.2–4.9)
Urgency of surgery	
Elective (%)	13 (18.8)
Urgent (%)	40 (58.0)
Emergency (%)	13 (18.8)
Salvage (%)	3 (4.3)
Comorbidities	(*n* = 69)
Arterial hypertension (%)	63 (91.3)
Atrial fibrillation (%)	35 (50.7)
Insulin-dependent diabetes (%)	21 (30.4)
Chronic kidney disease (%)	43 (62.3)
Hyperlipidaemia (%)	33 (47.8)
Malignancy[a] (%)	10 (17.2)
Prior pacemaker[a] (%)	17 (29.3)
Previous endocarditis[a] (%)	2 (3.4)
Recent non-cardiac surgery[b] (%)	12 (23.5)
COPD (%)	20 (29.0)
Chronic steroid therapy[b] (%)	6 (11.5)
Coronary artery disease (%)	31 (44.9)
Previous PTCA/Stenting[a] (%)	15(25.9)
Peripheral artery disease (%)	16 (23.2)
Preoperative adverse cerebrovascular events (%)	18 (26.1)
Preoperative septic emboli (%)	17 (24.6)
Double-valve endocarditis (%)	13 (18.8)
Abscess formation (%)	12 (17.4)

Data are presented as medians (25th–75th percentiles) or absolute numbers (percentages).

[a]Data recorded in 58/69 cases.

[b]Data recorded in 51/69 cases.

COPD: chronic obstructive pulmonary disease; EuroSCORE II: European System for Cardiac Operative Risk Evaluation II; PVE: prosthetic valve endocarditis; STS PROM: Society of Thoracic Surgeons Predicted Risk of Mortality; TAVR: transcatheter aortic valve replacement.

Table 2: Echocardiographic data

Preoperative data	(*n* = 69)
LVEF	
≥50%	37 (53.6)
31–49%	24 (34.8)
≤30%	8 (11.6)
Aortic regurgitation	
Mild to moderate (%)	30 (43.5)
Moderate to severe (%)	13 (18.8)
Mitral regurgitation	
Mild to moderate (%)	39 (56.5)
Moderate to severe (%)	5 (7.2)
Tricuspid regurgitation	
Moderate to severe	9 (13.0)
Pulmonary hypertension (%)	19 (27.5)
TAVR PG max[a] (mmHg)	20.0 (5.2–28.8)
TAVR PG mean[b] (mmHg)	13.0 (6.8–16.0)
TAVR PVL, *n* (%)	30 (43.5)
Vegetations (%)	45 (77.6)
Postoperative data	
AVR PG max[c] (mmHg)	14.0 (10.0–20.0)
AVR PG mean[c] (mmHg)	7.5 (5–11.3)
AVR PVL[d] (%)	1 (1.9)

Data are presented as medians (25th–75th percentiles) or absolute numbers (percentages).

[a]Data recorded in 68/69 cases.

[b]Data recorded in 50/69 cases.

[c]Data recorded in 39/69 cases.

[d]Data recorded in 53/69 cases.

AVR: aortic valve replacement; LVEF: left ventricular ejection fraction; PG: pressure gradient; PVL: paravalvular leakage; TAVR: transcatheter aortic valve replacement.

Table 3: Details of causative organisms

Causative organism	(*n* = 69)
BCNIE (%)	3 (4.3)
Gram-positive bacteria	
Enterococcus faecalis (%)	22 (31.9)
Methicillin-sensitive *Staphylococcus aureus* (%)	11 (15.9)
Staphylococcus lugdunensis (%)	1 (1.4)
Other CoNS[a] (%)	17 (24.6)
Viridans group *streptococci*[b] (%)	10 (14.5)
ß-haemolytic *streptococci*[c] (%)	1 (1.4)
Proprionibacterium acnes (%)	2 (2.9)
Parvimonas micra (%)	1 (1.4)
Corynebacterium striatum (%)	1 (1.4)

Data are presented as absolute numbers (percentages).

[a]Other Coagulase-negative staphylococci (CoNS): *S. epidermidis* (13), *S. hominis* (2), *S. sciuri* (1), *S. haemolyticus* (1).

