

Original Article

Is Transcatheter Aortic Valve Replacement Futile in Patients Over Ninety Years of Age?

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Objectives : 1 Determine the survival benefit of nonagenarians undergoing TAVR to those with medical treatment (MT), and general population.
2 Assess the improvement and evolution of quality of life in the TAVR patients.

Methods : Retrospective cohort study of patients evaluated for TAVR in a single tertiary center comparing TAVR vs. MT and TAVR vs. matched general provincial population

Findings

TAVR vs. MT (n=171) (n=84)	General provincial population (matched: age, sex, year of referral)	Quality of Life
 MT: More CAD & less dyslipidemia  Better survival than MT Adjusted HR [95%CI] for MT vs. TAVR: 1.99 [1.37-2.88], p<0.001	 Better survival with TAVR (up to 12.5% at 3 years)	 6MWT  KCCQ/DASI  EuroQol - 5D Sustained improvement up to 1-year post-intervention

Conclusions : Nonagenarians should not be rejected from TAVR procedure solely regarding their age as the benefit of the procedure could outweigh the risks, and improve long-term survival and quality of life in well selected patients.

Legend: CAD = coronary artery disease; CI = confidence interval; DASI = Duke Activity Status Index; EuroQol - 5D = European Quality of Life 5 dimensions; KCCQ = Kansas City Cardiomyopathy Questionnaire; HR = hazard ratio; TAVR = transcatheter aortic valve replacement; 6MWT = 6-min walk test.

ABSTRACT

Background: Clinical outcomes and quality of life (QoL) indices are not well described after transcatheter aortic valve replacement (TAVR) in patients aged ≥ 90 years.

Methods: We conducted a retrospective cohort study of TAVR among nonagenarian patients between 2008 and 2020. The survival of TAVR

RÉSUMÉ

Introduction : Les résultats cliniques et les indices de la qualité de vie (QoV) après le remplacement valvulaire aortique par cathéter (RVAC) chez les patients ≥ 90 ans ne sont pas bien décrits.

Méthodes : Nous avons réalisé une étude de cohorte rétrospective sur le RVAC chez les patients nonagénaires entre 2008 et 2020. Nous

patients among nonagenarians was compared to the provincial estimated survival for an age- and sex-matched general population. QoL was assessed up to 1 year postintervention, using standardized questionnaires.

Results: During the study period, $n = 268$ patients aged ≥ 90 years were evaluated for severe aortic stenosis. TAVR was performed in $n = 171$ (48% female; median [IQR] Rockwood Clinical Frailty Scale score: 4 [3-4]); $n = 84$ underwent medical therapy; and $n = 13$ underwent surgical aortic valve replacement. Survival was significantly better following TAVR, compared to that after MT (adjusted hazard ratio [95% CI]: 1.99 [1.37-2.88], $P < 0.001$). TAVR patients demonstrated a survival advantage compared with the general population, with an estimated relative mortality of 0.86 (0.75-0.87). TAVR patients showed sustained improvements in functional status and QoL up to 1 year compared to baseline (all $P < 0.05$): the 6-minute walk test results improved from 192 to 252 m; the Kansas City Cardiomyopathy Questionnaire score improved from 64 to 81; the Duke Activity Status Index score improved from 13 to 16; and the health state scale result of the Euro Quality of life - 5 Dimensions improved from 63% to 74%.

Conclusions: Nonagenarians undergoing TAVR experience a slightly better survival rate, compared to that of an age- and sex-matched general population, and they have significant improvements in functional status and several QoL indices following the procedure.

avons comparé la survie des patients nonagénaires qui avaient subi un RVAC à la survie provinciale estimée d'une population générale appariée selon l'âge et le sexe. Nous avons évalué la QdV jusqu'à 1 an après l'intervention au moyen de questionnaires standardisés.

