

# Sutureless bioprosthesis for aortic valve replacement: surgical and clinical outcomes

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## Abstract

Aortic valve stenosis is the most common adult valve disease in industrialized countries. The ageing population and the increase in comorbidities urge the development of safer alternatives to the current surgical treatment. Sutureless bioprosthesis have shown promising results, especially in complex procedures and in patients requiring concomitant surgeries. **Objectives:** Assess the clinical and hemodynamic performance, safety, and durability of the Perceval<sup>®</sup> prosthetic valve. **Methods:** This single center retrospective longitudinal cohort study collected data of all adult patients with aortic valve disease who underwent aortic valve replacement with a Perceval<sup>®</sup> prosthetic valve between February 2015 and October 2020. Of the 196 patients included (mean age 77.20±5.08 years; 45.4% female; mean EuroSCORE II 2.91±2.20%), the majority had aortic stenosis. **Results:** Overall mean cross-clamp and cardiopulmonary bypass times were 33.31±14.09 and 45.55±19.04 minutes, respectively. Mean ICU and hospital stay were 3.32±3.24 and 7.70±5.82 days, respectively. Procedural success was 98.99%, as two explants occurred. 4 valves were reimplanted due to intra-operative misplacement. Mean transvalvular gradients were 7.82±3.62 mmHg. Pacemaker implantation occurred in 12.8% of patients, new-onset atrial fibrillation in 21.9% and renal replacement support was necessary in 3.1%. Early mortality was 2.0%. We report no structural valve deterioration, strokes or endocarditis and one successfully treated valve thrombosis. **Conclusions:** Our study confirms the excellent clinical and hemodynamic performance and safety of a truly sutureless aortic valve, up to 5-year follow-up. These results were consistent in isolated and concomitant interventions, solidifying this device as a viable option for treatment of isolated aortic valve disease.

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## Abstract

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**Objectives:** Assess the clinical and hemodynamic performance, safety, and durability of the Perceval<sup>®</sup> prosthetic valve.

**Methods:** This single center retrospective longitudinal cohort study collected data of all adult patients with aortic valve disease who underwent aortic valve replacement with a Perceval<sup>®</sup> prosthetic valve between February 2015 and October 2020. Of the 196 patients included (mean age  $77.20 \pm 5.08$  years; 45.4% female; mean EuroSCORE II  $2.91 \pm 2.20\%$ ), the majority had aortic stenosis.

**Results:** Overall mean cross-clamp and cardiopulmonary bypass times were  $33.31 \pm 14.09$  and  $45.55 \pm 19.04$  minutes, respectively. Mean ICU and hospital stay were  $3.32 \pm 3.24$  and  $7.70 \pm 5.82$  days, respectively. Procedural success was 98.99%, as two explants occurred. 4 valves were reimplanted due to intra-operative misplacement. Mean transvalvular gradients were  $7.82 \pm 3.62$  mmHg. Pacemaker implantation occurred in 12.8% of patients, new-onset atrial fibrillation in 21.9% and renal replacement support was necessary in 3.1%. Early mortality was 2.0%. We report no structural valve deterioration, strokes or endocarditis and one successfully treated valve thrombosis.

**Conclusions:** Our study confirms the excellent clinical and hemodynamic performance and safety of a truly sutureless aortic valve, up to 5-year follow-up. These results were consistent in isolated and concomitant interventions, solidifying this device as a viable option for treatment of isolated aortic valve disease.

## Keywords

Sutureless bioprosthesis; Aortic valve replacement; Perceval valve; Aortic valve stenosis; Aortic valve disease.

## Introduction

Aortic valve stenosis is the most frequent type of adult valvular heart disease in industrialized countries (1). Its prevalence increases with age with up to 9.8% in the 80–89 year cohort (2) (3).

Conventional aortic valve replacement (AVR) through median sternotomy is the established gold-standard for the treatment of severe and/or symptomatic disease in patients with low-surgical risk(4). However, the continuous increase in patients age (5) and comorbidities, the growing percentage of patients who need concomitant surgical procedures, combined to the fact that the duration of aortic cross-clamping and cardiopulmonary bypass (CPB) are independent predictors of survival (6), (7), have created the need for interventions that minimize operative times and reduce surgical risk.

