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Initial Experience with Aortic Valve Replacement via a Minimally Invasive Approach: A Comparison of Stented, Stentless and Sutureless Valves

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Background: This study aimed to compare the short-term outcomes of MIS-AVR among 3 different types of biological heart valves.

Material/Methods: Complete data were obtained from 79 patients who underwent MIS-AVR between January 2010 and June 2015. Patients were divided into 3 groups: 27 patients (group A) received Medtronic 3f® (Medtronic Inc., Fridley, MN, USA), 36 patients (group B) received DokimosPlus® (LabCor Laboratórios Ltda., Belo Horizonte, Brazil) and 16 patients (group C) received Perceval® (Sorin Biomedica Cardio S.r.l., Saluggia VC, Italy) valves.
Operative and postoperative parameters such as duration of operation, bypass time, duration of ventilation, morbidity, and mortality were statistically analyzed using the Kruskal-Wallis test. Hemodynamic assessment with transthoracic echocardiography was performed before discharge.

Results: The EuroSCORE II ranged between 0.67 and 6.94 with no significant difference between the groups. The median operative time was 166 min (range 90–230 min) in total, with significantly shorter times in group C (120 min [range 90–200]). The median total ventilation time was significantly lower in group C and significantly higher in group A. Hemodynamic evaluation demonstrated a mean maximal velocity (v_{max}) over the aortic valve of 2.3 m/s (range 0.9–4.3 m/s) with average mean and peak pressure gradient values of 10 mmHg (range 3–24 mmHg) and 20 mmHg (range 5–42 mmHg), respectively. Group A showed the highest values for v_{max} (H>5.99).
No significant difference was found regarding duration of hospitalization. Mortality was 3%.

Conclusions: In conclusion, all 3 valves showed good perioperative results, satisfying hemodynamic performance, and low complication rates.

MeSH Keywords: Aortic Valve • Aortic Valve Insufficiency • Surgical Procedures, Minimally Invasive

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Background

Aortic valve disease is a major problem, especially in the aging population, due to degenerative processes. Severe aortic valve stenosis, which is a common form of valvular heart disease [1], usually requires surgical or interventional treatment for mechanical relief. Similarly, active infective endocarditis often needs to be treated operatively, as suggested by the current guidelines [2]. However, with increasing age and multimorbidity, a growing fraction of patients is burdened with a very high operative risk. In fact, before the establishment of transaortic valve replacement (TAVR), it had been estimated that one-third of all patients over 75 years of age with severe aortic stenosis would be rendered inoperable [3]. However, TAVR also bears complex complications and has several limitations [4].

Due to limited trauma, minimally invasive surgery of the aortic valve (MIS-AVR) reduces operative risk and possible complications [5–9], yet retains the advantage of open-heart surgery, including complete removal of the diseased valve, accurate implantation, and better longevity of the prosthesis. To further reduce operative time, the rapid deployment system (RDAVR) was introduced and proved to be suitable for MIS-AVR [10–13]. Furthermore, it may be a suitable technique for high-risk patients who are obliged to undergo surgery of the aortic valve due to conditions such as endocarditis [14].

The aim of this study was to compare the intra- and early postoperative results of patients after MIS-AVR.

Material and Methods

Study population

From January 2010 to June 2015, a total of 1133 patients underwent aortic valve replacement (AVR) at the Charité Hospital, Medical University Berlin. Out of all MIS-AVRs, a patient cohort of 79 patients was selected after applying final exclusion criteria, which were additional cardiac procedures and reoperation.

The patient cohort was subdivided into 3 groups: group A (n=27) received a stentless pericardial valve (3f®; Medtronic Inc., Fridley, MN, USA), group B (n=36) received a stented bioprosthesis (Dokimos®; LabCor Laboratories, Belo Horizonte, Brazil), and group C (n=16) received a sutureless system (Perceval valve®; Sorin Biomedica Cardio S.r.l., Saluggia VC, Italy).

Initially, patients were assessed regarding morbidities and health status. This included general data such as age, sex, body mass index, renal function, and mobility, as well as a list of pre-existing medical conditions such as arterial hypertension, chronic pulmonary disease, metabolic syndrome, malignant neoplasia, autoimmune defects, and infectious diseases.

