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Comparative study of male and female patients undergoing surgical aortic valve replacement

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Key question

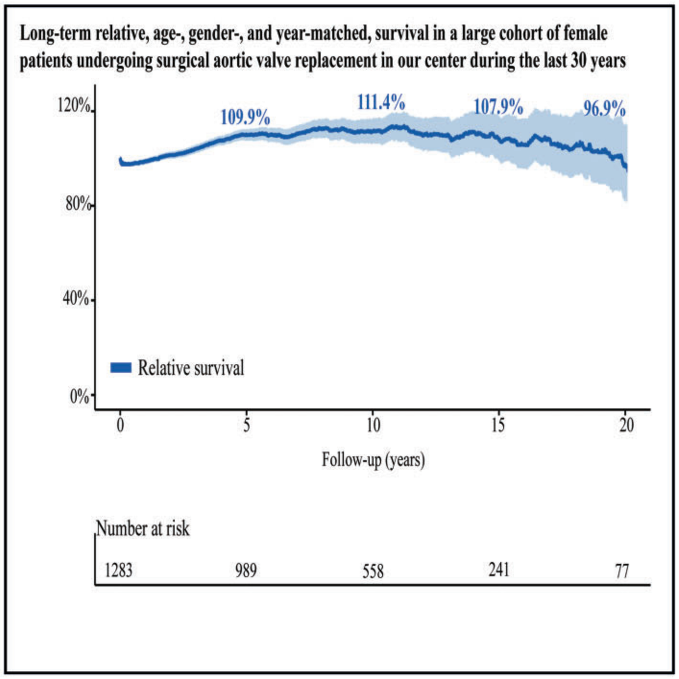
What are the long-term outcomes of female patients undergoing surgical aortic valve replacement?

Key finding(s)

Female patients undergoing surgical aortic valve replacement have excellent long-term survival compared to the age-, sex-, and year-matched Dutch population.

Take-home message

These satisfactory long-term results reinforce the role of surgical aortic valve replacement in the female population.



Abstract

BACKGROUND: Sex does have an effect on disease perception and outcomes after cardiac surgery.

OBJECTIVES: The aim of this study was to quantify the differences in cardiovascular risk profiles within an age-matched cohort and assess the long-term survival differences in males and females who underwent surgical aortic valve replacement (SAVR) with or without concomitant coronary artery bypass surgery.

METHODS: All-comers patients who underwent SAVR with or without coronary artery bypass surgery were included. Characteristics, clinical features and survival up to 30 years were compared between female and male patients. Propensity matching and age matching using propensity scores were used to compare both groups.

RESULTS: During the total study period between 1987 and 2017, there were 3462 patients {mean age 66.8 [standard deviation (SD): 11.1] years, 37.1% female} who underwent SAVR with or without coronary artery bypass surgery at our institution. In general, female patients were older than male patients (69.1 (SD : 10.3) versus 65.5 (SD : 11.3), respectively). In the age-matched cohort, female patients were less likely to have multiple comorbidities and undergo concomitant coronary artery bypass surgery. Twenty-year survival following the index procedure was higher in age-matched female patients (27.1%) compared to male patients (24.4%) in the overall cohort (*P* = 0.018).

CONCLUSIONS: Substantial sex differences in cardiovascular risk profile exist. However, when SAVR with or without coronary artery bypass surgery is performed, extended long-term mortality is comparable between males and females. More research regarding sex-dimorphic mechanisms of aortic stenosis and coronary atherosclerosis would promote more awareness in terms of sex-specific risk factors after cardiac surgery and contribute to more guided personalized surgery in the future.

Keywords: Sex • Women • Men • Incidence • Surgical • Transcatheter • TAVR • Transcatheter aortic valve implantation

ABBREVIATIONS

AR	Aortic valve regurgitation
AS	Aortic valve stenosis
CABG	Coronary artery bypass grafting
LV	Left ventricular
LVEF	Left ventricular ejection fraction
MI	Myocardial infarction
SAVR	Surgical aortic valve replacement
SD	Standard deviation
TAVI	Transcatheter aortic valve implantation

INTRODUCTION

Aortic valve disease is an emerging healthcare problem worldwide due to the dramatic increase in life expectancy and subsequently exponentially increasing prevalence [1]. The 85 plus population is projected to increase 351% between 2010 and 2050. Fortunately, there have been significant advances in both surgical and percutaneous treatments of moderate-to-severe forms of aortic valve stenosis (AS) over the last decade [2, 3].