Sutureless bioprosthesis has emerged as a viable alternative combining the best of both worlds. By avoiding sutures, it allows reduced aortic cross-clamping, CPB and global surgical times, as well as the possibility of complete excision of the native aortic valve and annular calcification, helping prevent paravalvular leaks, which is particularly useful in patients with severe aortic stenosis and an intermediate to high operative risk (8,9). Sutureless bioprostheses are especially beneficial in 1) patients who are more sensitive to ischemia; 2) in technically difficult procedures (such as small and/or highly calcified aortic roots, reoperations and in patients who require concomitant procedures) (10); 3) in patients with a high risk of patient-prosthesis mismatch (PPM); and 4) in patients who require faster recovery. Furthermore, by avoiding stitching through the annulus and suture knotting, the risk of tearing the aortic annulus and wall or embolizing foreign material is reduced (11). However, these advantages must be weighed against the apparent increased risk of PPI (Permanent Pacemaker Implantation) when compared to conventional AVR (12).

The Perceval<sup>®</sup> valve (Sorin Group, Saluggia, Italy) is currently the only truly sutureless valve available, with extensive research supporting its excellent hemodynamic performance, safety, and versatility of use. However, several questions remain unanswered, namely long-term survival and valve durability, risk of endocarditis, the impact of the apparent increased need for postoperative PPI and safety of concomitant valvular procedures (13).

Our study aims to analyze the clinical and hemodynamic performance, safety and durability of the Perceval valves implanted in patients with aortic valve disease, both in isolated AVR as well as in patients who underwent concomitant procedures, over a period of 5 years in a tertiary single European center.

# Materials and Methods

## Study design

In this retrospective longitudinal cohort study, data of all adult patients with aortic valve disease who underwent AVR with a Perceval<sup>®</sup> prosthetic valve between February 2015 and October 2020 in Hospital de Santa Maria (Lisbon, Portugal) was retrospectively collected from an available hospital database. Approval of the study and access to the data was granted by the ethical committee of the hospital involved (Comissão Ética Centro Hospitalar Lisboa Norte, identification number: 510/18).

## Patients

Data collected included demographics and preoperative characteristics, such as comorbidities, EuroSCORE II, presence of atrial fibrillation or pacemaker, left ventricular (LV) function and history of previous cardiac surgery. We also collected intraoperative data, such as the aortic cross-clamping and CPB times, size of the valves implanted and transvalvular gradients, as well as in-hospital stay and postoperative complications.

Endpoints were the clinical and hemodynamic performance, safety and durability of the Perceval valve in AVR, evaluated through the following criteria: mortality and overall long-term survival, structural valve deterioration, operatory times (aortic clamping and CPB times), mean ICU and total hospital stay, postoperative complications - including PPI and infection rates (respiratory, urinary and/or bacteremia of unknown origin), endocarditis, stroke, early mortality (defined as in-hospital or up to 30 days after surgery), abnormal bleeding (defined as  $> 2\text{ml/kg/h}$  in first 2-3 hours,  $> 1\text{ml/kg/h}$  in the next 3 hours and/or  $> 0.5\text{ml/kg/h}$  in 12 hours), new-onset atrial fibrillation (paroxysmal, persistent or permanent), significant renal dysfunction (14) and need for intra-aortic balloon pump, surgical exploration for bleeding, renal replacement support (performed through continuous veno-venous hemodiafiltration) or aminergic support  $> 24\text{h}$  (performed with at least one of the following: epinephrine, norepinephrine, dobutamine) - and postoperative echocardiographic findings.

## The Perceval<sup>®</sup> valve

The Perceval<sup>®</sup> prosthetic valve (Sorin Group, Saluggia, Italy) consists in 3 bovine pericardial cusps mounted on a self-expanding nitinol stent comprising two rings, allowing for stabilization simultaneously at the aortic annulus and at the sinotubular junction (STJ), and nine vertical struts covered by a thin coating of Carbofilm, to improve biocompatibility. The stent holds the valve in place without any permanent suture, by exerting radial force on the patient's aortic annulus and aortic root. It is also flexible, allowing it to adapt to the anatomy of the aorta and its movements, thus relieving the stress on the leaflets. The valve is folded up by collapsing the inflow and outflow rings with an atraumatic compression device, allowing the pericardial leaflets not to be crimped and remain mobile, ensuring they are not damaged (15) - in contrast to the necessary crimping of the TAVI, in which the leaflet's collagen fibers are damaged (10). The Perceval<sup>(r)</sup> valve is currently available in four sizes: S, to be implanted in annular sizes from 19 to 21 mm, M from 22 to 23 mm, L from 24 to 25 mm and XL for patients with annular sizes of 27 mm (6).

Although the concept of sutureless bioprosthesis exists for over 40 years (16), the first reports evaluating implantation feasibility and valve safety in humans were only released in 2007. It was CE approved in 2011 and FDA approved in 2016 (17).

