Aortic valve replacement in patients over 60: Real-world surgical outcomes

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Abstract
Objective: With the advent of transcatheter aortic valve implantation (TAVI) has come an expectation that there will be a decline in surgical aortic valve replacement (SAVR). This has been fueled by trials comparing outcomes between TAVI and SAVR in lower-risk patients. The aim of this study was to examine outcomes following SAVR in patients over the age of 60.

Materials and Methods: This retrospective cohort study observed 1005 patients ≥60 who underwent isolated primary SAVR from January 2015 to December 2018. The cohort was stratified by surgical risk, defined as European System for Cardiac Operative Risk Evaluation (EuroSCORE II) < 4 versus ≥4. The cohort was also divided by age (60–69, 70–79, ≥80) for additional comparisons. Outcomes included in-hospital complications and patient survival.

Results: The median age and EuroSCORE II were 75 years and 1.6, respectively. The overall 30-day mortality was 1.7% and increased significantly with surgical risk (p = .007). The 30-day mortality of elective patients was 1.1%. Overall, 1- and 2-year survival rates were 94.3% and 91.7%, respectively, which significantly decreased with surgical risk (p < .001) and age (p = .002, p = .003). The rates of postoperative stroke and pacemaker implantations were 1.2% and 3.6%, respectively.

Conclusions: SAVR can be performed in patients ≥60 years old with excellent outcomes, which compare favorably with outcomes from TAVI trials, with their highly selected patient cohorts. SAVR remains a reliable, tried and tested, treatment option in these patients.

KEYWORDS
outcomes, surgical aortic valve replacement, survival, TAVI

1 | INTRODUCTION

Over the last decade, there has been considerable evolution in the field of transcatheter aortic valve implantation (TAVI). There have been a number of trials comparing early outcomes between surgical aortic valve replacement (SAVR) and TAVI in high surgical risk patients.1,2 These trials have shown equivalence and even superiority of TAVI in early outcomes.1,2 Now trials are focusing on intermediate and even lower-risk surgical candidates, but this remains an area of controversy.3,4
One question that remains surrounds long-term outcomes of TAVI, which is clearly of relevance to the younger and lower-risk cohort as the majority of trials to date report early- or mid-term outcomes, over which little structural valve degeneration (SVD) is observed in either cohort. Although long-term data is lacking for TAVI in lower surgical risk patients, longer-term outcomes following SAVR are very well established. In elderly patients, the lifespan of a cohort as the majority of trials to date report early observed in either cohort. Although long-term incidence of clinically relevant SVD of only 6.6%. TAVI in lower surgical risk patients, longer-term outcomes following SAVR are very well established. In elderly patients, the lifespan of a SAVR biologic prosthesis is estimated to be in excess of 15 years. In anticipation of the increased investigation of TAVI in lower surgical risk cohorts, the aim of this study was to examine contemporary outcomes following SAVR in patients ≥60 years at a high-volume center.

2 | MATERIALS AND METHODS

2.1 | Patient population

All patients ≥60 years that had SAVR between January 1st, 2015 and December 31st, 2018, at the Royal Papworth Hospital, Cambridge, UK, were identified. Patients who had undergone previous cardiac surgery or had SAVR with concomitant procedures were excluded. The study was approved by the Royal Papworth Hospital Research and Development clinical ethics department. Consent of patients was waived. A Heart team discussion occurs for all urgent cases while elective cases are referred directly by the Cardiology team. Of these, patients with multiple comorbidities are discussed at valve (and when appropriate TAVI) multidisciplinary team meetings.

Patients were divided into low risk and high risk by European System for Cardiac Operative Risk Evaluation (EuroSCORE) II (<4 and ≥4), as defined in the EACTS Guidelines for the management of valvular heart disease. The cohorts were also divided by age (60–69, 70–79, ≥80) for further comparisons.

2.2 | Outcomes

Demographic, intra-procedure and post-procedure data, including incidence of complications, length of hospital, and intensive care unit (ICU) stay were retrieved from our surgical and ICU databases. Mortality information was obtained from the UK national patient administration system and was available for all patients. Acute Kidney Injury (AKI) grade was calculated using the Acute Kidney Injury Network classification. The diagnosis of chest infection was based on documentation in the notes of a patient and/or administration of a course of antibiotics with chest documented as the indication. This did not require a positive sputum culture or clear chest radiographic evidence.