Résultats : Durant la période étudiée, nous avons inclus des patients ($n = 268$) âgés de ≥ 90 ans et évalués pour une sténose aortique sévère. Le RVAC a été réalisé chez 171 patients (48 % de sexe féminin; score médian [écart interquartile] à l'échelle de fragilité clinique de Rockwood [Rockwood Clinical Frailty Scale] : 4 [3-4]); 84 ont reçu un traitement médical (TM); 13 ont subi un remplacement valvulaire aortique chirurgical. La survie était significativement meilleure à la suite du RVAC, comparativement à celle des patients TM (rapport de risque ajusté [IC à 95 %] : 1,99 [1,37-2,88], $P < 0,001$). Par rapport à la population générale, les patients ayant subi un RVAC ont démontré un avantage sur le plan de la survie, soit une mortalité relative estimée de 0,86 (0,75-0,87). Les patients ayant subi un RVAC ont montré des améliorations continues de l'état fonctionnel et de la QdV jusqu'à 1 an par rapport au début (toutes les valeurs $P < 0,05$) : les résultats à l'épreuve de marche de 6 minutes sont passés de 192 à 252 m; les scores au questionnaire Kansas City Cardiomyopathy Questionnaire (KCCQ) sont passés de 64 à 81; les scores au questionnaire Duke Activity Status Index (DASI) sont passés de 13 à 16; les résultats à l'échelle de l'état de santé de l'EQ-5D (de l'EuroQoI Group) sont passés de 63 % à 74 %.

Conclusions : Les nonagénaires qui subissent un RVAC ont un taux de survie légèrement meilleur à celui d'une population générale appariée selon l'âge et le sexe, et montrent des améliorations significatives de leur état fonctionnel et de plusieurs indices de la QdV à la suite de l'intervention.

A 4-fold increase in the number of people aged 85 years and older is expected between 2006 and 2045 in most industrialized countries.¹ The incidence of age-related diseases, such as aortic stenosis (AS), is also expected to rise. Transcatheter aortic valve replacement (TAVR) is a safe and effective therapeutic option for patients with severe AS.²⁻⁴ Interest is growing in clinical outcomes and quality of life following TAVR in very elderly patients with promising data previously published.⁵ Patients aged 90 years and above have been traditionally underrepresented or excluded in prospective and observational TAVR studies,⁶⁻⁸ with some data suggesting that TAVR among nonagenarians is superior to medical therapy for severe symptomatic AS.⁷ However, these previous studies had small numbers of nonagenarian patients and were mainly post hoc subanalyses of larger studies conducted in younger populations. Moreover, the long-term survival benefit following TAVR, compared to survival in the general nonagenarian population without severe AS, remains less certain. Accordingly, if TAVR were to be expanded broadly to patients ≥ 90 years, this would have important implications regarding

healthcare resource allocation and cost-effectiveness. Thus, patient-centred outcomes (ie, quality of life, functional status) in these patients could provide complementary insights regarding the survival benefit of TAVR observed in previous studies, to guide treatment options in this specific population. Our objectives were therefore to describe clinical outcomes, quality of life, and changes in function after TAVR in a cohort of Canadian nonagenarians and to compare these factors to the estimated survival of the age- and sex-matched general population.

Patients and Methods

Study design and population

We conducted a retrospective study including all nonagenarian patients evaluated for severe AS and referred to TAVR or who remained on medical treatment (MT), between 2008 and 2020, at our institution. No specific exclusion criteria were predefined. We thus include all patients ≥ 90 years of age with severe AS, and all patients were evaluated by the multidisciplinary heart team. Demographic, baseline clinical and echocardiographic characteristics, and postoperative data were retrieved from our TAVR database, which collects patient data prospectively for all consecutive patients. The study was approved by our institutional research ethics board, which waived individual patient consent, owing to the retrospective nature of the study (approval number 2021-3627, 22050).

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See page 790 for disclosure information.

During the study period, $n = 268$ patients aged 90 years and above were referred for TAVR at our institution. Of these, $n = 171$ (64%) underwent TAVR, $n = 84$ (31%) were treated medically, and $n = 13$ (5%) were treated with surgical AVR (these patients were excluded from the analysis).

Cognitive, frailty, functional status, and quality-of-life assessments

TAVR patients had several predefined cognitive, frailty, and functional status tests prior to intervention. However, due to various reasons related to clinical considerations, not all patients underwent these tests. Cognitive assessment was accomplished in 70% of patients ($n = 120$) with the use of the Folstein Mini-Mental State Examination on a scale of 0 to 30. An abnormal Folstein examination result was established by any of the following: (i) a score under the predicted value; (ii) according to the following classification—normal (ie, a score of 26-30); mild impairment (ie, a score of 20-25); moderate (ie, a score of 10-19); and severe (ie, a score of 0-9); and (iii) according to level of education (ie, a score < 22 if 0-4 years of education; a score < 26 if 5-8 years of education; and a score < 29 if ≥ 9 years of education).⁹ Frailty was assessed by the “eye-ball” ($n = 132$; 77%) and the Rockwood Clinical Frailty Scale tests ($n = 85$; 49%).^{10,11} Also, the 6-minute walk test (6MWT) was conducted in 65% of patients ($n = 111$).