[b]*S. mitis* group: *Streptococcus mitis* (2), *Streptococcus oralis* (1); *S. bovis* group: *Streptococcus bovis* (1), *Streptococcus gallolyticus* (2); *S. salivarius* group: *Streptococcus salivarius* (3), *S. sanguinis* group: *Streptococcus gordonii* (1).

[c]*Streptococcus dysgalactiae* (1).

BCNIE: blood culture-negative infective endocarditis.

TAVR procedure and the proximity of the groin with genitourinary/intestinal system has been reported to be a predisposing factor for the frequent isolation of enterococci [16]. This is reflected in our results as transfemoral access was used in 94.2% of this cohort and Enterococci were isolated in almost a third of the patients. Access-site infection has been reported in about 1 in 8 patients and multiple infection sites have been reported in 3.4% [16].

This only serves to underscore the importance of the perioperative prophylaxis. Current guidelines suggest that antibiotic prophylaxis should be considered for patients at highest risk for IE before high-risk procedures (Evidence level IIC), whereas antibiotic prophylaxis is not recommended in other forms of valvular or congenital heart disease before high-risk procedures (Evidence level III C) [7]. Furthermore, Stortecky *et al.*[11] reported that in 47.9% of patients suffering from TIE, the causative organism identified was not susceptible to the periprocedural antibiotic prophylaxis.

Enterococci have been reported to be more frequent in self-expanding valve prostheses, whereas coagulase-negative Staphylococci in balloon expanding valve prosthesis recipients, respectively [17]. Differences in the design of TAVR prostheses valve may also play a role in the development of TIE, the much

Table 4: Details of surgery

Details of surgery	(*n* = 69)
Cardiac reoperations (%)	12 (17.4)
Duration of surgery (min)	196 (158–261)
Duration of cardiopulmonary bypass (min)	108 (84–152)
Duration of aortic cross-clamping (min)	77 (58–101)
Concomitant procedures	
Mitral valve surgery	
Mitral valve repair (%)	13 (18.9)
Mitral valve replacement (%)	10 (14.5)
Tricuspid valve repair (%)	6 (8.7)
CABG (%)	6 (8.7)
Aortic root enlargement (%)	6 (8.7)
Aortic root replacement (%)	4 (5.8)
Supracoronary ascending aortic replacement (%)	2 (2.9)
Abscess debridement (%)	10 (14.5)
Repair of the aortomitral continuity (%)	3 (4.3)
Repair of the LVOT (%)	1 (1.4)
Repair of the aortic wall due to strut penetration (%)	1 (1.4)
Prostheses implanted	
Biological (%)	58 (84.1)
Rapid deployment (%)	6 (8.7)
Mechanical (%)	5 (7.2)

Data are presented as medians (25th–75th percentiles) or absolute numbers (percentages).

CABG: coronary artery bypass grafting; ECLS: extracorporeal life support; LVOT: left ventricular outflow tract.

Table 5: Morbidities and outcomes

Morbidities	(*n* = 69)
Adverse cerebrovascular events	
Ischaemic stroke (%)	12 (17.4)
Haemorrhagic stroke (%)	1 (1.4)
Re-explorative surgery (%)	13 (18.8)
Tracheostomy (%)	11 (15.9)
Pacemaker implantation (%)	9 (13.0)
Renal replacement therapy (%)	33 (47.8)
Ventilator-associated pneumonia (%)	24 (34.8)
Surgical site infection (%)	4 (5.8)
ECLS support (%)	2 (2.9)
Duration of ECLS support (days)	3 (3-3)
Outcomes	**(*n* = 69)**
Survival to discharge (%)	61 (88.4)
Length of hospital stay (days)	19 (12–30)
Length of ICU stay (days)	4 (2–13)
Length of PMV (h)	13 (5–43)

Data are presented as medians (25th–75th percentiles) or absolute numbers (percentages).