2.3 | Statistical analysis

Statistical analysis was performed using GraphPad Prism 9.0.0 (GraphPad Software, Inc.), and R 3.6.1 (R Core Team). We have presented categorical variables as numbers (percentages) and continuous variables as median (IQR, interquartile range), as all continuous variables recorded were not deemed to have a normal distribution using the D’Agostino–Pearson test and Shapiro–Wilk test. All variables were compared using nonparametric tests. The categorical variables were analyzed using the χ² or Fisher’s exact test within the age and EuroSCORE II groups. Continuous variables were compared using the Mann–Whitney U test or the Kruskal–Wallis test. The Kaplan–Meier method was used to plot the patient survival rates, with the log-rank (Mantel–Cox) test used to compare groups. p < .05 was considered statistically significant.

3 | RESULTS

Over the 5-year period of study, 1005 patients ≥60 years underwent SAVR at our center. For the purpose of comparison, they were divided based on EuroSCORE II, <4 (n = 857) and ≥4 (n = 148). Additionally, the cohort was subdivided by age: 60–69 years (n = 258), 70–79 years (n = 447), and ≥80 years (n = 300).

3.1 | Patient characteristics

Patient demographics are summarized in Table 1. The median age of patients was 75 years and the median EuroSCORE II was 1.6.

There was a higher proportion of females (p < .03) and older age (p < .001) patients in the high surgical risk cohort. As would be predicted, patients in the higher score cohort suffered greater comorbidity—specifically hypertension (p = .01), chronic pulmonary disease (p < .001), neurological disease (p < .001), diabetes (p = .003), and peripheral vascular disease (p < .001). They also had higher NYHA scores (p < .001).

3.2 | Intraoperative characteristics

Intraoperative characteristics are summarized in Table 2. In this cohort, 19.2% of operations were performed on an urgent or emergent basis. The vast majority were performed through a median sternotomy (98.2%) and used a bioprosthetic valve (97.5%). The median cardiopulmonary bypass (CPB) time was 68 min and the aortic cross-clamp time of 51 min.

There was a significant increase in the proportion having urgent operations (p < .001) and receiving bioprosthesis (p = .04) between the surgical risk groups. There was a reduction in cross-clamp time (p < .001) with increasing EuroSCORE II, but no significant reduction in CPB time in the higher-risk group (p = .42). In keeping with this observation, a statistically significant trend was observed with a decreased proportion of procedures being performed by non-consultant grade surgeons (p = .005).

3.3 | Patient outcomes

Patient outcomes are summarized in Table 3. The incidence of re-exploration for bleeding was 3.7%. The incidence of AKI was 20.8%, and
39.0% experienced fast atrial fibrillation. Three additional patients returned to theater for other complications: two required coronary artery bypass grafting, and one underwent repair of type A aortic dissection. The incidence of cerebrovascular accident (CVA) for the cohort was 1.2% and pacemaker implantation 3.6%. The median ICU and hospital lengths of stay were 24.1 h and 8.2 days, respectively. In all, 85.8% of patients were discharged home and 14.2% were transferred to a local hospital or for further rehabilitation before discharge home. The overall 30-day mortality was 1.7%; for elective patients, this was 1.1%.

In the higher surgical risk group, a higher proportion required blood transfusion ($p < .001$), and more units of blood were transfused ($p = .008$).

The table below shows the patient characteristics:

| Variable                                | SAVR (n = 1005) | <4 (n = 857) | ≥4 (n = 148) | p value  |
|-----------------------------------------|-----------------|--------------|--------------|---------|
| Age (median (IQR))^a                    | 75 (69–81)      | 74 (68–79)   | 81 (76.3–84) | <.001   |
| Sex = male (%)^b                        | 523 (52.0)      | 458 (53.4)   | 65 (43.9)    | .03     |
| BMI (median (IQR))^a                     | 27.8 (24.6–32.1)| 28.4 (25.0–32.4)| 25.5 (23.1–30.3)| <.001   |

**Comorbidity (%)^b**
- Hypertension                              584 (58.1) 484 (56.5) 100 (67.6) .01
- Chronic pulmonary disease                198 (19.7) 145 (16.9) 53 (35.8) <.001
- Neurological disease                     115 (11.4) 81 (9.5) 34 (23.0) <.001
- Diabetes                                  201 (20.0) 158 (18.4) 43 (29.1) .003
- Peripheral vascular disease              85 (8.5) 46 (5.4) 39 (26.4) <.001
- Current smoker                           45 (4.5) 38 (4.4) 7 (4.7) .87
- Ex-smoker                                 433 (43.1) 358 (41.8) 75 (50.7) .04