## Surgical technique

Indications for AVR were in agreement with the ESC/EACTS Guidelines for the management of valvular heart disease at the time of the interventions (18). The surgical approach was either standard median sternotomy or upper J ministernotomy. All patients were operated on or supervised by an experienced surgeon

in this procedure. Anaesthetic and surgical techniques were standardized. A high transverse aortotomy close to the epiaortic fat pad was performed, leaving a free edge for closure after implantation of the device. The native calcified aortic valve was excised, and the aortic annulus completely decalcified. Sizing of the annulus was done using dedicated sizers.

Concomitant procedures were performed in line with current department practices and always with the goal of minimizing aortic cross-clamping and CPB times. For instance, aortic graft anastomosis, when needed, was performed prior to cannulation using tangential aortic cross-clamping.

After aortotomy closure in the usual fashion, thorough de-airing with CO<sub>2</sub>, release of the aortic cross-clamp and weaning from CPB were performed. Valve function was evaluated by intraoperative transesophageal echocardiography in all patients. Following the procedure, patients were transferred to the ICU and managed accordingly. Antiplatelet therapy was instituted. (19).

## Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics v27.1 (New York, United States of America). Categorical variables are reported as absolute and relative frequencies. For continuous data, means, median and standard deviations were calculated. Cumulative survival and freedom from events were estimated using the Kaplan–Meier method, with 95% confidence intervals.

## Results

### Preoperative characteristics

Between February 2015 and October 2020, 198 patients were submitted to AVR with a Perceval<sup>(r)</sup> prosthetic valve in Hospital de Santa Maria (Lisbon, Portugal). 2 patients were excluded due to valvular explantation, resulting in a total of 196 patients analyzed. Aortic stenosis was the main surgery indication (96.4%), followed by aortic regurgitation (1.53%), native valve endocarditis (1.02%), prosthetic valve endocarditis (0.51%) and mechanic valve dysfunction (0.51%).

Preoperative baseline characteristics of the cohort are shown in table 1. The mean overall age was 77.20±5.08 and 45.4% of patients were female. EuroSCORE II predicted an in-hospital mortality risk of 2.91 ± 2.20%. The most prevalent preoperative risk factors were impaired renal function (85.2%), arterial hypertension (88.3%), overweight or obesity (75.8%) and dyslipidemia (71.9%). Coronary disease was present in 34.7% of the cohort, atrial fibrillation in 17.9% and 8.7% had a history of stroke or transient ischemic attack. Most patients (69.4%) had preserved left ventricular function, defined as an ejection fraction higher than 55%.

Table 1 - Preoperative baseline characteristics and risk factors (mean ± Standard Deviation)

Patients	% (± SD)
<b>Demographics</b>	
Sex (female)	45.4
Age (in years)	77.20±5.08
EuroSCORE II	2.91±2.20
Preserved LV function (LVEF >55%)	69.4
<b>Risk Factors</b>	
Chronic Kidney Disease (CKD) <sup>1</sup>	85.2
Arterial Hypertension	88.3
Overweight/obesity <sup>2</sup>	75.8
Dyslipidemia	71.9
Diabetes Mellitus (DM)	41.8
DM Insulin treated	2.6
Coronary Artery disease	34.7

Atrial fibrillation/flutter	17.9
Smoking history <sup>3</sup>	18.9
Chronic Respiratory disease	14.3
Peripheral arterial disease	4,6
Previous stroke or transient ischemic attack	8,7
Preoperative Permanent Pacemaker	3.1
Previous cardiac surgery	2.0

<sup>1</sup> Impaired renal function was defined as glomerular filtration rate <85%

<sup>2</sup> Overweight/obesity was defined as a body mass index >25.

<sup>3</sup> Former or active.

### Intraoperative outcomes

Intraoperative outcomes of the cohort are shown in table 2. Overall mean total surgery time was 131.67±56.71 minutes, with mean aortic cross-clamping and CPB times of 33.31±14.09 minutes and 45.55±19.04 minutes, respectively. Of all surgeries, 15 (7.65%) were minimally invasive, via upper J mini-sternotomy.

The M size of Perceval<sup>®</sup> valve was the most frequently implanted prosthesis, accounting for 69 patients of the entire cohort (35.6%), followed by the size L in 64 patients (33.0%), XL in 35 (17.0%) and the size S in 28 (14.4%).