Recent interest has focused on sex differences in the preoperative and postoperative outcomes of patients undergoing cardiac surgery. For example, female patients having coronary artery bypass grafting (CABG) have higher-risk profiles and subsequently, being female is an independent predictor for worse outcomes. Besides, female patients are less likely and at a later stage to undergo CABG [4]. Likewise, this underdiagnosis and undertreatment are also noted in valvular surgery [5], although both female and male patients share similar incidence of severe AS. However, females present with a distinct risk profile such as the smaller body size and older age, which poses unique challenges for the surgical team.

Therefore, the characteristics of patients undergoing surgical aortic valve replacement (SAVR) with or without coronary revascularization and the associated differences due to sex have become a focus in AVR studies. The purpose of this study is to (i) describe the differences in male and female patients undergoing SAVR with or without CABG, (ii) describe the differences in baseline characteristics after adjusting for age and (iii) compare the long-term survival and predictors of survival in male and female patients.

METHODS

Ethical statement

This study was conducted according to the privacy policy of the Erasmus Medical Centre and to the Erasmus Medical Centre regulations for the appropriate use of data in patient-oriented research, which are based on international regulations, including the Declaration of Helsinki (Institutional MEC Number: MEC-2019-0721), and patient informed consent was waived. All the authors vouch for the validity of the data and adherence to the protocol.

Study design

All adult (≥18 years) patients who underwent SAVR between 1987 and 2017 at the Erasmus University Medical Centre in the Netherlands are included. Only patients who underwent surgical implantation of bioprosthetic or mechanical aortic valve prosthesis were included. Electronic medical records were used to retrieve patient and procedural characteristics. Survival status was obtained through the Death Registry, held nationally.

Endpoints and definitions

The primary end point is to assess the prevalence of female patients and the differences of patient characteristics in the SAVR population. Further end points were noted as difference in survival between female and male patients. The primary indication for operation [AS, aortic valve regurgitation (AR) or combined AS and AR] was determined based on the initial echocardiogram and according to the clinical guidelines in use at the time of the surgery, corresponding to the current European and American valvular guidelines [6, 7]. In general, SAVR within 24 h of establishing the indication was classified as emergent. Renal impairment was defined as a creatinine level of ≥2.0 mg/dl. Left ventricular (LV) function was classified as normal if the LV ejection fraction (LVEF) was >50%, mildly reduced if the LVEF was 40–49%, moderately reduced if the LVEF was 30–39% and severely reduced if the LVEF was <30%, as measured by a trained echocardiographer [8].

Statistical analysis

Discrete variables are presented as numbers, percentages or proportions and compared with either the Chi-squared test or the Fisher exact test, where appropriate. Continuous variables are presented as mean ± standard deviation or median with the interquartile range if there was evidence of non-normal distributed data according to the Kolmogorov–Smirnov test and compared with either the two-sample *t*-test or Wilcoxon rank-sum test, where appropriate.

Non-parsimonious logistic regression was used to estimate each patient's probability of being female. Propensity scores were calculated for each female and male patients. To account for only age, propensity scores were calculated for age and matched in an exact manner. The propensity score matching is performed by the means of nearest-neighbour matching. The balance between treatment groups was assessed with the use of standardized mean differences. A standardized mean difference of 0.1 or less was deemed to be the ideal balance, and a standardized difference of 0.2 or less was deemed to be an acceptable balance [9].

Time-to-event analyses were performed with the use of Kaplan–Meier estimates and were compared with the use of the stratified log-rank test. Furthermore, the relative survival can be used as an estimate of cause-specific mortality [10]. The Human Mortality Database is used to obtain the age-, sex- and calendar-year-matched expected survival data of the general population in the Netherlands [11]. The Human Mortality Database is continuously updated and includes mortality data from the Netherlands up until 2016. Relative survival is estimated through the Ederer II method [12, 13]. Two-sided *P*-values <0.05 were considered to be statistically significant. Standardized mean difference below 10% (0.1) was deemed to be an ideal balance [9]. Data analyses were done using SPSS 25.0 (SPSS Inc, Chicago, IL, USA) and R software, version 3.5 (R Foundation, Vienna, Austria). Figures were generated using Microsoft Excel (Microsoft, Redmond, WA, USA) and R software, version 3.5 (R Foundation, Vienna, Austria).