Renal function was assessed by calculating creatinine clearance using the Cockroft-Gault formula and divided into 4 groups: unimpaired (>85 ml/h), moderately impaired (51–85 ml/h), severely impaired (<50 ml/h), and renal impairment requiring dialysis.

A risk profile was established for each patient by calculating their EuroSCORE II [15].

The patients were operated on only by qualified surgeons capable of performing all 3 MIS-AVR methods, were previously discussed in a heart team, and were fully informed of all options and procedures before giving written consent.

The choice of the bioprosthesis was left to the discretion of the operating surgeon. Pure aortic regurgitation was seen as a contraindication for sutureless prostheses (group C).

Surgical technique

Our group has published the detailed surgical techniques for MIS-AVR in 1996 [16], which has been used with minor modifications regarding venous cannulation.

In brief, all patients were operated on under general anesthesia and orotracheal intubation. After limited skin incision of approximately 7 cm, a right upper hemisternotomy ("J Sternotomy") was performed between the jugular notch and the 3rd or 4th intercostal space. Cardiopulmonary bypass was established by standard cannulation of the aorta and the right atrium. Intermittent antegrade warm blood cardioplegia was used. The ascending aorta was opened transversely 10–20 mm above the sino-tubular junction for the implantation of a stented or stentless bioprostheses, and 35 mm above the right coronary artery for the sutureless bioprosthesis. The diseased heart valve was precisely explanted, followed by debridement of the annulus as well as decalcification, which was extended up to the mitral valve if necessary.

Following precise sizing, the selection and implantation of a suitable prosthesis was performed.

Group A received the 3f® valve, which was implanted using a standard continuous 3-0 polypropylene suture and 4-0 polypropylene sutures were used for adaptation of the commissural hinge points.

Group B received the Dokimos® valve, which was implanted with 15–20 horizontal felt-armed 2-0 mattress sutures.

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Group C received the Perceval® valve. This sutureless valve was implanted by initially placing three 3-0 polypropylene guiding sutures, then cautiously lowering the valve into the annulus and expanding a balloon for 30 s at a pressure of 4 mBar, finally allowing the nitinol stent to adapt to the annulus under a continuous flow of 37°C sterile physiologic solution before removing the guiding sutures.

Intraoperative transesophageal echocardiography was performed for control of proper hemodynamic function of the prosthesis and possible air residues. High-flow CO_2 (2–4 L/min) was used to ease deairing. After sufficient reperfusion time, adequate hemostasis, and chest closure, patients were transferred to the intensive care unit. The postoperative care followed institutional guidelines, including platelet aggregation inhibition with 100 mg acetylsalicylic acid and low-molecular-weight heparin.

Intraoperative parameters were duration of the operation from first incision to chest closure, total cross-clamp time, total cardiopulmonary bypass time, and acute intraoperative complications including low cardiac output (LCO) as well as the use of intra-aortic balloon pump (IABP) or extra-corporeal membrane oxygenation (ECMO) implantation.

The postoperative clinical course was compared using the amount of transfusions needed, incidence of arrhythmias, permanent pacemaker implantation, neurological complications, hospital-acquired pneumonia (HAP), acute kidney failure or dialysis, systemic inflammatory response syndrome (SIRS), wound infections and sepsis, as well as need for reexploration, further significant complications, and death. The duration of ventilation was recorded and divided into short-time ventilation (<48 h) and longtime ventilation (>48 h). Furthermore, the duration of intensive care and total hospitalization days were assessed.

Postoperative hemodynamic performance of the prostheses was tested by transthoracic echocardiography using a GE Vivid 7 Dimension ultrasound scanner (General Electric, Fairfield, CT, USA) at discharge. General and regional heart contractility, cardiac output, morphology of the valve, regurgitation, and maximal velocity, as well as transaortic peak and mean gradient, were evaluated with standard views by experienced echocardiographers according to an internal protocol. Mean values were obtained during a span of 3 (sinus rhythm) or 5 (non-sinus rhythm) heartbeats. Transaortic valve gradients were calculated using the Bernoulli equation.

Regurgitation was ranked from grade I° (slight regurgitation) to grade III° (severe regurgitation).