Isolated AVR was performed in 122 (62.24%) patients. Concomitant single CABG surgery was performed in 22 (11.22%) patients, double CABG surgery in 23 (11.73%) and triple CABG surgery in 4 (2.04%). Other concomitant procedures included mitral and/or tricuspid valvular repair/replacements in 12 patients (6.12%), Morrow procedure in 10 (5.10%), supracoronary ascending aorta replacement in 2 (1.02%) and Dor procedure in 1 (0.51%) patient. 2 patients (1.02%) had already undergone previous cardiac surgery.

The Perceval<sup>®</sup> valve was successfully implanted in 196 patients (98.98%), whereas in 2 cases (2/198 = 1.01%), conversion to conventional bioprosthesis (Edwards Perimount Magna Ease<sup>®</sup>) was required after valve explantation due to severe displacement. In 4 cases (2/196 = 2.04%) reimplantation was necessary to readjust the valve, due to misplacement/paravalvular leaks.

Table 2 - Intraoperative outcomes (mean ± SD)

Patients	Patients	n = 196	%
<b>Operatory data</b>	<b>Operatory data</b>		
Total surgery (minutes)	Total surgery (minutes)	131.67±56.71	
Cardiopulmonary bypass (minutes)	Cardiopulmonary bypass (minutes)	45.55±19.04	
Aorta cross-clamping (minutes)	Aorta cross-clamping (minutes)	33.31±14.09	
Valve size	Valve size		
S (n)	S (n)	28	14.4
M (n)	M (n)	69	35.6
L (n)	L (n)	64	33.0
XL (n)	XL (n)	35	17.0
<b>Intra-operative valve complications</b>	<b>Intra-operative valve complications</b>		
Reimplantation	Reimplantation	4	2.0
Significant paravalvular leaks <sup>1</sup>	Significant paravalvular leaks <sup>1</sup>	0	0.0

Operation Details	Operation Details		
Isolated aortic valve replacement	Isolated aortic valve replacement	122	62.24
+CABG x1	+CABG x1	22	11.22
+CABG x2	+CABG x2	23	11.73
+CABG x3	+CABG x3	4	2.04
+Mitral/Tricuspid Repair/Replacement	+Mitral/Tricuspid Repair/Replacement	12	6.12
+Morrow Miectomy	+Morrow Miectomy	10	5.10
+Ascending aorta replacement	+Ascending aorta replacement	2	1.02
+Dor procedure	+Dor procedure	1	0.51
Previous cardiac surgery	Previous cardiac surgery	2	1.02
Minimally Invasive Approach	Minimally Invasive Approach	15	7.65
Mean transvalvular gradients (mmHg)	Mean transvalvular gradients (mmHg)	7.82±3.62	

### Postoperative outcomes

Postoperative results are shown in table 3. The average ICU stay was 3.32±3.24 days and the average total hospital stay 7.70±5.82 days. Mean transvalvular gradients were 7.82±3.62 mmHg. 4 patients (2.04%) died, one due to refractory cardiogenic shock, two due to septic shock and multiorgan failure following urgent surgery for native valve endocarditis and one after neurologic complications related to an underlying type A aortic dissection.

The most common immediate postoperative complications over the entire cohort were the need for aminergic support for over 24 hours (45.1%), new-onset atrial fibrillation (21.9%), PPI (12.8%) and significant acute kidney injury (AKI) (10.5%). Less prevalent postoperative complications included infections (10.2%), abnormal bleeding (9.2%), renal replacement support (3.1%), early mortality (2.0%), intra-aortic balloon pump implantation (2.0%) and the need for surgical exploration for bleeding (1.0%).

During follow-up, no structural valve deterioration, strokes, or endocarditis were reported. One patient developed valve thrombosis (0.5%), which was successfully treated with oral anticoagulants. Figure 1 shows the overall Kaplan-Meier cumulative survival curve throughout 5 years. The survival rate at the end of 1 year was 94%, at 3 years 86% and 5 years 71%.

Table 3 – Postoperative outcomes (mean ± SD)

Patients	%
<b>In-hospital stay</b>	
ICU stay (days)	3.32±3.24
Hospital stay (days)	7.70±5.82
<b>Post-operative complications</b>	
Aminergic support >24h	45.1
New-onset Atrial fibrillation	21.9
PPI	12.8
Significant AKI	10.5
Infection	10.2
Abnormal bleeding	9.2
Renal replacement support	3.1
Early mortality	2.0

Intra-aortic balloon pump	2.0
Surgical exploration for bleeding	1.0
Valve thrombosis	0.5
Stroke	0.0
Endocarditis	0.0

ICU: intensive care unit  
PPI: Permanent pacemaker implantation  
AKI: acute kidney injury

