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# Risk Predictors for Long-Term Outcomes in Patients Undergoing REDO Isolated Aortic Valve Replacement with Sutureless Versus Sutured Bioprosthesis

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## Abstract

**Objective:** Long-term clinical outcomes in patients undergoing redo aortic valve replacement with sutured (SAVR) and sutureless aortic bioprosthesis remain hindered. We sought to evaluate risk predictors that influence survival after redo-SAVR versus redo-sutureless Aortic Valve Replacement (AVR).

**Methods:** All consecutive 82 patients undergoing isolated redo-AVR with either SAVR or sutureless bioprosthesis between 08/2010-03/2020 at our institution were included. Patients with concomitant procedures were excluded from the analysis. Primary outcome was analyses of long-term all-cause mortality. A propensity-adjusted analysis was used to compare groups. Kaplan-Meier were constructed to evaluate long-term survival.

**Results:** Preoperatively, redo-SAVR (n=57) and redo-sutureless (n=25) patients baseline characteristics were compared. Mean age was 67.2 *vs*. 68.5-year-old and mean Euroscore II 11% *vs*. 7.5%, in redo-SAVR *vs*. redo-sutureless, respectively. Intraoperatively, redo-SAVR experienced a higher cardiopulmonary (p=0.23) and aortic cross-clamp time (p=0.002) compared to redo-sutureless group. Postoperatively, only new incidence of Atrial Fibrillation (POAF) was higher in redo-SAVR group. Primary outcome of all-cause death at 5-years follow-up was redo-SAVR 7/57 (12.2%) *vs*. redo-sutureless 2/25 (8%), p=0.82; (HR 1.3 [0.2, 7.5]). New risk predictors for mortality in patients undergoing redo-SAVR included body mass index ≥ 30 kg/m$^2$ HR (1.21 [1.04, 1.5]), and tobacco use HR (11.1 [1.1, 112.3]).

**Conclusion:** Patients undergoing redo-SAVR experienced a higher incidence of POAF compared to patients undergoing redo sutureless valves. There were no differences on long-term all-cause death among groups.

**Keywords: Sutureless; Aortic valve replacement; Reoperation; Sutured bioprosthesis; Long-term outcomes**

## Key-Points

1) Understanding risk factors impacting in long-term prognosis in patients undergoing redo-AVR with SAVR or sutureless bioprosthesis may improve clinical outcomes.

2) Management of POAF after redo-AVR may improve in-hospital prognosis.

## Introduction

Landmark clinical trials describing the utilization of sutureless aortic bioprosthesis [1] for Aortic Valve Replacement (AVR) evidenced that this prosthesis provide a short aortic cross-clamp and cardiopulmonary bypass time. In this context, meta-analysis and review studies have shown both

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benefits and [2,3] drawbacks of sutured and sutureless bioprosthesis including valve degeneration, pacemaker implantation and repeat intervention.

With technical advancement the sutureless bioprosthesis have been proven to be adaptable in redo-interventions by decreasing the operating time and overall, in-hospital complications rate [3]. While this is true to some extent, there is an ongoing debate on which bioprosthesis better fits an individual patients' profile in redo interventions.

The Pivot, Pivotal and CAVALIER clinical trials showed that sutureless valves outcomes had a lower incidence of periprocedural complications and suitable for elderly patients [1,4,5].

The goal of this study is to analyze risk predictors that impact long-term prognosis in patients undergoing repeat isolated repeat intervention for isolated AVR with bioprosthesis.

## Methods

### Study population

We identified all patients who underwent redo-AVR with either Sutured AVR (SAVR) and sutureless bioprosthesis between September 2005 and December 2020 at University of Florence, Italy. The study protocol was approved by the Institutional Review Board (IRB 2348IT). Patient individual consent was waived due to the retrospective nature of the study. Consecutive patients that underwent isolated AVR were included in the study. Patients with a concomitant procedure were excluded from the study. Patients were identified *via* operation codes in a digital operation registry, as well as from a centralized cardiac surgery database for all operations. In this database, the underlying in-hospital outcomes were recorded from the charts and death certificate made out by the responsible doctor.