CABG: coronary artery bypass grafting; ECLS: extracorporeal life support; ICU: intensive care unit; PMV: postoperative mechanical ventilation.

larger stent frame of self-expanding valves could act as an anchor during bacteraemia and irritate the endothelium and damage it, thereby make them more susceptible to TIE [3, 16, 17]. Furthermore, superficial damage on the leaflet surface during crimping may cause the implanted valve to be prone to bacterial colonization. This may be aggravated by residual aortic regurgitation causing endothelial damage and pathological flow patterns.

High-risk profiles of patients such as advanced age, diabetes, immunosuppression, renal failure and concurrent infections

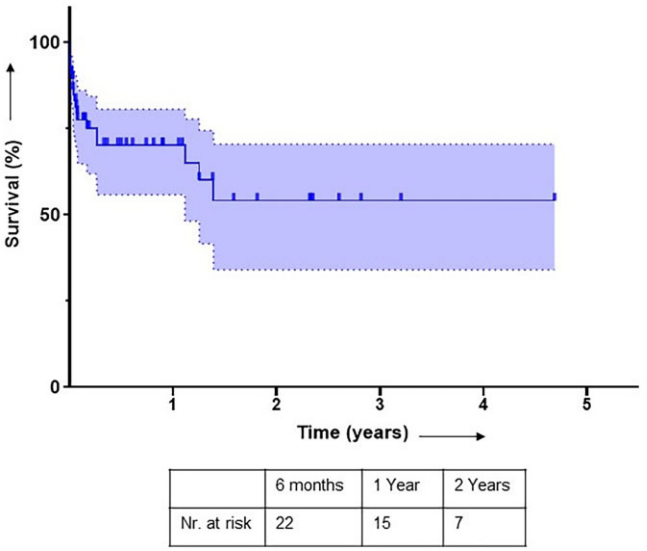

Figure 3: Kaplan–Meier survival curve of the patients undergoing surgery for infective endocarditis following TAVR.

further demonstrate individual vulnerability [10, 18]. In our cohort, majority of the patients were 70 years and older, however, as previous studies have shown age alone should not be a contraindication for complex valve surgery [19]. In cases of PVE, more than one-third of cases are caused by nosocomial infection or non-nosocomial healthcare-associated infections in outpatients with extensive medical caregiver contact, with TAVR patients being more susceptible to these infections [7].

Diagnostic challenges

It is a matter of common knowledge that echocardiography may be normal or inconclusive in up to 30% of PVE patients and that the low sensitivity of the Duke criteria frequently leads to false-negative diagnoses [7]. Furthermore, data on echocardiographic interpretation of post-TAVR endocarditis are limited. This may be due to the unique characteristics with respect to variable valve locations, abscess formation and obstructive patterns with leaflet thickening and fluctuating transvalvular gradients [20]. In the literature, it has been demonstrated that the diagnostic yield of echocardiography in TIE ranges between 55% and 86% [21]. Leaflet thickening and increased mean gradients (≥5 mmHg) have been observed in up to 80% of confirmed TAVR endocarditis, respectively [22].

The presence of abscesses, prosthesis dehiscence and new valvular regurgitation in the setting of TIE often complicate the diagnosis. The current guidelines on IE have acknowledged the usefulness of modern imaging techniques such as computed tomography scans, 18-fluorodeoxyglucose positron emission tomography or leucocyte scintigraphy (radiolabelled leucocyte single-photon emission computed tomography) in cases where the diagnosis is difficult by means of standard methods [7, 23]. However, these imaging procedures are not universally available. Thus, it may be postulated that a substantial number of cases remain undiagnosed due to lack of data and clinical experience [17, 24]. Furthermore, timely diagnosis may allow for early surgical intervention and prevent progress of the disease and destruction of surrounding tissue.

Surgical challenges

About half the patients in this cohort suffered from early PVE. Early surgical explantation of TAVR prosthesis is relatively uncomplicated, due to the lack of extensive endothelialization [25, 26]. This may be complicated in the setting of PVE as early PVE rarely remains restricted to leaflets alone; since it frequently involves the stent frame and annulus, leading to valve dehiscence and paravalvular abscesses [27]. Possible destruction of the aortic root, stent ingrowth in the ascending aorta or weakness of the aorto-mitral continuity are feared complications since they can be associated with a dismal outcome. In our cohort, repair of the aortomitral continuity, aortic root replacement and abscess debridement were carried out in 4.3%, 5.8% and 14.5% of patients, respectively.