**Preoperative creatinine = μmol/L (median (IQR))^a**
- 83 (68.5–101) 80 (68–97) 101 (79.5–126) <.001

**Preoperative heart rhythm (%)^b**
- Sinus                                     864 (86.0) 755 (88.1) 109 (73.6) .001
- AF/atrial flutter                         107 (10.6) 75 (8.8) 32 (21.6) .001
- Other                                     34 (3.4) 27 (3.2) 7 (4.7) <.001

**NYHA classification (%)^b**
- I                                         165 (16.4) 157 (18.3) 8 (5.4) .001
- II                                        439 (43.7) 405 (47.3) 24 (16.2)
- III                                       363 (36.1) 279 (32.6) 84 (56.8)
- IV                                        38 (3.8) 16 (1.9) 22 (14.9) .001

**Aortic valve hemodynamics (%)^b**
- Stenosis                                  796 (79.2) 681 (79.4) 115 (77.7) .001
- Regurgitation                             46 (4.6) 40 (4.7) 6 (4.1) .001
- Mixed                                     88 (8.8) 72 (8.4) 16 (10.8) .61

**LV function (%)^b**
- Good (>50%)                                830 (82.6) 757 (88.3) 73 (49.3) .001
- Moderate (31%–50%)                         139 (13.8) 92 (10.7) 47 (31.8)
- Poor (<30%)                                36 (3.6) 8 (0.9) 28 (18.9) .001

**EuroSCORE (median (IQR))^a**
- 6.4 (4–10.2) 5.8 (3.7–8.4) 18.7 (11.4–26.3) <.001

**EuroSCORE II (median (IQR))^a**
- 1.6 (1–2.8) 1.4 (1–2.1) 5.9 (4.6–9.0) <.001

Note: Data presented as n (%) or median (IQR, interquartile range). Chronic pulmonary disease includes asthma or chronic obstructive pulmonary disease that requires long-term medication. Neurological disease includes transient ischemic attack and cerebrovascular accident with or without a residual deficit. Bold values indicate statistical significance $p < .05$.

Abbreviations: AF, atrial fibrillation; BMI, body mass index; EuroSCORE, European System for Cardiac Operative Risk Evaluation; LV, left ventricle; NYHA, New York Heart Association; SAVR, surgical aortic valve replacement.

^aMann–Whitney U test.

^bχ² test.
group \((p = .002)\) and the requirement of intra-aortic balloon pump (IABP; \(p = .01\)), but the incidence of other postoperative complications was similar. These patients had significantly prolonged ICU \((p < .001)\) and hospital \((p < .001)\) stays. However, 30-day mortality was also significantly higher in the high-risk group \((p = .007)\).

### 3.4 Patient survival

Overall 1- and 2-year survival rates were 94.3% and 91.7%, respectively. Patient survival was significantly reduced in the high-risk cohort \((p < .001)\). Considering only elective operations, overall 1- and 2-year survival was 95.4% and 93.1%, respectively. For the elective high-risk patients \(\geq 4\), the 1- and 2-year survival rates were 88.1% and 79.7%.

### 3.5 Age groups

Patient demographics and intraoperative details stratified by age are shown in Tables S1 and S2. Key outcomes are shown in Table 4.

Noteworthy outcomes include a significant proportion of older patients incurring AKI \((p < .001)\) and having significantly prolonged ICU \((p < .001)\) and hospital \((p < .001)\) stays. Furthermore, there was an increase in the proportion transferred for ongoing care rather than being discharged home. Longer-term patient survival was significantly reduced with age \((p < .001)\).

### 4 DISCUSSION

In this study, we report outcomes following SAVR in 1005 patients \(\geq 60\) years old at a high-volume center over a 5-year period. We observed overall 30-day mortality of 1.7%. In the elective cohort, it was just 1.1%. SAVR has long been established as the gold-standard treatment option for patients with aortic valve disease.\(^{10,11}\) As such, we have mid- and long-term performance data on the development of SVD. At our center, we recently published a study where we followed 100 consecutive patients receiving the Carpentier-Edwards Perimount Magna Ease (CEPME) prosthesis \((p = .002)\) of patients in the present series.\(^{12}\) At a median of 5.1 years, none of the patients had evidence of significant SVD. Two patients had evidence of leaflet...
thickening but with no hemodynamic significance. None of the patients had required reintervention. This highlights the durability of modern bioprostheses.\textsuperscript{12}

Over recent years there has been significant interest in the potential of TAVI as a less invasive alternative treatment option for these patients.\textsuperscript{13} As such it is time to evaluate "real-world" outcomes following surgery to enable clinicians to offer patients the best treatment option. For TAVI to become an established treatment option for intermediate- and low-risk patients, it will be necessary to demonstrate that TAVI is comparable to surgery both in short-term and perhaps more importantly in longer-term outcomes.