### In-hospital and patients follow-up

During the entire hospital stay, patients were monitored by continuous five-lead telemetry, and atrial rhythm changes were detected from the computer and from the ward nurses and doctors. A standard 12-lead Electrocardiogram (ECG) was routinely performed on postoperative days 1, 2 and 5, and more often if an arrhythmia was detected. Episodes of arrhythmia were noted on patient surveillance charts and assessed twice daily and at discharge by the heart surgeon responsible for the case. All patients had at least one follow-up time point available. Follow-up was done at our outpatient's clinic and from the hospital registry. In case the patient did not present in the follow-up appointment we contacted the referring cardiologist to obtain follow-up clinical data.

### Primary and secondary goals and definitions

The main goal of this study is to identify risk predictors for mortality and analyze their impact on long-term prognosis in patients undergoing redo-AVR with SAVR and sutureless bioprosthesis. Primary outcome was analyses of long-term outcomes all-cause mortality. Clinical definitions are included in supplemental document 1. Covariates, exposures are included in a supplemental document 2. Patients were selected according to VARC 3 criteria [6]. Postoperative Atrial Fibrillation (POAF) was defined as an ECG-verified episode lasting more than 1-min during the entire hospital Length of Stay (LOS).

### Statistical analysis for propensity-adjusted analysis

Groups were compared by one way ANOVA for continuous variables and chi-square test of independence for categorical variables. Propensity-adjusted scores were calculated *via* a multiple logistic regression model with redo-SAVR *vs*. redo-sutureless, as the outcome in the model and preoperative variables as independent variables. Because of the small sample size, not all preoperative variables could be included in the propensity score model. Variables included were age, gender, Body Mass Index (BMI), Euroscore II, NYHA, hypertension, dyslipidemia, Chronic Obstructive Pulmonary Disease (COPD), prior stroke, Peripheral Vascular Disease (PVD), aortic stenosis, smoke, Ejection Fraction (EF), chronic dialysis, Coronary Artery Disease (CAD), and STEMI within the last 90 days. The purpose of propensity-adjusting method is to reduce bias, including residual confounding, and has been shown to reduce allocation biases. Propensity-adjustment was used for postoperative and long-term outcomes *via* linear and logistic regression models with redo-sutureless as the reference and propensity scores as covariates. To illustrate the effect of prosthesis choice on long-term survival, Kaplan–Meier cumulative curves were constructed and compared by log-rank test. All-cause mortality was compared between surgical groups with a Cox proportional hazard ratio and the propensity score plus age as covariates. A sensitivity analysis was done using redo-sutureless status as a time-dependent variable in a series of covariate-adjusted Cox proportional hazards regression models for all-cause mortality and the falsification end points using variables from the propensity model as covariates. This analysis allowed inclusion of patients who died within the first 30-days of surgery and was performed to account for possible immortal time bias. Finally, preoperative risk factors for each surgical group were determined by building Cox proportional hazard ratios *via* backward selection and compared by AIC. All analyses were performed in Stata 17.0 (Statacorp, LLC. College Station, TX). 95% confidence intervals and p-values are reported with a p-value <0.05 considered significant.

### Propensity-adjustment significance compared to propensity-score matching

Propensity-matching provides excellent matching before the analysis, while the propensity-adjustment accounts for biases during the analysis. Therefore, while seeing significant differences between preoperative variables, these differences are adjusted during the modeling process. Propensity-matching reduces the size of the groups while propensity-adjustment maintains the sample size of the groups. As shown by multiple studies [7], propensity-adjustments provides similar or better adjustment for biases when compared to propensity-matching because of the retainment of the sample size which increases the statistical power of the analysis and is particularly suitable for smaller sample sizes. In addition, the propensity-matched analysis bears allocation biases which are not present in the propensity-adjusted analysis.