RESULTS

Characteristics of female patients

A total of 3462 patients underwent SAVR with or without CABG. The incidence of female patients in the overall cohort according to the age was 26.3%, 28.8%, 26.1%, 31.5%, 43.9% and 52.0% for patients aged <40, 40–49, 50–59, 60–69, 70–79 and >80 years, respectively (Fig. 1). The prevalence of female patients operated after 2000 or undergoing isolated SAVR is presented in Supplementary Material, Figs. S1 and S2. Female patients were older than male patients at the time of surgery {mean age 61.1 [standard deviation (SD): 10.3] years vs 65.5 (SD: 11.3) years, $P < 0.001$}. The prevalence of hypertension (42.5% vs 33.6%), diabetes mellitus (17.3% vs 14.5%) and isolated AS (77.5% vs 69.8%) were significantly higher in female patients compared to male patients (all *P*-values <0.05). Female patients had lower prevalence of myocardial infarction (MI) (7.6% vs 15.3%) and previous percutaneous coronary intervention (5.0% vs 8.8%, $P < 0.001$). Further the LVEF at the time of surgery was better in female patients, with 86.3% of the patients having an LVEF of ≥50%, compared to 75.6% of the males ($P < 0.001$). After adjustment for age, the differences in indication for surgery, hypertension, concomitant CABG and preoperative LV function remained. Detailed characteristics of the overall cohort, propensity score-matched cohort and age-matched cohorts are shown in Table 1. Sub-analyses on the characteristics of patients operated after 2000 and patients undergoing isolated SAVR are shown in Supplementary Material, Tables S1 and S2, respectively.

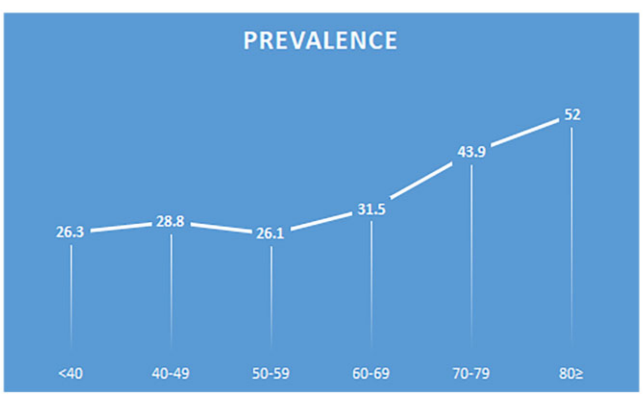


Figure 1: Prevalence of female patients. Prevalence of female patients according to different age categories in the overall cohort. Values are given in percentages.

Procedural characteristics of female patients

The indication for surgery was AS (77.5%), AR (7.8%) or combined AS and AR (14.7%). Concomitant CABG was performed less often compared to male patients (29.6% vs 40.6%, $P < 0.001$); this difference remained after age matching ($P < 0.001$). The use of bioprosthetic valve was lower in female than in male patients (42.8% vs 46.1%, $P = 0.002$), after accounting for age, female patients were more likely to receive bioprosthetic valves (37.6% vs 31.8%, $P = 0.007$). The diameter of the implanted prosthesis was smaller in female patients compared to male patients in both unmatched [21.9 mm (1.8) vs 24.6 mm (2.1), $P < 0.001$] and age-matched population [21.9 mm (SD: 1.8) vs 24.4 mm (SD: 2.0), $P < 0.001$].

Long-term outcomes after surgery

A total of 1941 patients died during follow-up (1185 male and 756 female patients, $P = 0.009$). Survival according to sex was 86.2% vs 81.8% at 5 years, 61.1% vs 59.7% at 10 years, 18.9% vs 25.4% at 20 years of follow-up ($P = 0.09$), in male and female patients, respectively, (Fig. 2A–C). The difference did not persist after propensity score matching ($P = 0.17$) and reverted after age matching. In the age-, sex- and year-matched Dutch control, the relative survival in male patients was 96.8%, 89.0%, 76.5% and 66.0% at 5, 10, 15 and 20 years of follow-up, respectively (Fig. 3A). The relative survival in female patients was 109.9%, 111.4%, 107.9% and 96.9%, at 5, 10, 15 and 20 years of follow-up, respectively (Fig. 3B). The survival according to age, type of surgery and surgical risk for female patients is shown in Table 2 and in Supplementary Material, Tables S3 and S4 for the overall population and male patients, respectively.

Factors associated with survival during follow-up in the age-matched population

In multivariable analyses, the presence of cardiovascular risk factors such as increasing age ($P < 0.001$), diabetes mellitus ($P < 0.001$), previous MI ($P = 0.013$) and the presence of atrial fibrillation ($P < 0.001$), previous stroke ($P = 0.016$) and the need for concomitant CABG ($P = 0.001$) were predictors of mortality in the age-matched female population (Supplementary Material, Table S5). In the age-matched male population, increasing age ($P < 0.001$), diabetes ($P = 0.004$), hypercholesterolaemia ($P = 0.001$), decompensation ($P = 0.011$) and COPD ($P = 0.04$) were independent predictors of mortality (Supplementary Material, Table S5). Further predictors are shown in Supplementary Material, Tables S5–S7, for the overall age-matched population, operated after 2000 and undergoing isolated SAVR, respectively.