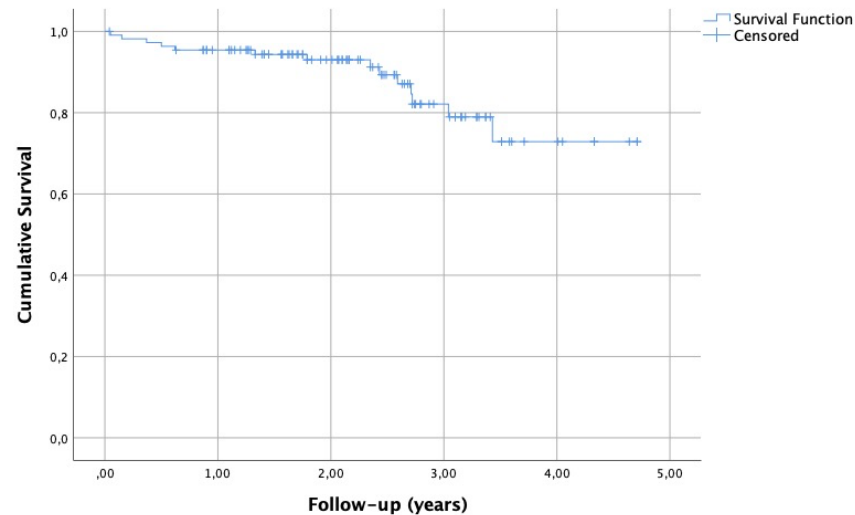


Figure 1 – Follow-up overall mortality (Kaplan–Meier survival curve)

Discussion

The Perceval<sup>®</sup> prosthetic valve (Sorin Group, Saluggia, Italy) has been increasingly used in European cardiac surgery centers for treatment of aortic valve disease since its first reports in 2007. As a truly sutureless bioprosthesis with proven excellent hemodynamic outcomes, safety and marked reduction in aortic cross-clamping and CPB times, it has been shown to reduced postoperative morbidity and mortality as well as cost reduction of up to 25% when compared to conventional biological heart valves (8,20), especially when treating older patients and in those with comorbidities. However, several questions are yet unanswered, especially regarding long-term durability, endocarditis risk, and the need for postoperative PPI.

In our retrospective study, we sought out to assess the clinical and hemodynamic performance, safety, and durability of the Perceval<sup>®</sup> valve for isolated AVR and in concomitant procedures.

Our cohort is composed essentially by elderly patients, with an average overall age of over 77 years and a small standard deviation of approximately 5 years. Additionally, most patients had one or more preoperative risk factors and/or comorbidity, with an average in-hospital mortality risk measured by an EuroSCORE II of almost 3%, despite the majority having preserved LV function.

The overall total surgical time, aorta cross-clamping and CPB times took into consideration the surgeries where reimplantation of the valve was necessary. The times obtained represent a significant reduction in comparison to the mean aorta cross-clamping and CPB times of 78 and 106 min reported in conventional AVR, according to the Society of Thoracic Surgeons database. This major reduction of over 50% in both

times could translate into improved clinical results, especially in patients with comorbidities such as diabetes mellitus (7) or in a medium-high surgical risk profile, as aortic clamping and CPB times are considered independent predictors of morbidity and mortality in heart surgery (10).

The Perceval<sup>®</sup> valve was successfully implanted in 98.99% as in 2 cases (2/198 = 1.01%) conversion to conventional bioprosthesis was required due to valve migration. One way of possibly reducing the likelihood of these events is by strictly obliging the manufacturer's preoperative echo-doppler aortic root evaluation recommendations (a patient is suitable if the ratio between the diameter of the STJ and the annular diameter is [?] 1,3) (21).

In 4 cases (2.04%) reimplantation was necessary to readjust the valve, due to minor misplacement and/or paravalvular leaks found in the intraoperative transesophageal echocardiography, which is paramount to assure correct placement and function. Reimplantation through the "x-movement" technique, allowed an "*en bloc*" bioprosthesis excision, simple re-folding and easy reimplantation of the valve without damage to the leaflets or the bioprosthesis structure. (22). Reasons for these misplacements are still unclear but in one of the cases, migration followed cardiac manual manipulation due to additional manual de-airing. (23).

In our study, we report no significant paravalvular leaks, a result below the already low 1-2% commonly observed in trials with the Perceval<sup>(r)</sup> valve (6). In comparison, TAVI causes a greater number of moderate-to-severe paravalvular leaks (7-12%), followed by conventional AVR (1,9%), which at 2 years have been shown to be independent predictors of mortality (10,24). Consequently, correct measurement, placement and final visual confirmation of correct valve placement could help avoid these complications.