### Valve design

The sutureless valve system consists of a tissue component made from bovine pericardium 163 and a self-expandable Nitinol stent, which has the dual role of supporting the valve and fixing it 164 in place. Prior to implantation the prosthesis diameter is reduced to a suitable size for loading it 165 on the holder. The valve is then positioned and released in the aortic root, where the stent design 166 and its ability to apply a radial force to the annulus allow stable anchoring of the device. The 167 handled delivery system includes the balloon catheter for expansion of the frame in the left 168 ventricular outflow tract, securing the valve in a supra-annular position.

### Surgical procedure for redo AVR using sutureless bioprosthesis

We perform full sternotomy using the sutureless bioprosthesis replacement. In addition, we perform standard central aortic and right atrial venous cannulation. After the institution of on-pump we cross-clamp the aorta and deliver antegrade and retrograde cardioplegia. We than open the aorta and remove the prosthetic valve with an adequate removal of annular calcification and debridement. We than implant the valve at the annulus level and balloon it with 2.5 ATM (as demonstrated by Yanagawa et al. [8]. After correct valve deployment and testing we close the aorta in standard fashion.

## Results

### Preoperative characteristics

Preoperative characteristics were similar among groups (Table 1). Mean age was 67.2-years old in the redo-SAVR *vs.* 68.5-years old in the redo-sutureless group, respectively. In addition, male population included 50.9% *vs.* 68% in the redo-SAVR *vs.* redo-sutureless bioprosthesis groups while mean EuroScore II values were 11% *vs.* 7.5% in the redo-SAVR *vs.* redo-sutureless, groups.