Late surgical explantations are more challenging due to endothelialization of the TAVR prosthesis as well as calcifications and thrombus formation at the aortic root [25]. In the setting of late explantation of TAVR prostheses, balloon-expandable prosthesis may be easier to remove due to the ability to crush the valve and facilitate its mobilization [26]. However, self-expanding prosthesis has multiple points of apposition in the ascending aorta, the anterior leaflet of the mitral valve and left ventricular outflow tract, which makes their explantation more challenging. Repair of the left ventricular outflow tract and the aortic wall due to strut penetration was performed in 1 patient, respectively.

In this cohort, 12 patients had undergone previous cardiac surgery prior to the index TAVR procedure. Reoperations may further complicate the procedure due to the presence of adhesions and increased risk of bleeding [19]. In our cohort, 6 patients had undergone valve-in-valve procedures. The limited space, extensive endothelialization and bulky foreign valve prosthesis conglomerates make the explantation of these prostheses challenging.

Infection of adjacent heart valves and the progress of other cardiovascular diseases following index TAVR procedure often warrant additional surgery [1]. Double valve endocarditis was diagnosed in about one-fifth of the patients whereas one-third of the patients underwent concomitant mitral valve surgery and 6 patients underwent concomitant tricuspid valve repair. Additional coronary artery bypass grafting procedures were performed in 6 patients.

Outcomes

Neurological complications have been reported to occur in 20–40% of patients suffering from IE [28]. In our cohort, preoperative cerebral emboli were diagnosed in more than one-fourth of the patients, additionally another 18.4% of the patients suffered from postoperative adverse cerebrovascular events. This high rate of adverse cerebrovascular events suggests that timely surgical treatment of TIE is warranted. Current literature reports the mortality following TIE has been reported to range from 22% to 47% [2, 8–12, 16, 17, 29], in high-risk cohorts that were predominantly treated conservatively. In our cohort, which predominantly consists of low and intermediate-risk patients, the observed rate of mortality was 11.6%, lower than the rate predicted by the EuroSCORE II (17%), which is also consistent with values reported in the literature. In contrast, the STS score calculated as 3.1% seems to underestimate the mortality risk in this particular cohort of patients; therefore, clinical assessment of the patients still seems mandatory. The remarkably low-risk scores at the time of TAVR of the admitted patients speak for an appropriate selection process already in the referring hospitals. Similarly, survival at 1 year has been reported to range between 25% and 58% [10, 11, 16, 30, 31]. Whereas the survival at 1 year in this intermediate-risk group was 68%. Mangner *et al.* [31] compared the outcomes of surgically and conservatively treated patients in the setting of TAVR endocarditis and found no differences in the 1 year mortality between the groups. However, the authors go on to suggest that the possible benefits of surgery for TIE may have been masked due to underpowering of the study. TIE is an emerging clinical entity that demands a patient-centred approach. Surgery should not be categorically excluded in patients suffering from TIE. An endocarditis-team approach is best suited for decision-making in this complex cohort.

Limitations

Our study is a descriptive retrospective registry of patients with IE after TAVR considered operable by the Endocarditis-Team, and therefore, does not reflect the status of treatment of IE after TAVR. Patients who remained undiagnosed or were treated conservatively are out of the scope of this study. The small number of patients is associated with a low power of statistical analyses. Furthermore, the incidence larger prospective studies including all TAVR patients with IE are required.

CONCLUSIONS

The simultaneous rise in TAVR procedures and TIE warrants a more liberal consideration of surgery as a curative option in especially low- and intermediate-risk patients. Our results suggest that TIE can be treated according to the guidelines for PVE, namely with early surgery. Which according to our findings is associated with acceptable morbidity and mortality rates. Lack of clinical experience and limited diagnostic imaging techniques, reduced indications of antibiotic prophylaxis and surgical complexity, in addition to predisposing factors make TIE a challenging disease. Surgery should be discussed liberally as a treatment option in patients with TIE by the 'endocarditis team' in referral centres.