DISCUSSION

The observed male–female differences in presentation, procedural characteristics and treatment outcomes in patients

Table 1: Baseline characteristics, stratified according to the overall cohort, propensity score-matched cohort and age-matched cohort

	Female (1283)	Male (2179)	*P*-Value	SMD	PSM female (566)	PSM male (566)	*P*-Value	SMD	AM female (1024)	AM male (1024)	*P*-Value	SMD
Age at operation (years), mean [SD]	69.1 [10.3]	65.5 [11.3]	<0.001	0.340	68.0 [10.7]	67.8 [10.4]	0.78	0.016	69.2 [10.1]	69.2 [10.1]	>0.999	<0.001
Indication, *n* (%)			<0.001	0.217			0.38	0.104			0.07	0.119
AS	994 (77.5)	1520 (69.8)			445 (78.6)	426 (75.3)			811 (79.2)	792 (77.3)		
AR	100 (7.8)	308 (14.1)			48 (8.5)	59 (10.4)			78 (7.6)	112 (10.9)		
Combined	188 (14.7)	347 (15.9)			72 (12.7)	81 (14.3)			135 (13.2)	120 (11.7)		
Bicuspid, *n* (%)	195 (15.2)	398 (18.3)	0.023	0.082	87 (15.4)	89 (15.7)	0.87	0.010	148 (14.5)	144 (14.1)	0.85	0.011
Previous cardiac operation, *n* (%)	76 (5.9)	132 (6.1)	0.931	0.006	31 (5.5)	31 (5.5)	>0.999	<0.001	53 (5.2)	58 (5.7)	0.70	0.022
Atrial fibrillation, *n* (%)	171 (13.3)	271 (12.4)	0.480	0.027	72 (12.7)	70 (12.4)	0.93	0.011	128 (12.5)	146 (12.5)	0.27	0.052
Diabetes mellitus, *n* (%)	222 (17.3)	317 (14.5)	0.035	0.075	112 (19.8)	109 (19.3)	0.88	0.013	193 (18.8)	180 (17.6)	0.49	0.033
Decompensation cordis, *n* (%)	189 (14.7)	320 (14.7)	>0.999	0.001	79 (14.0)	74 (13.1)	0.73	0.026	140 (13.7)	124 (12.1)	0.32	0.047
Hypertension, *n* (%)	545 (42.5)	733 (33.6)	<0.001	0.183	234 (41.3)	228 (40.3)	0.76	0.022	464 (45.3)	389 (38.0)	0.001	0.149
Hypercholesterolemia, *n* (%)	241 (18.8)	369 (16.9)	0.182	0.048	114 (20.1)	111 (19.6)	0.88	0.013	212 (20.7)	200 (19.5)	0.544	0.029
Previous myocardial infarction, *n* (%)	97 (7.6)	334 (15.3)	<0.001	0.246	51 (9.0)	55 (9.7)	0.76	0.024	75 (7.3)	183 (17.9)	<0.001	0.32
Previous PCI, *n* (%)	64 (5.0)	191 (8.8)	<0.001	0.150	40 (7.1)	36 (6.4)	0.72	0.028	55 (5.4)	102 (10.0)	<0.001	0.73
COPD, *n* (%)	240 (11.0)	240 (11.0)	0.542	0.024	58 (10.2)	71 (12.5)	0.26	0.072	104 (10.2)	118 (11.5)	0.36	0.044
Endocarditis, *n* (%)	31 (2.4)	106 (4.9)	0.001	0.131	17 (3.0)	23 (4.1)	0.42	0.057	24 (2.3)	35 (3.4)	0.19	0.064
History of cancer, *n* (%)	94 (7.3)	149 (6.8)	0.635	0.019	47 (8.3)	42 (7.4)	0.66	0.033	78 (7.6)	82 (8.0)	0.81	0.015
Stroke/TIA, *n* (%)	93 (7.2)	208 (9.5)	0.024	0.083	52 (9.2)	54 (9.5)	0.92	0.012	81 (7.9)	98 (9.6)	0.21	0.059
Stroke	38 (3.0)	97 (4.5)	0.036	0.079	21 (3.7)	28(4.9)	0.38	0.061	34 (3.3)	43 (4.2)	0.35	0.046
TIA	62 (4.8)	132 (6.1)	0.151	0.054	35 (6.2)	34 (6.0)	>0.999	0.007	53 (5.2)	65 (6.3)	0.30	0.050
Arterial disease, *n* (%)	47 (3.4)	125 (5.7)	0.009	0.098	27 (4.8)	25 (4.4)	0.89	0.017	39 (3.8)	56 (5.5)	0.09	0.079
Carotid	5 (0.4)	24 (1.1)	0.043	0.083	3 (0.5)	5 (0.9)	0.72	0.042	5 (0.5)	13 (1.3)	0.10	0.084
Peripheral	42 (3.3)	107 (4.9)	0.027	0.083	24 (4.2)	21 (3.7)	0.76	0.027	34 (3.3)	48 (4.7)	0.14	0.070
CABG, *n* (%)	380 (29.6)	884 (40.6)	<0.001	0.231	184 (32.5)	174 (30.7)	0.57	0.038	300 (29.3)	472 (46.1)	<0.001	0.32
Valve size (mm), mean [SD]	21.9 [1.8]	24.6 [2.1]	<0.001	1.356	22.7 [1.8]	22.9 [1.6]	0.053	0.115	21.9 [1.7]	24.4 [2.0]	<0.001	1.317
Urgency, *n* (%)			0.137	0.100			0.07	0.177			0.21	0.108
Urgent, *n* (%)	11 (1.0)	29 (1.5)			5 (0.9)	6 (1.1)			7 (0.7)	9 (0.9)		
Semi(-elective), *n* (%)	1123 (99.0)	1883 (98.5)			561 (99.1)	560 (98.9)			1017 (99.3)	1015 (99.1)		
LVEF (%), *n* (%)			<0.001	0.299	470 (83.0)	474 (83.7)	0.67	0.074			<0.001	0.245
Preserved	1013 (86.3)	1524 (75.6)			38 (6.7)	42 (7.4)			882 (86.1)	791 (77.2)		
Mildy reduced	54 (4.6)	166 (8.2)			50 (8.8)	40 (7.1)			52 (5.1)	89 (8.7)		
Moderately reduced	91 (7.8)	230 (11.4)			8 (1.4)	10 (1.8)			79 (7.7)	113 (11.0)		
Severely reduced	16 (1.4)	97 (4.8)							11 (1.1)	31 (3.0)		
Valve (biological), *n* (%)	587 (42.8)	1004 (46.1)	0.002	0.104	208 (36.7)	202 (35.7)	0.76	0.022	385 (37.6)	326 (31.8)	0.007	0.121