**Table 1:** Preoperative characteristics.

| Variables | SAVR n=57 | Redo-Sutureless n=25 | p-value |
|---|---|---|---|
| **Age years (mean/SD)** | 67.2 (14.1) | 68.5 (8.3) | **<0.001** |
| **Gender n(%)** | | | 0.353 |
| Female n(%) | 28 (49.1%) | 8 (32.0%) | |
| Male n(%) | 29 (50.9%) | 17 (68.0%) | |
| **Classification of Intervention** | | | **0.001** |
| Elective n(%) | 39 (68.4%) | 15 (60.0%) | |
| Urgent n(%) | 18 (31.6%) | 10 (40.0%) | |
| Euroscore II (Mean/SD) | 11.0 (9.3) | 7.5 (6.0) | 0.088 |
| Euroscore >7 (Yes) n(%) | 33 (57.9%) | 10 (40.0%) | 0.305 |
| **NYHA Functional Classification n(%)** | | | 0.015 |
| Class I n(%) | 0 (0.0%) | 0 (0.0%) | |
| Class II (Mild) n(%) | 5 (8.8%) | 6 (24.0%) | |
| Class III (Moderate) n(%) | 47 (82.5%) | 17 (68%) | |
| Class IV (Severe) n(%) | 5 (8.8%) | 2 (8.0%) | |
| BMI kg/m$^2$ (Mean/SD) | 27.8 (6.3) | 28.0 (5.6%) | 0.28 |
| Obese ≥ 30 kg/m$^2$ n (%) | 16 (28.1%) | 8 (32.0%) | 0.766 |
| **Creatine level (Median/IQR)** | 92 (79-109) | 82 (73-107.5) | **<0.001** |
| Dialysis n(%) | 13 (22.8%) | 6 (24.0%) | **0.006** |
| Tobacco Use n(%) | 23 (40.3%) | 12 (48.0%) | 0.115 |
| COPD n(%) | 10 (17.5%) | 5 (20.0%) | 0.93 |
| HTN n(%) | 47 (82.5%) | 18 (72.0%) | 0.203 |
| Dyslipidemia n(%) | 42 (73.7%) | 19 (76.0%) | 0.339 |
| CAD n(%) | 23 (40.3%) | 17 (68.0%) | 0.001 |
| PVD n(%) | 22 (38.6%) | 10 (40.0%) | 0.479 |
| Diabetes n(%) | 16 (28.1%) | 8 (32.0%) | 0.726 |
| Stroke n(%) | 18 (31.6%) | 8 (32.0%) | 0.254 |
| Permanent Pacemaker n(%) | 5 (8.8%) | 1 (4.0%) | **0.024** |
| Aortic Stenosis n(%) | 31 (54.4%) | 17 (68.0%) | 0.232 |
| Atrial Fibrillation n(%) | 17 (29.8%) | 2 (8.0%) | 0.032 |
| Primary AVR operation combined (Yes) n(%) | 25 (43.9%) | 9 (36.0%) | 0.801 |
| Bicuspid Valve (Yes) n(%) | 22 (39.3%) | 5 (20.0%) | 0.029 |
| Associated CABG (Yes) n(%) | 10 (17.5%) | 8 (32.0%) | 0.199 |
| Associated Mitral Valve (Yes) n(%) | 6 (10.5%) | 0 (0.0%) | 0.138 |
| Associated Tricuspid Valve (Yes) n(%) | 1 (1.7%) | 0 (0.0%) | 0.609 |
| Associated Ascending/Hemi/ Total Arch (Yes) n(%) | 7 (12.3%) | 2 (8.0%) | 0.829 |
| Bentall (Yes) n(%) | 2 (3.5%) | 1 (4.0%) | 0.988 |
| EF% (mean/SD) | 50.5 (12.8) | 54.2 (10.6) | 0.302 |
| EF<50% n(%) | 15 (26.3%) | 4 (16.0%) | 0.046 |
| Platelet count (Mean/SD) | 193.0 (60.5) | 201.3 (65.7) | 0.318 |
| Warfarin Therapy (Yes) n(%) | 10 (17.5%) | 0 (0.0%) | 0.084 |
| Antiplatelet Therapy (Yes) n(%) | 47 (82.5%) | 19 (76.0%) | 0.182 |
| **Aortic Valve Peak Gradient** | | | 0.058 |
| Mild (<=50 mmHg) | 19 (33.3%) | 8 (32.0%) | |
| Moderate (<=75 mmHg) | 17 (29.8%) | 7 (28.0%) | |
| Severe (>75 mmHg) | 21 (36.8%) | 10 (40.0%) | |
| Aortic Valve Max Gradient mmHg (Mean/SD) | 65.6 (32.1) | 67.9 (26.1) | 0.014 |
| Aortic Valve Mean Gradient mmHg (Mean/SD) | 39.5 (20.3) | 39.0 (17.4) | 0.061 |
| Vmax m/s (Mean/SD) | 3.8 (0.99) | 3.8 (0.90) | 0.041 |

NYHA class: New York Heart Association class; BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; HTN: Hypertension; CAD: Coronary Artery Disease; PVD: Peripheral Vascular Disease; CABG: Coronary Artery Bypass Grafting; EF: Ejection Fraction; Vmax: Maximal Velocity

**Table 2:** Intraoperative characteristics.

| Intra-operative Variables | SAVR n=57 | Redo-Sutureless n=25 | p-value |
|---|---|---|---|
| Trace/Mild Paravalvular Leak n(%) | 0 (0.0%) | 1 (4.2%) | **<0.001** |
| Cardiopulmonary Bypass Time (min) (Mean/SD) | 109 (40.9) | 87.4 (38.9) | **0.023** |
| Aortic Cross-Clamp Time (min) (Mean/SD) | 88.3 (34.4) | 62.5 (29.4) | **0.002** |
| Intra-aortic Balloon Pump n(%) | 1 (1.7%) | 1 (4.0%) | 0.529 |

### Intraoperative outcomes

Intraoperatively, aortic cross-clamp time 88.3 (± 34.4) *vs.* 62.5 (± 29.4) minutes and cardiopulmonary bypass time 109 (± 40.9) *vs.* 87.4 (± 38.9) minutes was higher in the redo-SAVR group compared to the redo sutureless group, respectively (Table 2).