TAVR patients were also evaluated systematically at 1 to 3 months and 1 year after intervention with functional status assessment (ie, 6MWT) and with various standardized quality-of-life questionnaires, such as the Kansas City Cardiomyopathy Questionnaire (KCCQ),¹² the Duke Activity Status Index (DASI),¹³ and the Euro Quality of Life - 5 Dimensions (EuroQoL-5D).¹⁴

Study endpoints

Early and late clinical outcomes were compared between nonagenarian TAVR patients and medically treated patients. Long-term survival data of nonagenarians undergoing TAVR were compared to the age- and sex-matched general nonagenarian population survival for the specific year of the TAVR procedure, using data retrieved from Statistics Canada.¹⁵

Late deaths were ascertained by linking the institutional database with vital statistics compiled by the single provincial government healthcare insurer; thus, follow-up was 100% complete. The clinical outcomes of interest in this study among TAVR patients were defined according to the Valve Academic Research Consortium-2 (VARC-2) consensus definitions.¹⁶

Statistical analysis

Categorical variables are described as counts and percentages. Continuous data were tested for normality of distribution and homogeneity of variances with the Shapiro-Wilk and Levene tests, respectively, and then expressed as mean \pm standard deviation or median (interquartile range [IQR]), as appropriate. For baseline characteristics, comparisons between groups were made using either χ^2 tests or Fisher's exact tests, and the Student t test or the Wilcoxon Mann-Whitney U test, as appropriate. Survival curves using the Kaplan-Meier test and the log-rank test were obtained to compare TAVR patients to MT patients and to nonagenarians from the general

population. For the latter, survival was compared to age- and sex-specific life expectancy of the general provincial population at the year of the TAVR procedure. Univariate and multivariate Cox proportional hazard models of late mortality were performed among TAVR and MT patients, and results are presented as hazard ratio (HR) and 95% confidence interval (CI). Multivariate adjustment included all variables with a $P < 0.10$ in univariate analysis for the prediction of mortality. Analysis of quality of life (QoL) in TAVR patients at follow-up was performed with either a paired t -test or a Wilcoxon signed-rank test, for continuous variables, and the McNemar-Bowker test, for categorical variables. Patients with missing data were excluded from these analyses. A P -value of < 0.05 was considered statistically significant. All analyses were performed using SPSS (V.27, IBM, Chicago, IL) and SAS (V.9.4, SAS Institute, Cary, NC) software.

Results

Among the 84 patients who did not undergo TAVR and instead were redirected toward MT, the breakdown is as follows: 45 patients were offered TAVR but refused the procedure, 17 patients were considered to be too frail for the procedure after a standardized assessment, and 22 patients had prohibitive noncardiovascular comorbidities. No patients had important life expectancy-limiting illnesses, such as active cancer. Baseline characteristics of the study population are presented in Table 1. TAVR patients are 48% of female patients with several comorbidities, a median (IQR) European System for Cardiac Operative Risk Evaluation II (EuroSCORE II) of 6.0% (4.4%-9.8%), and 11% had mild cognitive impairment. According to the Rockwood Clinical Frailty Scale, TAVR patients were considered mildly frail (median [IQR]: 4 [3-4]). The TAVR and MT groups were comparable, except for a significantly higher prevalence of dyslipidemia (71% vs 57%, $P = 0.031$), and a significantly lower prevalence of coronary artery disease (57% vs 70%, $P = 0.037$), among the TAVR patients. Echocardiographic data were similar in the 2 groups, with the exception of higher systolic pulmonary artery pressure in the TAVR patients (48 ± 15 vs 42 ± 16 mm Hg, $P < 0.001$).