This study includes patients operated on an urgent and emergent basis (representing 19.2% of our cohort) and surgery for infective endocarditis, to present "real-world" practice. We observed a stroke rate of

| Outcome                                                                 | SAVR (n = 1005) | <4 (n = 857) | ≥4 (n = 148) | p value |
|-------------------------------------------------------------------------|-----------------|--------------|--------------|---------|
| 12-hour blood loss = ml (median (IQR))\textsuperscript{a}              | 225 (150–375)   | 225 (150–365) | 233 (150–425) | .31     |
| Return to theater for bleeding (%)\textsuperscript{b}                  | 37 (3.7)        | 29 (3.4)     | 8 (5.4)      | .23     |
| Haemofiltration (%)\textsuperscript{c}                                 | 9 (0.9)         | 8 (0.9)      | 1 (0.7)      | >.99    |
| IABP (%)\textsuperscript{c}                                            | 4 (0.4)         | 1 (0.1)      | 3 (2.0)      | .01     |
| RBC transfusion (%)\textsuperscript{b}                                 | 385 (38.3)      | 293 (34.2)   | 92 (62.2)    | <.001   |
| RBC transfusion units (median (IQR))\textsuperscript{c}                | 2 (1–3)         | 2 (1–3)      | 2 (1–4)      | .008    |
| CVA (%)\textsuperscript{c}                                             | 12 (1.2)        | 11 (1.3)     | 1 (0.7)      | >.99    |
| Fast AF (%)\textsuperscript{b}                                         | 392 (39.0)      | 328 (38.3)   | 64 (43.2)    | .25     |
| AKI (%)\textsuperscript{b}                                             | 209 (20.8)      | 164 (19.1)   | 45 (30.4)    | .002    |
| Stage I                                                                 | 130 (12.9)      | 105 (12.3)   | 25 (16.9)    | .23     |
| Stage II                                                                | 62 (6.2)        | 46 (5.4)     | 16 (10.8)    |         |
| Stage III                                                               | 17 (1.7)        | 13 (1.5)     | 4 (2.7)      |         |
| Pacemaker implantation (%)\textsuperscript{b}                          | 36 (3.6)        | 29 (3.4)     | 7 (4.7)      | .42     |
| Chest infection (%)\textsuperscript{b}                                 | 82 (8.2)        | 68 (7.9)     | 14 (9.5)     | .53     |
| Readmission due to a sternal wound infection (%)\textsuperscript{c}     | 5 (0.5)         | 5 (0.6)      | 0 (0.0)      | >.99    |
| Length of stay (median (IQR))\textsuperscript{a}                      |                |              |              |         |
| ICU = hours                                                             | 24.1 (21.0–40.0)| 23.7 (20.8–30.2)| 28.9 (22.5–101.1)| <.001 |
| Hospital stay = days                                                    | 8.2 (6.3–11.8)  | 8.0 (6.2–10.4)| 13.0 (9.2–18.0)| <.001  |
| Discharged home (%)\textsuperscript{b}                                 | 862 (85.8)      | 771 (90.0)   | 91 (61.5)    | <.001  |
| Mortality (%)\textsuperscript{c}                                       |                |              |              |         |
| Inpatient                                                               | 9 (0.9)         | 6 (0.7)      | 3 (2.0)      | .13     |
| 30 days (all)                                                           | 17 (1.7)        | 10 (1.2)     | 7 (4.7)      | .007    |
| 30 days (elective)                                                      | 9 (1.1)         | 8 (1.1)      | 1 (1.7)      | .49     |
| 30 days (urgent/ emergency)                                            | 8 (4.1)         | 2 (1.9)      | 6 (6.7)      | .15     |
| Survival (%)\textsuperscript{c}                                        | 94.3            |              |              |         |
| 1 year                                                                  | 91.7            | 96.0         | 84.5         | <.001  |
| 2 years                                                                 | 94.0            | 78.4         |              | <.001  |

Note: Data presented as n (%). Abbreviations: AF, atrial fibrillation; AKI, acute kidney injury; CVA, cerebrovascular accident; IABP, intra-aortic balloon pump; ICU, intensive care unit; RBC, red blood cell; SAVR, surgical aortic valve replacement.