Conflict of interest: none declared.

Data Availability Statement

The data underlying this study cannot be shared publicly in accordance with national data safety guidelines, to protect the privacy of individuals that included in the study. The data will be shared on reasonable request to the corresponding author.

Author contributions

Shekhar Saha: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Visualization; Writing—original draft; Writing—review & editing. **Dominik Joskowiak:** Conceptualization; Formal analysis; Writing—original draft; Writing—review & editing. **Mateo Marin-Cuartas:** Data curation; Validation. **Mahmoud Diab:** Data curation; Validation. **Benedikt M. Schwaiger:** Data curation; Validation. **Rodrigo Sandoval-Boburg:** Data curation; Investigation. **Aron-Frederik Popov:** Methodology; Validation. **Carolyn Weber:** Data curation; Investigation. **Sam Varghese:** Data curation; Investigation. **Andreas Martens:** Data curation. **Serghei**

Cebotari: Data curation. **Maximilian Scherner:** Formal analysis; Methodology. **Walter Eichinger:** Methodology; Supervision. **David Holzhey:** Formal analysis; Supervision. **Daniel-Sebastian Dohle:** Data curation; Investigation. **Thorsten Wahlers:** Project administration; Supervision; Validation. **Torsten Doenst:** Project administration; Supervision; Writing—original draft; Writing—review & editing. **Martin Misfeld:** Methodology; Supervision; Validation. **Julinda Mehilli:** Validation. **Steffen Massberg:** Supervision; Writing—review & editing. **Christian Hagl:** Methodology; Project administration; Supervision; Validation; Writing—original draft; Writing—review & editing.

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Real-world experience with Thopaz+

The Oxford University Hospitals NHS Foundation Trust experience

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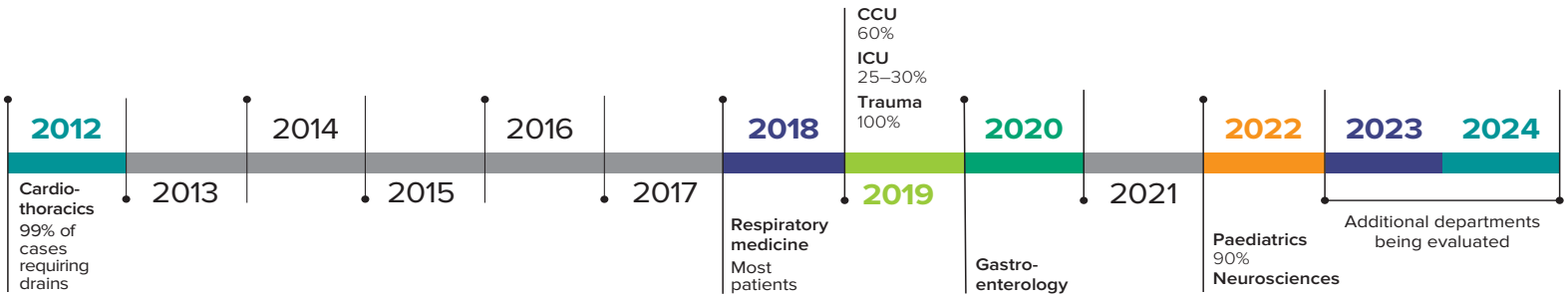
Thopaz+ is a portable digital chest drainage and monitoring system developed by Medela. It offers continuous objective monitoring of fluid loss and air leaks, which facilitates assessment of patients' progress, as well as standardisation of chest drainage management across different departments.[1] Clinical evidence has demonstrated that Thopaz+ is a useful tool in the management of patients that require chest drains and has clear clinical advantages compared with underwater seal drains.[1–3]

Thopaz+ and its predecessor, Thopaz, have been used within the Cardiothoracic Department at Oxford University Hospital NHS Trust since 2012. A report on this experience contributed to National Institute for Health and Care Excellence (NICE) Medical Technology Guidance 37.[1,4] Use of Thopaz+ in Oxford has since expanded to other departments within the trust. This document summarises the experience with Thopaz+ based on interviews with healthcare professionals (HCPs) at Oxford University Hospital NHS Trust in February/March 2024.