The most common immediate postoperative complications (Table 3) were in line with the expected for a major cardiac procedure. The relatively high rate of postoperative aminergic support might be related to the fluid restriction protocol used in our department. New-onset atrial fibrillation is usually multifactorial and is the most common dysrhythmic complication occurring after any cardiac surgery, affecting typically between 30% and 50% of the patients, more than we report (25). Although the incidence of acute kidney injury is relatively high (10,5%), only a reduced number of patients required renal replacement technique (3,1%).

The overall incidence rate for PPI of 12.8% is within the interval incidence described in the literature, of 3.1% (26) to 17% (27) although it is above rates for conventional bioprosthesis reported of 3.0 to 11.8% (28) and comparable to the ones reported for TAVI (29). Current best available evidence suggests baseline conducting system disease is the most powerful independent predictor of PPI requirement following AVR. Other patient-related predictors are advanced age, annular calcification, (27). Operative-related factors such as incomplete decalcification of the aortic ring, valve oversizing, valve and guiding sutures position, reoperations, longer perioperative CPB time, and procedural implanting steps and sizing's learning curve effect are also important (13). In our center, all patients were operated on or supervised by an experienced surgeon in this procedure. That said, standardizing the implantation technique could offer benefits in reducing the PPI incidence.

We report one case of valvular thrombosis (0.51%), which was successfully treated with oral anticoagulants (Vitamin K antagonist). Following the procedure, all patients received antiplatelet treatment according to the standard protocol in use in our center, consisting of acetylsalicylic acid or clopidogrel for a period of 3 to 6 months when sinus rhythm was present. Antiplatelet and anticoagulation management after sutureless valve placement is not standardized, as no specific recommendations have been made in recent guidelines (17).

We found no structural valve deterioration, endocarditis cases or strokes up to the 5-year follow-up, presumably because the Perceval<sup>(r)</sup> valve allows less manipulation of the aortic root and annulus, zero permanent contact with foreign material such as sutures (13) and it has been shown to present high resistance against endocarditis in comparison with conventional prostheses. Nevertheless, 5 years of follow-up is still a short time compared to the data available for conventional prostheses of up to 25 years (30).

The mean postoperative transvalvular gradients after surgery confirm the excellent hemodynamic perfor-



mance of the Perceval<sup>(r)</sup> valve, coherent with other studies (6) and significantly lower when compared to the ones provided by conventional prostheses (28) and TAVIs (29).

ICU and total in-hospital stay were markedly lower when compared to reports of conventional bioprostheses (31) and similar when compared to TAVIs (29).

Early overall mortality (in-hospital or up to 30 days after surgery) was 2.0%, below the one predicted by the initial EuroSCORE, in line with the 2.8% reported for conventional prostheses and significantly lower than with TAVIs (10,30,32,33). Of the four patients who died, none of their deaths was caused directly from a failure in the prosthetic valve or the procedure themselves (cardiogenic and septic shock, neurological complications). These results show good short-term clinical outcomes despite the risk profile and advanced age of the cohort.

Overall cumulative survival at 1, 3 and 5 years and the correspondent Kaplan-Meier curve are the ones expected taking into consideration our cohort's age, comorbidities, and type of interventions. It is up to par with the mean corresponding cumulative survival of conventional AVR (34) and better than with TAVIs up to 2 years (29), showing safety of use and good mid-term durability, with no structural valve deterioration.

Additionally, the Perceval<sup>(r)</sup> valve enables standardization and simplification of MIS approaches, in a way conventional prostheses have not yet made possible. MIS is associated with a significant technical difficulty due to reduced visualization that increases aortic cross-clamping and CPB time, extending the learning curve (10).

## Conclusions

All patients with indication for AVR with a biological bioprosthesis could potentially benefit from a shorter and easily reproducible treatment. This seems to be especially beneficial in patients more sensitive to ischemia, technically difficult procedures, patients with a high risk of PPM, and patients who require faster recovery.

Our study further confirms the excellent clinical and hemodynamic performance and safety of the Perceval<sup>(r)</sup> valve, a truly sutureless aortic prosthesis, in a moderately large cohort of patients, even up to the 5-year follow-up. Consistent with current literature, the Perceval<sup>(r)</sup> valve allowed reduced aortic cross-clamping, CPB and surgical times due to its easy and rapid implantation technique as well as low rates of mortality, complications, or dysfunctions early and up to 5 years, even in our cohort of mostly older patients with comorbidities. Additionally, it has been proven to facilitate the reproducibility and resurgence of minimally invasive approaches, reducing additional postoperative complications.