Statistics

All data were retrospectively collected from hospital charts and reported as numeric percentages for categorical variables and as median with range for continuous variables. To determine significant differences among the 3 independent groups, the Kruskal-Wallis test was performed for each ordinal variable. The Kruskal-Wallis test compares datasets of 3 or more independent groups and generates a ranking of the data among the groups in ordinal numbers without units. An H value was determined to assess the significance, and if H exceeded the critical χ^2 value of 5.99 (at 2 degrees of freedom and a p value of 0.05), the difference between the datasets of the 3 groups could be accepted as significant. For H calculation and the ranking, the online software *http://vassarstats.net/kw3.html* was used [17]. Further statistical analyses were done using IBM SPSS 23 (SPSS Inc., Chicago, IL, USA) and Microsoft Excel (Microsoft Inc., Redmond, WA, USA).

Results

Median patient age was 69 years (range 35–86 years), distributed among groups A, B, and C with median 71.1, 62.3 and 70.6 years (range 54–86, 35–80 and 58–83 years), respectively; 40% (n=32) were female and 60% (n=47) were male. Group C had the highest fraction of female patients, with 81% (n=13); and group B had significantly more male patients (75%). Median BMI was 27.6 (range 18.7–51.6) and was evenly distributed among all groups. Twelve patients had been diagnosed with cancer; most cases were in Group C (n=7, 41%), 1 patient in group B presented with advanced terminal prostate cancer and infective endocarditis subsequent to port infection. One patient from group A suffered from neurological immobility due to myotonic disease. A summary of general preoperative status can be seen in Table 1.

The operative risk was assessed with the EuroSCORE II, which ranged between 0.67 and 6.94. The Kruskal-Wallis test showed no overall difference of EuroSCORE II among the 3 groups (H >5.99).

In group A, 2 patients suffered from insulin-dependent diabetes mellitus, and pulmonary hypertension was present in 15 patients (19%).

Renal function was unimpaired in 41 patients and severely impaired in 10 patients (13%). Additionally, 2 patients required long-term dialysis beforehand.

Eleven patients suffered from chronic obstructive pulmonary disease with steroid treatment, with the fewest patients in group B (3%). Of all patients, 10% were admitted with

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Table 1. General preoperative findings of the study cohort.

Parameter*	Group A n=27		Group B n=36		Group C n=16	
Nicotine abuse	9	(33%)	6	(17%)	6	(37%)
Ethanol abuse	6	(22%)	4	(11%)	1	(6%)
Arterial hypertension	22	(81%)	23	(64%)	13	(81%)
Hyperlipoproteinaemia	13	(48%)	7	(19%)	8	(50%)
Malignant neoplasia	1	(4%)	4	(11%)	7	(44%)
Automimmune defects	2	(7%)	3	(8%)	2	(13%)
Metabolic defects	5	(19%)	7	(19%)	4	(25%)
Anaemia	8	(30%)	9	(28%)	5	(31%)
Infectious diseases	2	(7%)	5	(13%)	3	(19%)
Extracardial operations	12	(44%)	15	(42%)	12	(75%)

* Total number of patients for each individual parameter is expressed as a percentage of the subtotal of each group in parenthesis.

extracardiac arteriopathy, including a history of peripheral artery disease, amputations, and vessel interventions.

Median NYHA class of all patients was II and ranged from I to IV with no significant difference between the 3 groups. One patient from group B presented with low cardiac output prior to the procedure. Further risk factors according to EuroSCORE II are shown in Table 2.

Pre-existing additional cardiologic conditions were found in 60% of all patients, most commonly slight mitral insufficiency (35%), followed by arrhythmias (20%) and coronary artery disease (CAD) (18%), in which stenoses were either irrelevant or had been treated earlier (n=11).

Aortic valve stenosis and mixed disease (26%) were the leading reasons for aortic valve dysfunction, distributed evenly among all 3 groups. Pure aortic valve regurgitation was found in 8% of patients, distributed in groups A and B only, as it poses a contraindication for the sutureless system.

Two patients were in a critical preoperative condition; causes were low cardiac output in one and acute renal and hepatic failure in the other. All operations were elective, except for 6 (8%) urgent patients with active endocarditis; 4 of them were in group B and 2 in group C. Table 3 shows the distribution of cardiac preconditions in detail.