AM: age matched; AR: aortic regurgitation; AS: aortic stenosis; CABG: coronary artery bypass grafting; COPD: chronic obstructive pulmonary disease; LVEF: left ventricular ejection fraction; PCI: percutaneous coronary intervention; PSM: propensity score matched; SD: standard deviation; SMD: standardized mean difference; TIA: transient ischaemic attack.

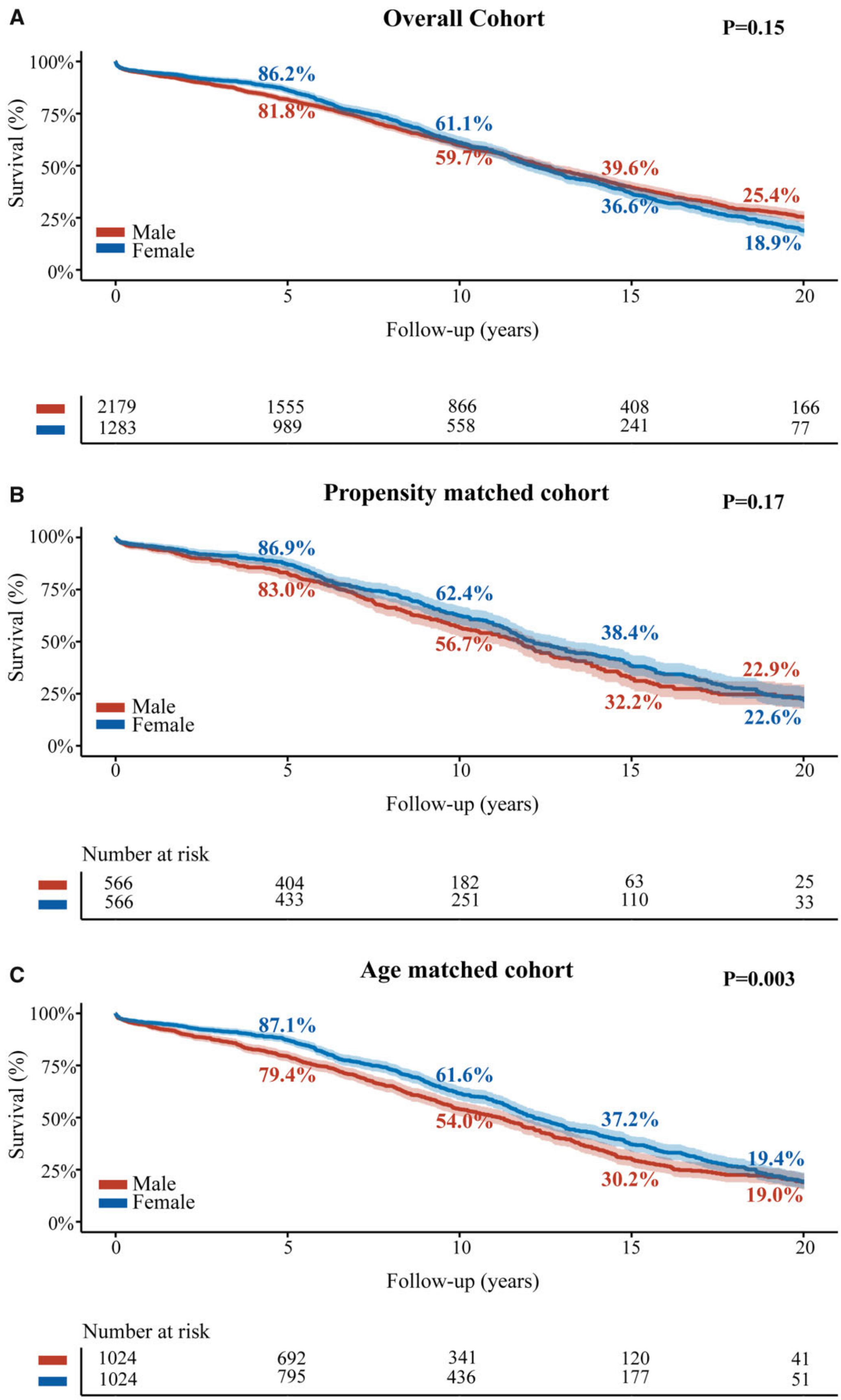


Figure 2: Survival after SAVR ± CABG. (A) Survival in the overall cohort. Blue line represents female patients and red line represents male patients. (**B**) Survival in the propensity matched cohort. Blue line represents female patients and red line represents male patients. (**C**) Survival in the age-matched cohort. Blue line represents female patients and red line represents male patients. CABG: coronary artery bypass grafting; SAVR: surgical aortic valve replacement.