### Postoperative and long-term clinical outcomes

Postoperatively, the redo-SAVR group had a higher incidence of Postoperative Atrial Fibrillation (POAF) compared to the redo sutureless group (Table 3). Long-term outcomes and a double robust sensitivity analysis did not show differences among groups at 1-, 2-, 3- and 5- years follow-up (Tables 4-7 and Figure 1). Table 5 is a Cox proportional hazard regression with two models, the first is univariable and the second is propensity-adjusted. We are comparing redo-SAVR group with redo-sutureless AVR as the reference group.

### Risk predictors impacting long-term prognosis analysis

New risk predictors for mortality in patients undergoing redo SAVR included Body Mass Index (BMI) ≥ 30 kg/m$^2$ HR (1.21 [1.0, 1.5]), and tobacco use HR (11.1 [1.1, 112.8]) (Table 8).

**Table 3:** Postoperative outcomes.

| Prosthesis | | | | Propensity Score Adjusted | |
|---|---|---|---|---|---|
| | Redo SAVR n=57 | Redo Sutureless n=25 | p-value | Redo SAVR n=57 | p-value |
| **Post-operative Characteristics** | | | | **Adj. Mean Difference (95% CI)*** | |
| Intubation Time (hrs) (Mean/SD) | 34.3 (72.1) | 12.2 (14.6) | 0.014 | 20.0 (-7.4, 47.4) | 0.151 |
| ICU Time (hrs) (Mean/SD) | 79.3 (113.6) | 43.8 (54.7) | 0.005 | 21.2 (-23.5, 65.9) | 0.35 |
| Peak Creatinine (Median/IQR) | 96 (74-114) | 108 (75-141) | 0.567 | -20.2 (-66.1, 25.8) | 0.385 |
| EF % (mean/SD) | 47.3 (15.0) | 51.8 (7.6) | 0.169 | -2.8 (-10.0, 4.32) | 0.436 |
| Chest Tube Loss (ml) Median/IQR) | 410 (250-790) | 310 (235-525) | 0.269 | 206.8 (-64.4, 478.0) | 0.134 |
| Vmax m/s (Mean/SD) | 2.6 (0.6) | 2.6 (0.9) | 0.725 | -0.1 (-0.5, 0.3) | 0.749 |
| Gmed mmHg (Mean/SD) | 16.2 (7.3) | 15.5 (5.1) | 0.798 | 1.3 (-2.8, 5.4) | 0.531 |
| Hospital Length of Stay (Days) (Mean/SD) | 10.2 (8.2) | 11.2 (8.2) | <0.001 | -1.9 (-5.7, 1.95) | 0.336 |
| | | | | Adj. Odds Ratio (95% CI)* | |
| Repeat intubation n(%) | 5 (8.8%) | 2 (8.0%) | 0.242 | 1.0 (0.1, 6.9) | 0.997 |
| Readmission to ICU n (%) | 3 (5.3%) | 4 (16.0%) | 0.044 | 0.1 (0.02, 1.0) | 0.053 |
| Inotrope use n (%) | 54 (94.7%) | 24 (96.0%) | <0.001 | 0.8 (0.07, 9.3) | 0.877 |
| Norepinephrine use n (%) | 56 (98.2%) | 23 (92.0%) | <0.001 | 8.2 (0.6, 106.8) | 0.107 |
| Epinephrine use n (%) | 11 (19.3%) | 2 (8.0%) | 0.021 | 1.8 (0.3, 10.7) | 0.512 |
| Dobutamine use n (%) | 29 (50.9%) | 8 (32.0%) | 0.005 | 2.0 (0.7, 6.2) | 0.207 |
| MI n (%) | 6 (10.5%) | 1 (4.0%) | 0.129 | 0.99 (0.08. 11.78) | 0.995 |
| Renal Failure n (%) | 9 (15.8%) | 2 (8.0%) | 0.532 | 1.5 (0.3, 9.0) | 0.623 |
| Other Arrythmia n (%) | 13 (22.8%) | 0 (0.0%) | 0.017 | N/A | |
| Atrial fibrillation n (%) | 27 (47.4%) | 2 (8.0%) | <0.001 | 5.7 (1.0, 30.5) | **0.043** |
| Respiratory Failure n (%) | 11 (19.3%) | 2 (8.0%) | 0.021 | 3.5 (0.6, 21.3) | 0.175 |
| Stroke/TIA n (%) | 4 (7.0%) | 1 (4.0%) | 0.71 | 1.8 (0.1, 20.8) | 0.648 |
| Permanent Pacemaker n (%) | 5 (8.8%) | 1 (4.0%) | 0.515 | 4.0 (0.3, 47.2) | 0.265 |
| Reoperation for Bleeding n (%) | 9 (15.8%) | 4 (16.0%) | 0.062 | 1.6 (0.03, 7.8) | 0.553 |
| Infection n (%) | 5 (8.8%) | 1 (4.0%) | 0.204 | 3.9 (0.3, 47.9) | 0.287 |
| Hospital Mortality n (%) | 4 (7.0%) | 1 (4.0%) | 0.309 | 1.6 (0.1, 25.5) | 0.729 |
| Intra-operative Mortality n (%) | 1 (1.7%) | 0 (0.0%) | 0.609 | N/A | |
| EF < 50% n (%) | 25 (43.9%) | 7 (28.0%) | 0.079 | 1.5 (0.5, 4.6) | 0.481 |
| Paravalvular Regurgitation n (%) | 0 (0.0%) | 1 (4.0%) | <0.001 | N/A | |
| RBC Units n (%) | 38 (66.7%) | 12 (48.0%) | <0.001 | 1.7 (0.5, 5.1) | 0.369 |
| Platelet Units n (%) | 23 (40.3%) | 9 (36.0%) | <0.001 | 1.4 (0.4, 4.8) | 0.539 |
| Plasma Units n (%) | 21 (36.8%) | 6 (24.0%) | 0.001 | 1.1 (0.3, 3.9) | 0.843 |
| Intra-aortic Balloon Pump n (%) | 1 (1.7%) | 0 (0.0%) | 0.609 | N/A | |