The median operative time was 166 min (range 90–230 min) distributed among groups A, B, and C, with median times of 170 min (range 140–230 min), 175 min (range 120–215), and 120 min (range 90–200), respectively. The total cross-clamp time was lowest in group C (30.3 min, range 20–53 min), followed by groups A and B (68 min [range 48–109 min] and 70.5 min [range 31–107 min]), respectively. The Kruskal-Wallis test confirmed significant differences among the 3 groups regarding total operative time, bypass time, and cross-clamp time. Group C ranked lowest in all 3 parameters. No conversion to full sternotomy was necessary.

Two patients suffered from low cardiac output (1 patient from group A and 1 from group B). The patient in group A received an IABP as circulatory support, which could be weaned and removed in the subsequent clinical course.

Two patients were ventilated for >48 h due to postoperative complications (220 h and 346 h; both from group A). Apart from the 2 long-term ventilated patients, median total ventilation time was 4.75 h (range 1–37 h), distributed in groups A, B, and C, with median times of 6, 3, and 3 h, respectively. Kruskal-Wallis analysis revealed a significant difference among the 3 groups, with group C ranking lowest (lowest ventilation time) and group A ranking highest (longest ventilation time).

Detailed information regarding intraoperative results is shown in Table 4.

Overall, patients spent a mean of 1 day (range 0–9 days) in the intensive care unit and were discharged from the hospital after a mean of 9 days (range 3–38 days). Patients from group A spent the most time in intensive care and until discharge (median 2 days [range 1–23] and 9 days [range 4–17 days], respectively). Kruskal-Wallis test results confirmed a difference in length of intensive care treatment: group C ranked lowest

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Table 2. Risk factors according to EuroSCORE II.

Parameters*	Group A (3F)	Group B (Dokimos)	Group C (Perceval)	Total
Number of patients	27	36	16	79
Age (years)**	71, 54–86	64, 35–80	73, 58–83	71, 35–86
Female	10 (37%)	9 (25%)	13 (81%)	32 (40%)
Renal Impairment: Creatinine clearance (ml/h)				
Moderately impaired (50–85 ml/h)	15 (56%)	4 (11%)	7 (44%)	26 (33%)
Severely impaired (<50 ml/h)	4 (15%)	3 (8%)	3 (19%)	10 (13%)
Dialysis	1 (4%)	1 (3%)	0	2 (3%)
Previous cardiac surgery	0	0	0	0
Chronic lung disease	4 (15%)	2 (6%)	5 (31%)	11 (14%)
Active endocarditis	0	4 (11%)	2 (13%)	6 (8%)
Critical pre-OP	1 (4%)	1 (3%)	0	2 (3%)
Diabetes on Insulin	2 (7%)	0	0	2 (3%)
Pulmonary hypertension	6 (22%)	5 (14%)	4 (25%)	15 (19%)
Urgency				
Elective	27 (100%)	32 (89%)	14 (88%)	73 (91%)
Urgent	0	4 (11%)	2 (13%)	6 (9%)
NYHA class	2; 1–4	3; 1–3	2; 1–3	3; 1–4
LVEF (%)				
Moderate (31–50%)	1 (4%)	6 (17%)	0	7 (9%)
Poor (21–30%)	0	1 (2%)	0	1 (1%)
Very poor (<20%)	0	0	0	0

* Total number of patients for each individual parameter is expressed as a percentage of the subtotal of each group in parenthesis;
** expressed in median and range. NYHA – New-York Heart Association; LVEF – left ventricular ejection fraction.

and group A ranked highest (H >5.99). No significant difference regarding overall hospitalization was found (H <5.99).

Major postoperative adverse effects were defined as mortality, surgical reexploration, and permanent neurological deficits. Hospital mortality was 3% (n=2); both patients were from group A, and died due to septic multi-organ failure on the 8th and 23rd postoperative day, respectively. Reexploration due to bleeding was necessary in 2 patients (3%); 1 patient from group A and 1 from group C. Moreover, 17 patients (21%) were delirious in the early postoperative phase, 11 of which had admitted a history of chronic alcohol abuse; however, no strokes or permanent neurological deficits were observed.

Other postoperative complications included new-onset arrhythmias, hospital-acquired pneumonia, and need for dialysis. New-onset atrial fibrillation occurred in 21% (n=17), which were converted pharmaceutically or electrically in 12 patients. In 5 patients (6%), a permanent pacemaker was implanted due to new-onset persisting non-sinus rhythm. Of those, 3 patients were in group A and 2 in group B.