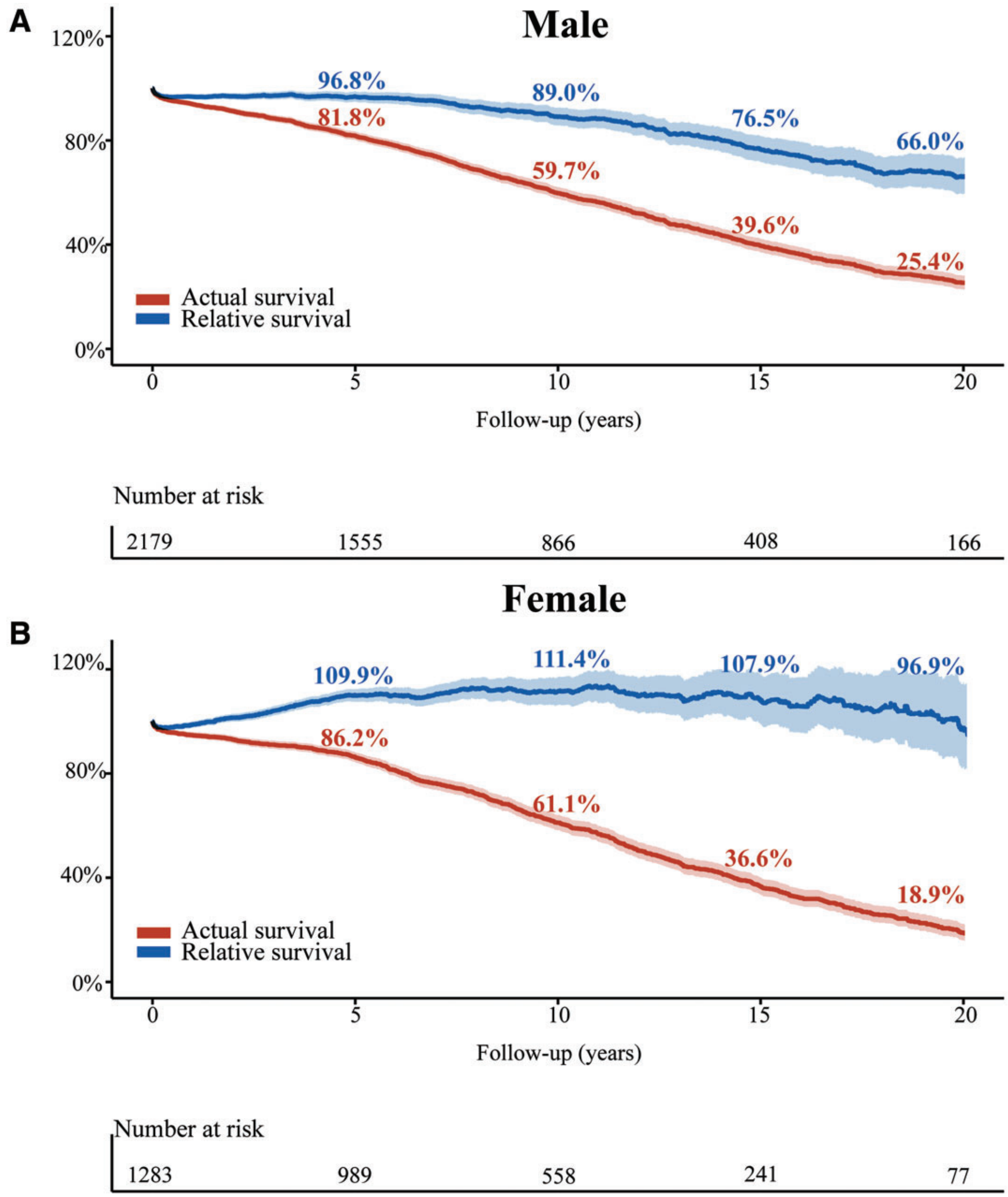


Figure 3: Survival in male and female patients and the relative age, and calendar-year-matched population in the overall cohort. (**A**) Survival in the male cohort. Red line represents actual survival in male patients. Blue line represents the age-, sex- and calendar-year-matched Dutch cohort. (**B**) Survival in the female cohort. Red line represents actual survival in female patients. Blue line represents the age-, sex- and calendar-year-matched Dutch cohort.

undergoing SAVR ± CABG highlight the importance of understanding the sex-related differences in patients undergoing SAVR. In this study, we identified 4 major findings of interest (i) female patients had more cardiovascular risk factors at presentation, (ii) the difference in hypertension remained after age-matching, whereas the difference in other cardiovascular risk factors disappeared, (iii) long-term survival rates are comparable between female and male patients and (iv) the long-term survival after SAVR is exceptionally higher in female patients than in the age-, sex- and year-matched Dutch population.

Males and females differ psychologically, based on, among others, biological endowments, effects of sex-related hormones and physical activity. Women tend to develop cardiovascular disease later on in life compared to men, which is explained by differences in the distribution of baseline risk factors and age-related changes of aforementioned; subsequently, the prevalence of comorbidities is higher in males than in females [14]. Men are also more likely to have had a history of MI or percutaneous coronary revascularization, which is in line with current evidence regarding patients undergoing CABG [15]. Furthermore, female patients more often present in a later stage of disease, and maladaptive LV remodelling occurs less frequently in female patients, leading