\textsuperscript{a}Mann–Whitney U test.
\textsuperscript{b}\chi\textsuperscript{2} test.
\textsuperscript{c}Fisher’s exact test.
1.2% and a permanent pacemaker implantation rate of 3.6%. The incidence of these did not significantly change with increasing EuroSCORE II or age. The overall 30-day mortality was 1.7%. For elective patients, it was just 1.1%.

We observed a significant reduction in aortic cross-clamp time with increased surgical risk. We believe that this relates to a reduced likelihood for a consultant to train on higher-risk cases. The need for blood transfusion significantly increased with surgical risk (and patient age). This may relate to a higher incidence of anemia with age.

For the higher-risk patients, 38.5% were discharged to their local hospital or for convalescence. This reflects these patients' older age and consequent longer postsurgical recovery.

There are other studies that have examined outcomes following SAVR. Thourani et al. analyzed 141,905 patients from the USA Society of Thoracic Surgeons (STS) database. In terms of complications, their findings were similar—an incidence of stroke of 1.5% and a heart block of 4.0%. The overall 30-day mortality was 3.0%. They also divided patients into risk categories based on the STS Predictive Risk of Operative Mortality (PROM) and observed a greater incidence of complications and mortality with the increased risk groups. Their high-risk group (STS PROM > 8%) had similar demographics to our EuroSCORE II ≥ 4 group, but the 30-day mortality was significantly higher (12.9% vs. 4.7%). This difference may relate to operative volume. It is recognized that there is a correlation between the unit volume of cardiac surgical operations and patient outcomes.

In the United States, for example, one-third of Coronary Artery Bypass Grafting Surgery (CABG)-capable hospitals perform <100 CABG operations annually. The impact of volume on outcomes is likely magnified for higher-risk cases. A single-center study examining outcomes following SAVR was reported by Sharabiani et al. from the United Kingdom. They reported 30-day mortality for elective and urgent patients of 2.8%, and a similar stroke incidence (1.6%). A more recent multicentre European registry study reported on 1192 patients undergoing SAVR ± CABG, presenting 30-day mortality of 1.5%. This study similarly correlated survival with surgical risk. Their incidence of stroke was 1.8%, although it was 4.8% for their higher-risk (EuroSCORE II > 9) group. The authors similarly comment that their results are superior to the surgical arms of industry-sponsored TAVI trials.

To date, TAVI remains a relatively new treatment and data regarding longer-term durability continues to be sought. However, an incidence of SVD of 30% at 5 years was reported from the UK TAVI registry. The significance of TAVI valve durability has recently been questioned. Tam et al. have shown through discrete event simulation modeling that valve durability may be unlikely to result in reduced life expectancy other than in younger low-risk patient cohorts.

As such, much attention has focused on comparing short-term outcomes between TAVI and SAVR. Numerous multicentre randomized trials have and are being performed in patients of increasingly lower surgical risk and are reporting equivalence and even

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**FIGURE 1** Survival curve (Kaplan-Meier estimate) of the cohort. (A) Cohort stratified by surgical risk (EuroSCORE II); (B) cohort stratified by age. EuroSCORE, European System for Cardiac Operative Risk Evaluation.
superiority of TAVI in early outcomes. It is important to highlight that there has been much written in the literature questioning the methodology of these industry-sponsored trials, designed to favor TAVI through strict patient selection criteria. To offer some balance to this argument, we have demonstrated, in patients ≥60 years, that excellent outcomes can be achieved following SAVR.

Despite these questions on TAVI durability, it is clear that TAVI is having an impact on surgical practice. It would appear that with increased durability of modern valves, bioprostheses are being implanted in patients of younger age than in the past—also in anticipation of a future valve-in-valve procedure (rather than a redo surgery), also removing the requirement for therapeutic anticoagulation and its associate risks.

Even valve manufacturers are evolving—such as the Edwards Inspiris Resilia prosthesis which has been designed specifically with valve-in-valve TAVI in mind with an expandable ring.