Hospital-acquired pneumonia (HAP) occurred in 6 patients (8%): 4 patients in group A and 2 in group B. Four patients (5%) had renal dialysis postoperatively, 2 of which had been on dialysis preoperatively and 1 had a transplant failure. Overall, 4 patients (5%) developed sepsis due to HAP, prosthetic endocarditis, urinary tract infection, and in 1 patient with unclear focus. Two patients died in progress of septic multi-organ failure (group A). No patient had to be readmitted after discharge for related causes such as recurrent endocarditis and thromboembolic complications. Details are shown in Table 5. Valve sizing did not differ significantly among the groups (H <5.99).

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Table 3. Preoperative cardiac diagnoses.

Parameter *	Group A	Group B	Group C
Aortic valve	27 (100%)	36 (100%)	16 (100%)
Regurgitation		4 (11%)	0
Stenosis		21 (58%)	14 (88%)
Mixed		11 (31%)	2 (12%)
Mitral valve disease	11 (31%)	8 (22%)	9 (56%)
Regurgitation	11 (31%)	8 (22%)	6 (38%)
Stenosis	0	0	3 (18%)
Tricuspid disease	6 (22%)	7 (19%)	2 (3%)
Regurgitation	6 (22%)	6 (17%)	2 (3%)
Prior interventions	7 (26%)	3 (8%)	1 (6%)
Arrhythmias	7 (26%)	5 (15%)	4 (25%)
Recent mi	1 (4%)	0	0
Coronary artery disease	6 (22%)	3 (8%)	6 (37%)
1 Vessel disease	3 (11%)	2 (6%)	4 (25%)
2 Vessel disease	3 (11%)	1 (3%)	2 (13%)
3 Vessel disease	0	0	0

* Total number of patients for each individual parameter is expressed as a percentage of the subtotal of each group in parenthesis.

Table 4. Intraoperative results.

Parameters	Group A	Group B	Group C
Duration (h)*	02: 50 (2: 20–3: 50)	02: 55 (2: 00–3: 35)	2: 00 (01: 30–03: 20)
Bypass time (min)*	90.0 (61–139)	94.0 (45–130)	48.0 (36–87)
Ischaemiea (min)*	68.0 (48–109)	70.5 (69–107)	30.3 (20–53)
LCO**	1 (3.7%)	1 (2.7%)	0
IABP**	1 (3.7%)	0	0
Operative mortality	0	0	0

* Expressed as median and range, range is given in parentheses; ** number of patients and percentage. LCO – low cardiac output; IABP – intra-aortic balloon pump, total number of patients is expressed as a percentage of the subtotal of each group in parenthesis.

Furthermore, the median amount of erythrocyte concentrate, thrombocyte concentrate, and fresh frozen plasma needed showed no significant difference (H <5.99).

Median total postoperative left ventricular function was 60% (range 25–75%) in all groups.

Mean maximal velocity (v_{max}) over the aortic valve was 2.3 m/s (range 0.9–4.3 m/s) with average mean and peak pressure gradient values of 10 mmHg (range 3-24 mmHg) and 20 mmHg (range 5–42 mmHg), respectively. Group A showed the highest values for v_{max}, with median values of 2.6 m/s (range 1.8–4.3 m/s) The Kruskal-Wallis test confirmed these findings, with group A ranking highest and group B ranking lowest (H >5.99). More details are shown in Table 6.

Overall, 3 patients (4%) had slight regurgitation (<I°–I°), all from group A, with no need for further intervention. In all groups, no paravalvular leakage was observed.

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Table 5. Postoperative course, complications, mortality and morbidity.

Parameters*	Group A (n=27)	Group B (n=36)	Group C (n=16)
Transfusions: units of red blood cells**	1 (0–10)	0 (0–4)	2 (0–5)
Transfusions: units of platelets**	0 (0–3)	0 (0–16)	0 (0–4)
Transfusions: units of fresh frozen plasma**	0 (0–8)	0 (0–8)	0 (0–2)
Reintubation	3 (11%)	0	1 (6%)
Tracheostomy	1 (4%)	0	0
Bleeding requiring reexploration	1 (4%)	0	1 (6%)
Delirium	8 (29.6%)	6 (16.7%)	3 (18.8%)
Pneumothorax	2 (7%)	1 (3%)	0
Stroke	0	0	0
HAP	4 (15%)	0	2 (13%)
Pleural effusion	3 (11%)	2 (6%)	0
Acute kidney failure	1 (4%)	3 (8%)	0
Dialysis	2 (7%)	2 (6%)	0
Pericardial effusion	2 (7%)	0	2 (13%)
SIRS	6 (22%)	20 (56%)	6 (38%)
Sepsis	3 (11%)	0	1 (6%)
New-onset arrhythmias	6 (22%)	2 (6%)	7 (44%)
Total duration of hospitalization (days)*	9 (4–17)	7,5 (1–38)	11 (5–31)
Duration Intensive Care Unit (days)**	2 (0–23)	1 (1–7)	1 (1–9)
Mortality	2 (7%)	0	0