to better postoperative hypertrophy reversibility with subsequent better survival [16–18]. Female patients are also known to present with higher transaortic valve gradients, lower effective aortic valve orifice areas and higher prevalence of cardiac decompensation at the time of referral [19]. Female patients also tend to have smaller aortic annuli and, therefore, receive smaller implanted aortic valves; this had been also noted in earlier studies and has been shown to exhibit higher surgical risk

Table 2: Survival after surgical aortic valve replacement in female patients

	N	Survival (%)						
		1 year	5 years	10 years	15 years	20 years	25 years	30 years
Overall	1283	94.7	86.2	61.1	36.6	18.9	8.8	3.3
Age								
<50	78	93.4	93.4	88.1	68.5	53.6	45.9	13.8
50–59	121	98.3	95.7	85.8	71.5	55.5	39.2	31.4
60–69	336	97.9	88.7	69.4	53.2	32.5	9.8	0
70–79	605	93.1	84.1	55.5	24.6	6.6	1.4	–
≥80	143	91.4	77.2	30.8	7.3	–	–	–
Bioprosthetic	728	94.8	84.7	56.0	27.4	5.4	–	–
Mechanical	525	94.6	88.3	68.0	47.2	30.6	15.8	–
Surgery								
Isolated AVR	903	95.9	88.8	66.7	42.8	23.7	11.9	4.5
Bioprosthetic	517	96.3	87.4	60.0	31.2	5.6	–	–
Mechanical	386	95.5	90.6	74.8	54.9	37.3	19.9	7.6
AVR with CABG	380	91.7	80.0	48.0	22.3	8.0	2.2	–
Bioprosthetic	241	91.6	79.1	47.7	19.8	4.5	–	–
Mechanical	139	91.9	81.7	48.8	25.7	12.2	4.6	–
Risk								
High risk (LES ≥20)	26	80.3	68.0	28.3	22.7	–	–	–
Intermediate risk (LES 10–20)	107	92.4	80.6	45.5	13.7	–	–	–
Low risk (LES <10)	557	97.4	90.6	68.7	43.0	–	–	–

CABG: coronary artery bypass grafting; LES: logistic European System for Cardiac Operative Risk Evaluation.

profile in both SAVR and transcatheter aortic valve implantation (TAVI) [20, 21]. This in combination with equally prevalent heart disease in men and women [1], late presentation subsequently leads to surgical undertreatment of and worse outcomes in cardiovascular patients [22].