## Bibliography

1. Carrel T, Heinisch PP. History, development and clinical perspectives of sutureless and rapid deployment surgical aortic valve replacement. *Ann Cardiothorac Surg*. 2020 Sep;9(5):375–85.
2. Joseph J, Naqvi SY, Giri J, Goldberg S. Aortic Stenosis: Pathophysiology, Diagnosis, and Therapy. *Am J Med*. 2017 Mar 1;130(3):253–63.
3. Kanwar A, Thaden JJ, Nkomo VT. Management of Patients With Aortic Valve Stenosis. *Mayo Clin Proc*. 2018 Apr;93(4):488–508.
4. Bilku R, Borger MA, Briffa NP, Jahangiri M. Sutureless aortic valve prostheses. *Heart Br Card Soc*. 2019 Mar;105(Suppl 2):s16–20.
5. Barnhart GR, Shrestha ML. Current Clinical Evidence on Rapid Deployment Aortic Valve Replacement. *Innov Phila Pa*. 2016 Jan;11(1):7–14.

6. Shrestha M, Fischlein T, Meuris B, Flameng W, Carrel T, Madonna F, et al. European multicentre experience with the sutureless Perceval valve: clinical and haemodynamic outcomes up to 5 years in over 700 patients. *Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg*. 2016 Jan;49(1):234–41.
7. Ranucci M, Frigiola A, Menicanti L, Castelveccchio S, de Vincentiis C, Pistuddi V. Aortic cross-clamp time, new prostheses, and outcome in aortic valve replacement. *J Heart Valve Dis*. 2012 Nov;21(6):732–9.
8. Desser AS, Arentz-Hansen H, Fagerlund BF, Harboe I, Lauvrak V. Sutureless Aortic Valve Replacement for Treatment of Severe Aortic Stenosis: A Single Technology Assessment of Perceval Sutureless Aortic Valve.
9. Mazine A, Bonneau C, Karangelis D, Yanagawa B, Verma S, Bonneau D. Sutureless aortic valves: who is the right patient? *Curr Opin Cardiol*. 2017 Mar;32(2):130–6.
10. Martinez-Comendador J, Castano M, Gualis J, Martin E, Maiorano P, Otero J. Sutureless aortic bio-prosthesis. *Interact Cardiovasc Thorac Surg*. 2017 Jul 1;25(1):114–21.
11. Folliguet TA, Laborde F, Zannis K, Ghorayeb G, Haverich A, Shrestha M. Sutureless Perceval Aortic Valve Replacement: Results of Two European Centers. *Ann Thorac Surg*. 2012 May 1;93(5):1483–8.
12. Flynn CD, Williams ML, Chakos A, Hirst L, Muston B, Tian DH. Sutureless valve and rapid deployment valves: a systematic review and meta-analysis of comparative studies. *Ann Cardiothorac Surg*. 2020 Sep;9(5):36474–36374.
13. Pfeiffer S, Fischlein T, Santarpino G. Sutureless Sorin Perceval Aortic Valve Implantation. *Semin Thorac Cardiovasc Surg*. 2017 Spring;29(1):1–7.
14. Lopes, J. A. & Jorge, S. The RIFLE and AKIN classifications for acute kidney injury: a critical and comprehensive review. *Clin. Kidney J*. **6** , 8–14 (2013).
15. Sangani NK, Suri RM. Sutureless Aortic Valve Implantation. *Oper Tech Thorac Cardiovasc Surg*. 2013;18(4):288–304.
16. Totaro P, Nicolardi S, Zattera G, Vigano M. Old prosthesis with a modern concept: 41-year survival with a sutureless Magovern-Cromie aortic valve prosthesis. *Eur J Cardio-Thorac Surg Off J Eur Assoc Cardio-Thorac Surg*. 2011 May;39(5):789.
17. Sian K, Li S, Selvakumar D, Mejia R. Early results of the Sorin(r) Perceval S sutureless valve: systematic review and meta-analysis. *J Thorac Dis*. 2017 Mar;9(3):711–24.
18. Baumgartner H, Falk V, Bax JJ, De Bonis M, Hamm C, Holm PJ, et al. 2017 ESC/EACTS Guidelines for the management of valvular heart disease. *Eur Heart J*. 2017 Sep 21;38(36):2739–91.
19. Heimansohn D, Moainie S. Aortic Valve Replacement Using a Perceval Sutureless Aortic Bioprosthesis. *Oper Tech Thorac Cardiovasc Surg*. 2016 Dec 1;21(4):282–305.
20. Pollari F, Santarpino G, Dell’Aquila AM, Gazdag L, Alnahas H, Vogt F, et al. Better short-term outcome by using sutureless valves: a propensity-matched score analysis. *Ann Thorac Surg*. 2014 Aug;98(2):611–6; discussion 616–617.
21. LisaNova O. PERCEVAL(r) and PERCEVAL(r) PLUS Pre-operative Echo-Doppler AORTIC ROOT HEIGHT EVALUATION.
22. Di Bacco L, Pfeiffer S, Fischlein TJM, Santarpino G. Rapid Explantation of Rapid-Deployment Sutureless Valve in Case of Acute Endocarditis: How to Remove Safely Sutureless Perceval S Prostheses. *Innovations*. 2017 Nov 1;12(6):483–5.
23. Svenarud P, Persson M, van der Linden J. Effect of CO<sub>2</sub> Insufflation on the Number and Behavior of Air Microemboli in Open-Heart Surgery: A Randomized Clinical Trial. *Circulation*. 2004 Mar 9;109(9):1127–32.