Although the TAVI trials may suggest equivalence in intermediate-risk cases, the surgical arms of these trials appear to have inferior outcomes to those in our experience. The trial outcomes to those in our experience. The intermediate-risk PARTNER 2A trial (mean STS PROM of 5.2%) reported on 937 patients undergoing SAVR, of which 739 had isolated SAVR. Their reported 30-day mortality was 4.2%, which is significantly higher than what we observed. For our higher-risk cohort (EuroSCORE II ≥ 4) our elective 30-day mortality was only 1.7%. Furthermore, their incidence of complications was also higher, including stroke 5.3% (vs. 0.7%) and the requirement for permanent pacemaker 7.4% (vs. 4.7%). They also reported that 48% of patients were discharged home from the hospital, compared with 61.5% of our higher-risk group. Similarly, the 1-year mortality of 13% and 2-year mortality of 17% also compare unfavorably with our outcomes. The low-risk PARTNER 3 trial included patients with STS PROM < 4% (mean STS PROM of 1.5%; mean age of 73 years). In this trial, the 30-day mortality following SAVR was 1.1%, which was similar to our patients undergoing elective surgery. However, the incidence of stroke at 2.4% was double our experience. The NOTION trial similarly compared TAVI with SAVR in a lower-risk cohort. The mean EuroSCORE II of the cohort was 2.0% with a mean age of 79 years, and 81% of patients were considered low risk. They reported a 30-day mortality of 3.7% and stroke incidence of 3.0%, both notably higher than our series. These three large studies clearly show that the surgical arm outcomes do not reflect that which can be achieved at high-volume surgical centers and should be considered when interpreting the trial outcomes.

### TABLE 4 Outcomes (age)

| Outcome                                      | SAVR (n = 1005) | 60–69 years (n = 258) | 70–79 years (n = 447) | ≥80 years (n = 300) | p value |
|----------------------------------------------|-----------------|-----------------------|-----------------------|--------------------|--------|
| 12-hour blood loss = ml (median (IQR))a     | 225 (150–375)   | 225 (150–356)         | 225 (150–375)         | 225 (150–381.3)    | .96    |
| Return to theater for bleeding (%)b         | 37 (3.7)        | 9 (3.5)               | 11 (2.5)              | 17 (5.7)           | .07    |
| Haemofiltration (%)c                         | 9 (0.9)         | 4 (1.6)               | 3 (0.7)               | 2 (0.7)            | .44    |
| RBC transfusion (%)b                        | 385 (38.3)      | 72 (27.9)             | 159 (35.6)            | 154 (51.3)         | <.001  |
| CVA (%)b                                     | 12 (1.2)        | 2 (0.8)               | 7 (1.6)               | 3 (1.0)            | .76    |
| Fast AF (%)b                                 | 392 (39.0)      | 95 (36.8)             | 172 (38.5)            | 125 (41.7)         | .48    |
| AKI (%)b                                     | 209 (20.8)      | 41 (15.9)             | 82 (18.3)             | 86 (28.7)          | <.001  |
| Pacemaker implantation (%)b                 | 36 (3.6)        | 10 (3.9)              | 17 (3.8)              | 9 (3.0)            | .81    |
| Length of stay (median (IQR))d               |                 |                       |                       |                    |        |
| ICU = hours                                  | 24.1 (21.0–40.0)| 24.1 (21.1–30.2)      | 23.6 (20.7–29.1)      | 25.3 (21.7–31.1)   | <.001  |
| Hospital stay = days                         | 8.2 (6.3–11.8)  | 7.0 (6.0–9.6)         | 8.0 (6.2–11.1)        | 10.0 (8.1–14.4)    | .002   |
| Discharged home (%)b                         | 862 (85.8)      | 234 (90.7)            | 403 (90.2)            | 225 (75.0)         | <.001  |
| Mortality (%)                                |                 |                       |                       |                    |        |
| Inpatient                                   | 9 (0.9)         | 2 (0.8)               | 4 (0.9)               | 3 (1.0)            | .58    |
| 30-day (all)bc                               | 17 (1.7)        | 4 (1.6)               | 6 (1.3)               | 7 (2.3)            | .92    |
| 30-day (elective)                           | 9 (1.1)         | 3 (1.3)               | 4 (1.1)               | 2 (0.9)            | .40    |
| 30-day (urgent/emergency)bc                 | 8 (4.1)         | 1 (2.9)               | 2 (2.3)               | 5 (6.9)            | >.99   |
| Survival (%)b                               |                 |                       |                       |                    |        |
| 1-year                                      | 94.3            | 96.1                  | 96.0                  | 90.3               | .002   |
| 2-year                                      | 91.7            | 94.6                  | 93.1                  | 87.3               | .003   |

Note: Data presented as n (%) or median (IQR, interquartile range). Pacemaker implantation was recorded within 30-days postoperation. Bold values indicate statistical significance p < .05.