ICU: Intensive Care Unit; MI: Myocardial Infarction; TIA: Transitory Ischemic Attack; EF: Ejection Fraction; RBC: Red Blood Cells; Vmax: Maximal Velocity; Gmed: Mean Gradient

# Discussion

## Summary

1. Redo SAVR group had a high incidence of POAF compared to redo-sutureless AVR group.

2. We found new risk predictors for long-term mortality including BMI and tobacco use.

## Comments

This analysis provided several novel insights in the fragile population of patients undergoing repat AVR. Firstly, POAF incidence was higher in the redo-SAVR group compared to redo-sutureless bioprosthesis implantation in patients undergoing isolated redo-AVR. Secondly, new predictors that impact long-term prognosis appear associated with each group including BMI and tobacco smoke. Based on the findings from this study we speculate that preoperative evaluation based on patient's individual risk factors profile can help in prosthesis and interventional choice. In addition, optimization of modifiable risk predictors may improve clinical outcomes including rhythm control for patients with preoperative atrial fibrillation is mandatory.

The sutureless bioprosthesis have made a significant advancement in the last decade and its design has been increasingly preferred as a treatment for qualified patients with aortic valve disease with aortic valve replacement [5,6,8,9]. In addition, they have proven its noninferiority when compared to other sutured prosthesis [10-13]. The strongest points of these valves include a) the favorable