* Total number of patients for each individual parameter is expressed as a percentage of the subtotal of each group in parenthesis; ** expressed as median and range, range is given in parentheses. HAP – health-care acquired pneumonia; SIRS – Systemic Inflammatory Response Syndrome.

Table 6. Echocardiographic findings in the three study groups before discharge.

Parameters	Group A (n=27)	Group B (n= 36)	Group C (n=16)
Size of prosthesis (mm)*	25 21–27	25 21–27	25 21–27
Ejection fraction (%)*	60 (40–65)	55 (25–75)	60 (45–73)
Peak gradient over aortic valve (mmHg)*	29 (10–42)	17 (5–41)	17 (11–29)
Mean gradient over aortic valve (mmHg)*	16 (6–24)	8 (3–23)	9 (4–18)
Valvular insufficiency** ≤I°	2 (13%)	0	0

* Total number of patients for each individual parameter is expressed as a percentage of the subtotal of each group in parenthesis; ** expressed as median and range, range is given in parentheses.

Discussion

Severe aortic valve stenosis with hemodynamic relevance is a diagnosis that requires timely surgical or interventional action for mechanical relief as treatment, and it has been shown that patients had almost normal life expectancy after surgical treatment [1]. For patients with a low-to-moderate risk profile, surgical AVR remains the criterion standard.

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However, Yan et al. reported that almost 25% of all patients with severe aortic stenosis were deemed inoperable because of a high operative risk due to morbidity and age [3]. Recently, transcatheter aortic valve replacement (TAVR) has been introduced as an alternative for conventional operation, and proves to be a good technique in patients rendered inoperable or with extremely high risk. However, drastic complications may arise from TAVR implantation, such as strokes, aortic dissection, severe regurgitation, endocarditis, and major ventricular tachyarrhythmia [18]. In fact, Mohr et al. reported that 1–2% of complications needed immediate surgical correction, with a mortality of 50% during surgery [18].

The risk of misplacement can be vastly reduced by open-heart surgery, and the minimally invasive approach adds the benefits of limited surgical trauma to the ability to remove the diseased valve and adjust the prosthesis position visually for optimal placement. Thus, minimally invasive surgery reduces the risk for low- and intermediate-risk patients compared to conventional surgery [11], and improves survival [8,19].

However, due to the circumstances of reduced operative field and the increased technical demands, MIS-AVR is often associated with longer operative and cross-clamp times [8], as well as associated postoperative complications that may arise. However, there are also studies that contradict this finding, presenting results showing that MIS-AVR has a shorter operative time [20,21]. However, sutureless valves reduce the time and complications of MIS-AVR, and are thus a good option for MIS-AVR implants [12,13,21,22].

This study compared 3 different bioprostheses from a total study cohort of 79 patients after MIS-AVR, and assessed the overall hemodynamic function, operative duration, and early postoperative complications.

Preoperative data showed that the general health status was divided relatively homogenously among the 3 groups. Regarding previous diagnoses, group C presented with multiple cancer patients (44%). Therefore, these patients were subjected to sutureless MIS-AVR in order to reduce operating and ventilation time and thus reduce the postoperative risk profile of these morbid patients. Conventional AVR would have been contraindicated due to the high-risk profile as well as length and quality of the remaining life.

Furthermore, group B included a palliative cancer patient with multiple metastases and active endocarditis following a septic port inflammation. The operation was uneventful, with duration of 205 min. The patient was discharged on the 7th postoperative day, with 1 day spent in intensive care and no postoperative incidents or complications. These excellent results demonstrate that even high-risk patients, who cannot be treated appropriately with conventional antibiotic therapy, could benefit from MIS-AVR regarding length and quality of the remaining life.