*Evolution of Thopaz+ use in Oxford: initial introduction by department and current usage**



*Percentage of cases using Thopaz+, where known from interviews.

CHEST DRAINAGE PROTOCOLS

Each department has a chest drain protocol based on their use of Thopaz+ or underwater seal drains, and whether active suction or physio mode is needed.

MOBILISATION

Improved and earlier mobilisation is a major advantage of Thopaz+ in relation to complications associated with immobility.

OBJECTIVE AND CONTINUOUS MONITORING LEADS TO IMPROVED DECISION-MAKING

Continuous monitoring improves chest drain decision-making by providing objective estimates/measurement of leakage. It helps determine when air leaks are resolving (allowing for earlier drain removal and discharge planning) or when further intervention is needed (such as referral to a surgeon).

LENGTH OF STAY

Digital drainage facilitates day-case procedures by giving HCPs confidence that their patients have no persistent air leaks or fluid loss.

RESPIRATORY

70% of patients following pleural intervention and 60% undergoing thoracoscopy return home the same day.

CORONARY CARE UNIT (CCU)

Length of stay of 7 days with Thopaz+ compared with 10 days with underwater seal drains.

THROUGHOUT THE PATIENT JOURNEY

Thopaz+ can be used throughout a patient's journey, which can reduce the possibility of issues and errors, because drains can become kinked or displaced whenever a device is changed. Suction can be added to a Thopaz+ device set up to provide straightforward drainage simply by pressing a button to initiate suction via the device itself.

COSTS AND EFFICIENCIES

The use of the device can lead to improved operational efficiencies and cost savings, which may justify the acquisition costs. From an evidence-based practice project in the USA, a digital air leak detection device after pulmonary lobectomy led to cost savings of $2,659 per hospital day.[5]

IMPROVED PATENT SAFETY

Thopaz+ is a closed system, reducing incidents, errors, mishaps, and infections. As a dry system, Thopaz+ prevents issues with water and device positioning. Non-medical staff can manage Thopaz+ if it is knocked over, with no patient impact. Thopaz+ has its own suction source, preventing complications with wall suction becoming displaced or unclipped.

STAFF EXPERIENCE

Precise fluid and air leak measurements including time trends, improve clinician confidence and decision-making and facilitate continuity of care. The user-friendly interface makes it easier to track air leaks and fluid output. Nursing time is saved with easy canister replacement, reduced manual monitoring, and visual and audible notifications alert HCPs of issues.

PATIENT EXPERIENCE

Patients can move around freely without nursing or healthcare assistant support. Earlier discharge reduces hospital stay. Patients can monitor their progress in terms of reducing volumes of fluid and air leaks on the display.

Summary of the real-world experience with Thopaz+

The experience of HCPs within Oxford University Hospitals NHS Foundation Trust over the past 12 years has shown that Thopaz+ has multiple benefits in the right circumstances and should be available for the vast majority of patients requiring a chest drain.

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> Overall, our experience at Oxford University Hospitals NHS Foundation trust has shown that Thopaz+ is an indispensable asset for HCPs, redefining standards of care and operational efficiency across multiple medical departments. We encourage all units using chest drains to consider making the move from underwater seal drains to Thopaz+ in the vast majority of patients requiring chest drainage.

Quotes from interviews with a number of healthcare professionals at Oxford University Hospital NHS Trust:

> From the NHS perspective, I think it probably allows us to make earlier decisions about withdrawing chest drains and getting peopleout of hospital earlier.

> There are a number of ways to recoup the costs: efficiencies in the system, less litigation because things don't go wrong, staff sickness due to back injuries, and length of stay if you can get patients home quicker.

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Read the full report:

The summary report has been written by HSJ Advisory on behalf of Medela AG, reflecting the views expressed in interviews with healthcare professionals. Medela AG funded the project and had input into the development of this report.

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