**Table 4:** Univariate cox proportional hazard of long-term outcomes.

| Risk Factors | Redo SAVR | Redo sutureless |
|---|---|---|
| | HR (95% CI) | HR (95% CI) |
| Age (Years) | 1.02 (0.96, 1.08) | 1.09 (0.88, 1.34) |
| Gender (Female) | 0.84 (0.19, 3.77) | 2.38 (0.15, 38.22) |
| Euroscore II | 1.03 (0.96, 1.11) | 1.08 (0.92, 1.26) |
| NYHA | 0.39 (0.07, 2.29) | 0.48 (0.04, 6.14) |
| Dialysis | 1.23 (0.24, 6.33) | N/A |
| Tobacco use | 4.18 (0.81, 21.60) | 0.95 (0.06, 15.28) |
| COPD | **9.74 (2.14, 44.32)*** | 4.24 (0.26, 67.91) |
| Hypertension | 1.36 (0.16, 11.35) | 0.38 (0.02, 6.11) |
| Dyslipidemia | 0.91 (0.18, 4.70) | N/A |
| Coronary Artery Disease | 1.91 (0.43, 8.55) | 0.63 (0.04, 10.3) |
| PVD | 0.60 (0.12, 3.10) | 1.12 (0.07, 18.42) |
| Diabetes | 1.01 (0.19, 5.21) | 1.60 (0.1, 26.26) |
| Stroke | 0.38 (0.04, 3.16) | N/A |
| Ejection Fraction (EF) | 0.96 (0.91, 1.01) | 0.93 (0.84, 1.03) |
| EF<50% | 2.50 (0.56, 11.22) | 4.86 (0.30, 77.87) |
| STEMI w/in 90 days | N/A | 3.77 (0.23, 61.0) |
| History of Atrial Fibrillation | 3.34 (0.75, 14.9) | N/A |
| Aortic Stenosis | 0.66 (0.15, 2.94) | 0.52 (0.03, 8.32) |
| Prior Primary AVR | N/A | N/A |
| BMI kg/m$^2$ | **1.14 (1.05, 1.24)*** | 0.88 (0.66, 1.17) |
| BMI >30 kg/m$^2$ | 2.15 (0.48, 9.62) | N/A |
| Creatinine Level | 0.999 (0.990, 1.01) | 0.94 (0.85, 1.04) |
| Max Aortic Gradient mmHg | 1.03 (0.97, 1.09) | 1.02 (0.97, 1.09) |
| Mean Aortic Gradient mmHg | 1.07 (0.96, 1.18) | 1.07 (0.96, 1.18) |
| Vmax m/s | 0.87 (0.41, 1.80) | 0.25 (0.03, 2.09) |

**Table 5:** Multivariate Cox proportional hazard of long-term outcomes.

| Models | Mortality |
|---|---|
| | Redo-SAVR¥ HR (95% CI) |
| **Model 1** | |
| Univariable | 1.2 (0.2, 5.9) |
| **Model 2** | |
| P Score + Age | 1.3 (0.2, 7.5) |

*p<0.05, **p<0.001
¥reference group is SAVR

**Table 6:** Cumulative incidence of long-term outcomes.

| All Cause Mortality | SAVR n=57 | Redo-Sutureless n=25 | p-value |
|---|---|---|---|
| 1-year | 4 (7.0%) | 1 (4.0%) | 0.71 |
| 2-years | 5 (8.8%) | 1 (4.0%) | 0.731 |
| 5-years | 7 (12.3%) | 2 (8.0%) | 0.821 |
| 7-years | 7 (12.3%) | 2 (8.0%) | 0.821 |

**Table 7:** Unadjusted and adjusted models.

| Propensity -adjusted n (%) | Unadjusted | | Adjusted | |
|---|---|---|---|---|
| | Redo SAVR¥ HR (95% CI) | p-value | Redo SAVR¥ HR (95% CI) | p-value |
| **All-Cause Mortality** | | | | |
| 1-year | 1.8 (0.2, 15.8) | 0.609 | 1.7 (0.2, 19.0) | 0.67 |
| 2-years | 2.2 (0.3, 18.7) | 0.48 | 1.7 (0.2, 18.3) | 0.643 |
| 5-years | 1.3 (0.3, 6.5) | 0.71 | 1.3 (0.2, 7.5) | 0.74 |
| 7-years | 1.3 (0.3, 6.5) | 0.71 | 1.3 (0.2, 7.5) | 0.74 |