24. Kodali SK, Svensson LG, Fontana GP, Pichard AD, Lim S, Malaisrie SC, et al. Two-Year Outcomes after Transcatheter or Surgical Aortic-Valve Replacement. *N Engl J Med*. 2012;10.
25. Chivasso P, Marsico R, Domenico V. Atrial Fibrillation after Cardiac Surgery: Where are we Now? 2018;4.
26. Flameng W, Herregods M-C, Hermans H, Van der Mieren G, Vercalsteren M, Poortmans G, et al. Effect of sutureless implantation of the Perceval S aortic valve bioprosthesis on intraoperative and early postoperative outcomes. *J Thorac Cardiovasc Surg*. 2011 Dec;142(6):1453–7.
27. Mazine A, Teoh K, Bouhout I, Bhatnagar G, Pelletier M, Voisine P, et al. Sutureless aortic valve replacement: a Canadian multicentre study. *Can J Cardiol*. 2015 Jan;31(1):63–8.
28. Thalji NM, Suri RM, Michelena HI, Greason KL, Dearani JA, Daly RC, et al. Do differences in early hemodynamic performance of current generation biologic aortic valves predict outcomes 1 year following surgery? *J Thorac Cardiovasc Surg*. 2015 Jan;149(1):163-173.e2.
29. Meco M, Miceli A, Montisci A, Donatelli F, Cirri S, Ferrarini M, et al. Sutureless aortic valve replacement versus transcatheter aortic valve implantation: a meta-analysis of comparative matched studies using propensity score matching. *Interact Cardiovasc Thorac Surg*. 2018 Feb 1;26(2):202–9.
30. Bourguignon T, Bouquiaux-Stablo A-L, Candolfi P, Mirza A, Loardi C, May M-A, et al. Very long-term outcomes of the Carpentier-Edwards Perimount valve in aortic position. *Ann Thorac Surg*. 2015 Mar;99(3):831–7.
31. Mujtaba SS, Ledingham SM, Shah AR, Pillay T, Schueler S, Clark S. Aortic Valve Replacement with a Conventional Stented Bioprosthesis versus Sutureless Bioprosthesis: a Study of 763 Patients. *Braz J Cardiovasc Surg* [Internet]. 2018 [cited 2021 May 4];33(2). Available from: <https://bjcv.org/pdf/2859/v33n2a04.pdf>
32. Hamm CW, Mollmann H, Holzhey D, Beckmann A, Veit C, Figulla H-R, et al. The German Aortic Valve Registry (GARY): in-hospital outcome. *Eur Heart J*. 2014 Jun 21;35(24):1588–98.
33. Brown JM, O'Brien SM, Wu C, Sikora JAH, Griffith BP, Gammie JS. Isolated aortic valve replacement in North America comprising 108,687 patients in 10 years: changes in risks, valve types, and outcomes in the Society of Thoracic Surgeons National Database. *J Thorac Cardiovasc Surg*. 2009 Jan;137(1):82–90.
34. Schwarz F, Baumann P, Manthey J, Hoffmann M, Schuler G, Mehmel HC, et al. The effect of aortic valve replacement on survival. *Circulation*. 1982 Nov;66(5):1105–10.
35. Shrestha M, Folliguet TA, Pfeiffer S, Meuris B, Carrel T, Bechtel M, et al. Aortic valve replacement and concomitant procedures with the Perceval valve: results of European trials. *Ann Thorac Surg*. 2014 Oct;98(4):1294–300.