Generally, female patients do have a more prolonged overall survival after general cardiac surgery as well as CAGB. In our study, the comparable survival in female patients was consistent throughout the 20-year study period. This finding, however, may be explained by the demographic background of the general population in the Netherlands. Whereas the mean life expectancy of men currently is 80 years, it is 83 years for women. Female patients live longer in general and the patients' longevity might be better after alleviating the valvular problem. As seen in the initial postoperative period, relative survival compared to the Dutch-matched population seems excellent. In multivariable analyses, the presence of cardiovascular risk factors such as increasing age, diabetes, hypertension, hypercholesterolaemia, arterial disease and AF were predictors of mortality in the age-matched female population [23]. Furthermore, in our cohort, female patients received smaller prostheses. We did not assess for prosthesis–patient mismatch. However, prosthesis–patient mismatch is a well-known predictor of mortality and outcomes following SAVR and TAVI [24–26].

Two large multicentre trials have addressed male–female differences in the past [27, 28]. In the study of Glaser *et al.* [27], long-term survival up to 19 years of follow-up is depicted and shown to be great in overall after SAVR; we further expand upon those data and show survival data of up to 30 years of follow-up post-SAVR. In addition, we depict survival according to surgical risk strata (according to the logistic European System for Cardiac Operative Risk Evaluation), which can be benchmarked against the current TAVI use. The very well-performed study published by Hernandez-Vaquero is focused on the younger population, patients aged 50–65 years. We tried to build upon those 2 studies and depict data regarding the whole population, with a very large window of inclusion, and subsequently, as mentioned here above, very long-term results. Furthermore, to account for the difference in age, subsequent cardiovascular-associated effects of age of presentation [29], we accounted for age as variable and exactly matched on age to perform analysis on an age-matched group. However, the perceived differences in less-prevalent systemic cardiovascular risk factors remained in the age-matched cohort, highlighting the sex-related differences in male and female patients undergoing SAVR with or without CABG, despite being of the same age.

Current emerging data are demonstrating positve outcomes for TAVI, especially in female patients compared to male patients [30]. A large report from the ACC/TVT registry examined sex differences among 11 808 patients who underwent TAVI and found no difference in in-hospital mortality in women versus men after TAVI but significantly better 1-year survival in female patients versus male patients (adjusted hazard ratio: 0.73; 95% confidence interval, 0.63–0.85; $P < 0.001$) [30]. Similarly, in a patient-level meta-analysis including 11 310 patients, women had similar mortality compared with men at 30 days but had significantly better long-term survival (adjusted hazard ratio: 0.79; 95% confidence interval, 0.73–0.86; $P = 0.001$), despite higher rates of in-hospital complications [31]. However, this earlier demonstrated survival benefit associated with female sex identified in previous studies might diminish, due to the recent availability of larger valves (e.g. the 29-mm size), and the lack of earlier standardization for pre-procedural multidetector CT imaging both subsequently leading to paravalvular leakage and unsuitable valve sizes associated with increased mortality [32].

Limitations

Our study has multiple limitations. Our study is retrospective and single centre, which has its inherent shortcomings related to data capture, changes in definitions of comorbidities and patients being lost to follow-up, especially with a 30-year follow-up. Second, female patients tend to present later, we did not have data regarding initial presentation for the aortic valvular pathology and timing of AVR between females and males. Furthermore, other aspects of clinical outcome and specific valve-related outcomes, including symptom improvement, quality of life and structural valve dysfunction, was not uniformly assessed and need to be investigated in a prospective setting.

CONCLUSIONS

Women undergo less SAVR than men. Women also have a distinct risk profile, which poses unique challenges for surgical treatment of the diseased valve. Nevertheless, despite our data shown that women tend to be older and have more comorbidities than men, women tend to have similar mortality rates and benefit from these procedures.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *ICVTS* online.

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DATA AVAILABILITY

Data will not be made available to others.

Author contributions

Mevlüt Çelik: Conceptualization; Data curation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing. **Milan Milojevic:** Investigation; Methodology; Visualization; Writing—original draft; Writing—review & editing. **Andras P. Durko:** Conceptualization; Investigation; Methodology; Visualization; Writing—original draft; Writing—review & editing. **Frans B.S. Oei:** Conceptualization; Supervision; Writing—original draft; Writing—review & editing. **Ad. J.J.C. Bogers:** Conceptualization; Investigation; Methodology; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing. **Edris A.F. Mahtab:** Conceptualization; Investigation; Methodology; Supervision; Validation; Visualization; Writing—original draft; Writing—review & editing.

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