*p<0.05; **p<0.001
¥reference group is redo sutureless, adjusted for p-score and age

**Table 8:** Risk factor analysis. Double robust cumulative hazard function analysis.

| Risk Factors for Mortality | | | |
|---|---|---|---|
| **SAVR** | **HR (95% CI)** | **Redo-Sutureless** | **HR (95% CI)** |
| Ejection Fraction | 0.95 (0.89, 1.01) | Ejection Fraction | 0.92 (0.8, 1.0) |
| COPD | 1.58 (0.2, 10.5) | COPD | 4.9 (0.2, 96.4) |
| BMI | 1.21 (1.0, 1.4) | | |
| Atrial fibrillation | 1.43 (0.2, 9.2) | | |
| Tobacco Use | 10.22 (1.1, 94.8) | | |

COPD: Chronic Obstructive Pulmonary Disease; BMI: Body Mass Index

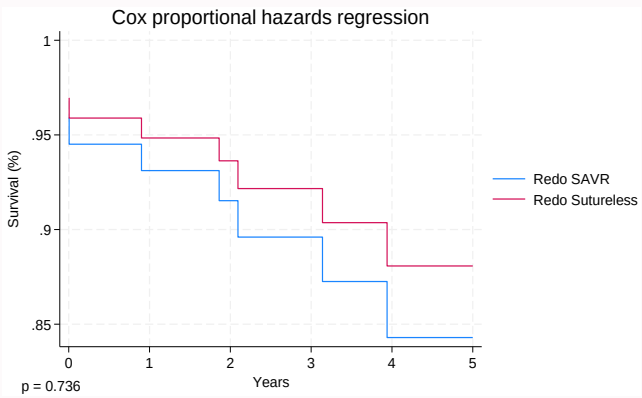


**Figure 1:** Kaplan-Meier survival curves.

hemodynamics outcomes, b) a friendly implant in hostile annulus environment such as endocarditis and reoperations, c) facilitating future ViV-TAVR as sinus struts protect coronary ostia from obstruction and Nitinol cage expandable [14-16]. In this context, our study found that patients undergoing redo AVR with sutureless bioprosthesis had favorable postoperative in-hospital and long-term outcomes.

The Cavalier clinical trial evidenced the critical benefits of using sutureless bioprosthesis [1]. However, future clinical trial comparing sutured and redo-sutureless outcomes with redo SAVR bioprosthesis will give more insight to the right choice of patient. In this context, it is crucial to have a strong and successful heart-team collaboration, capable of selecting the right patient for different types of bioprosthesis based on up-to-date clinical outcome from international literature. It is important that clinical cardiologist, interventional cardiologist, and cardiothoracic surgeons sees all the valves as complementary treatment options based on the patient-risk profile and cardiac anatomy rather than as competing procedures [17-20].

Given the apparent adequacy of our propensity-score weighting (with minimal standardized mean differences) based on elements available in claims data, it is likely that patients undergoing isolated redo AVR may benefit from these outcomes.

## Limitations

This retrospective study was subject to all limitations inherent to a non-randomized study, including potential selection bias

regarding which patients underwent redo-AVR with either of the aforementioned bioprosthesis. However, the rigorous propensity-matched and propensity-adjusted analysis limited these biases. In addition, the study includes a large timeframe (2005-2020) and many advanced techniques and changes in medical treatments have occurred in this period. Another limitation is the single-center data; therefore, our analysis needs further validation from multicenter studies.

## Conclusion

There was no difference in term of long-term all-cause death among the two groups. Patients undergoing redo SAVR experienced a higher incidence of POAF compared to patients undergoing redo sutureless bioprosthesis implantation. New risk predictors for patients undergoing redo AVR included BMI and smoke. We hypothesize that patient's individual risk factors profile can help in prosthesis and interventional choice. In addition, optimization of modifiable risk predictors may improve clinical outcomes.

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