Abbreviations: AF, atrial fibrillation; AKI, acute kidney injury; CVA, cerebrovascular accident; IABP, intra-aortic balloon pump; ICU, intensive care unit; RBC, red blood cell; SAVR, surgical aortic valve replacement.

aKruskal–Wallis test.
bχ² test.
cFisher’s exact test.
It is also worth considering the outcomes for the TAVI populations in these studies (summarized in Table 5). It can be seen that our surgical outcomes are generally superior to those of TAVI. There is a notable advantage when it comes to stroke and the requirement for permanent pacemaker implantation. However, TAVI remains superior in several other outcomes, notably the length of hospitalization. In addition, the PARTNER 3 trial reported much higher rates of patients discharged home/self-care in their TAVI cohort compared to SAVR (95.8% vs. 73.1%). The less invasive nature of TAVI likely explains the reduced length of stay.

It is clear from our series that outcomes are inferior with older age, particularly in those ≥80 years. Therefore, in view of the higher morbidity associated with SAVR and significantly faster recovery from TAVI, it would seem reasonable for the option of TAVI to be carefully considered in patients ≥80 years, particularly those with higher surgical risk.

### 4.1 Limitations

This is a single center, retrospective study which has inherent limitations; however, our prospectively maintained databases and clinical records allow for accurate data collection. We have analyzed a recent cohort of patients to present a contemporary analysis, which prevents us from examining the longer-term outcomes of these patients. There remained the challenge of comparing this with our real-world TAVI data as in the UK TAVI is recommended for high-surgical risk patients and in those not suitable for SAVR. Stratifying based on predictive-risk models is also inherently limited as there are factors impacting on the outcome not accounted for within these models. Furthermore, some of the multicentre randomized trials have used the STS score rather than EuroSCORE II for stratification. Unfortunately, we lacked data to retrospectively calculate the STS score for patients in our cohort.

### 5 Conclusions

SAVR can be performed in patients ≥60 years with excellent outcomes. We report 30-day mortality for all-comers of 1.7% and 1-year survival of 94.3%, which compare favorably with outcomes from TAVI trials, with their highly selected patient cohorts. SAVR remains a reliable, tried and tested, treatment option in these patients and can be performed with low risk.

### Conflict of interests

The authors declare that there are no conflict of interests.

### Author contributions

Jason M. Ali and Anoop S. Sumal wrote the original draft and interpreted data. Anoop S. Sumal, Harry Kyriacou, and Christopher J. Tuttle retrieved data. Anoop S. Sumal performed the statistical analysis and created figures. Jason M. Ali and Narain Moorjani conceptualized and supervised the work. All authors revised the final version.

### Data availability statement

Data available on request due to privacy/ethical restrictions

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### Table 5 Outcomes compared to multicentre transcatheter aortic valve implantation trials

| Outcome                          | SAVR (high risk): EuroSCORE II ≥ 4 (n = 148) | TAVI (intermediate risk): PARTNER 2A (n = 994) | TAVI (low risk): PARTNER 3 (n = 496) | TAVI (low risk): NOTION (n = 145) |
|----------------------------------|---------------------------------------------|-----------------------------------------------|-------------------------------------|----------------------------------|
| 30-day mortality (%)             | 4.7                                         | 3.4                                           | 0.4                                 | 2.1                              |
| 30-day stroke (%)                | 0.7                                         | 5.6                                           | 0.6                                 | 1.4                              |
| 30-day pacemaker implantation (%)| 4.7                                         | 8.6                                           | 6.5                                 | 34.1                             |
| 1-year survival (%)              | 84.5                                        | 88.2                                          | 99.0                                | 95.1                             |

Note: Data presented as %. Data of PARTNER 2A trial from Leon et al.31 PARTNER 3 trial from Mack et al.4 NOTION trial from Thyregod et al.26 Abbreviations: EuroSCORE, European System for Cardiac Operative Risk Evaluation.
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**SUPPORTING INFORMATION**

Additional supporting information may be found in the Supporting Information section.

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