Regarding cardiovascular risk stratification, EuroSCORE II showed no significant differences in preoperative risk. However, groups A and C had fewer extremely high-risk patients than group B. As opposed to groups A and B, group C had no patients with pure aortic regurgitation, as this is a contraindication for sutureless implants.

However, patients were not matched. This leads to a certain risk of bias, especially because sex imbalance between the groups may shift the risk for early postoperative outcome [23]. Overall, good perioperative and early postoperative results were obtained in all 3 patient groups.

Compared with conventional AVR, the cross-clamp times proved to be slightly shorter in this MIS-AVR approach (73.5±19.3 min in AVR *vs.* 70.3±17.4 min in MIS-AVR) [8].

The Perceval valve with the sutureless deployment system significantly reduced operative, bypass, cross-clamping, and ventilation times compared to groups A and B. This is important because reduced operative and ventilation times can decrease the risk of hospital-acquired infections (HAI) and associated morbidity.

Postoperatively, the group C presented with the fewest complications, with the exception of temporary arrhythmias, which occurred in 44% of the total patient cohort. However, of those patients, all arrhythmias were temporary and could be resolved pharmaceutically without permanent pacemaker implantation. This is notable, as ballooning of the valve does not lead to more permanent arrhythmias as reported before, supporting findings of other groups [21].

Compared to results of Fischlein et al. [14], it can be seen that the hemodynamic performance of the Perceval valve was similar, with a median mean pressure gradient over the aortic valve of 9 mmHg (range 4–18 mmHg). Furthermore, the hemodynamic function of the Dokimos valve is flawless compared to the other 2 groups, with the lowest v_{max} over the aortic valve.

Patients in group C seemingly had the most complications. Both ventilation time and mortality showed comparably poor results at first glance, even though the preoperative EuroSCORE II showed no significant differences against the other groups. However, the 2 longtime ventilated patients were in fact the patients who died on the 8th and 23rd postoperative days due to multiple organ failure and were multimorbid elderly women aged 80 and 83 years, both having noninsulin-dependent diabetes mellitus (NIDDM), arterial hypertension,

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coronary 1 vessel disease, impaired kidney function, and a high EuroSCORE II. Both developed septic organ failure after a urinary tract infection in one patient and unclear focus in the other. Not taking these 2 patients into account, the 3f cohort showed a similar uneventful clinical course as the other 2 groups. Hemodynamically, the 3f presented with higher peak and mean gradients over the aortic valve compared to the other groups, yet values remained in acceptable limits, a finding that has been shown earlier by our group [21].

Compared to the findings of our group using the 3f in conventional AVR, the cross-clamp time was notably longer in the MIS-AVR approach than in standard AVR (70.6 ± 14.4 min compared to 51.6±8.2 min, respectively) [24]. The 3f valve is a freehand-sewn stentless valve, and longer duration of the operation can be explained by the tedious and complex implantation. On the other hand, this ensures optimal and safe positioning, and the 10-year follow-up of Christ et al. showed a very low rate of reoperation, proving the 3f valve to be a sustainable implant [25–28].

Study limitations

The limitations of the study are the small sample size (n=79), the uneven size of the subdivided groups, and the inhomogeneity of sex distribution. This article presents our initial experience with minimally invasive aortic valve replacement using bioprostheses with specific stentless or sutureless designs. The patients from different groups had not been matched; as an example, pure aortic valve regurgitation was not present in group C, as this is a contraindication for sutureless systems. However, according to EuroSCORE II, patients had a similar risk profiles.

Furthermore, this study only analyzed the short-term perioperative results and was conducted at a single hospital, in which a sutureless valve program had just been established.

Conclusions

In conclusion, MIS-AVR can be safely performed with all types of bioprostheses. Good performance concerning intra- and perioperative results, hemodynamic performance, and low complication rates were achieved. Overall, our findings show the benefit of reduced operating time and associated reduced postoperative complications and morbidity for low- to medium-risk patients with severe aortic stenosis and regurgitation. Furthermore, individual results of high-risk and terminally ill patients may open new doors for treatment with advanced sutureless and stented valves. There is a clear trend towards the feasibility and intraoperative risk reduction of sutureless implants, but this needs to be verified in larger randomized multi-center studies.

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Disclosure statement

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