TAVR early outcomes

The periprocedural data and early outcomes, including postprocedural echocardiographic data, are depicted in Table 2. In-hospital mortality was observed in $n = 11$ patients (6%), and $n = 9$ (5%) had an early stroke or transient ischemic attack. The transfemoral approach was performed in $n = 123$ patients (72%), and in $n = 48$ patients (28%) an alternative approach was used, mostly transcatheter. Balloon-expandable prostheses were used in $n = 128$ patients (75%), and self-expandable prostheses were used in $n = 43$ (25%). Aortic valve predilatation was performed in $n = 76$ patients (51%), and $n = 21$ (12%) had postdilatation.

TAVR vs MT late survival

Survival up to 5 years was compared between the TAVR and MT groups, demonstrating a survival benefit of TAVR at 5 years (63% vs 23%, log-rank $P < 0.001$) (Figure 1). In univariate analysis, MT vs TAVR (HR 2.27 [95% CI: 1.57-3.26], $P < 0.001$), age (HR 1.29 [95% CI: 1.10-1.52], $P =$

Table 1. Baseline characteristics of the study population

Variable	TAVR (n = 171)	Medical treatment (n = 84)	P
Clinical data			
Age, y	91 ± 2	92 ± 2	0.11
Female	82 (48)	46 (55)	0.31
BMI, kg/m ²	25 ± 4	25 ± 5	0.70
BSA, m ²	1.71 ± 0.17	1.71 ± 0.18	0.76
History of stroke/TIA	22 (13)	18 (21)	0.08
Diabetes	26 (15)	20 (24)	0.09
Dyslipidemia	121 (71)	48 (57)	0.031
Arterial hypertension	151 (88)	69 (82)	0.18
COPD	22 (13)	14 (17)	0.41
Coronary artery disease	97 (57)	59 (70)	0.037
History of myocardial infarction	48 (28)	23 (27)	0.91
< 90 d	18 (11)	9 (11)	0.96
History of atrial fibrillation/flutter	75 (44)	31 (37)	0.29
Peripheral vascular disease	34 (20)	12 (14)	0.28
Cognitive impairment	4 (2)	5 (6)	0.16
EuroSCORE II, %	6.0 (4.4–9.8)	5.7 (3.3–8.8)	0.08
Cognitive status			
Folstein absolute score (n = 120)	28 (27–29)	—	—
Normal	107 (89)	—	—
Mild impairment	13 (11)	—	—
Moderate/severe impairment	0 (0)	—	—
Abnormal vs predicted Folstein	6 (2)	—	—
Abnormal vs education level (n = 101)	27 (27)	—	—
Frailty assessment			
Eyeball test (n = 132)	76 (58)	—	—
Rockwood Clinical Frailty Scale score (n = 85)	4 (3–4)	—	—
Score ≥ 5	16 (19)	—	—
Functional status			
6-min walk test distance, m (n = 111)	187 ± 86	—	—
Laboratory data			
Creatinine clearance (Cockcroft-Gault, mL/min)	36 (30–45)	37 (29–52)	0.54
< 60 mL/min	165 (97)	56 (89)	0.05
Creatinine level, μmol/L	96 (75–119)	103 (73–132)	0.31
Echocardiographic data			
LVEF, %	52 ± 13	50 ± 15	0.58
Indexed AVA, cm ² /m ²	0.36 ± 0.12	0.38 ± 0.17	0.37
SPAP, mm Hg	48 ± 15	42 ± 16	< 0.001
≥ moderate AR	30 (18)	13 (16)	0.68
≥ moderate MR	45 (26)	27 (32)	0.33
≥ moderate TR	41 (24)	17 (20)	0.50

Values are mean ± standard deviation, median (25th–75th percentile), or n (%). Bold text highlights the statistically significant associations.

AR, aortic regurgitation; AVA, aortic valve area; BMI, body mass index; BSA, body surface area; COPD, chronic obstructive pulmonary disease; EuroSCORE II, European system for cardiac operative risk evaluation; Folstein, Folstein Mini-Mental State Examination; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; SPAP, systolic pulmonary artery pressure; TAVR, transcatheter aortic valve replacement; TIA, transient ischemic attack; TR, tricuspid regurgitation.

0.002), diabetes (HR 1.75 [95% CI: 1.14–2.69], *P* = 0.011), and arterial hypertension (HR 1.61 [95% CI: 1.03–2.52], *P* = 0.038) were associated with an increased risk of late mortality (Table 3). After multivariate adjustment, MT was associated with an increased risk of late mortality in these patients (HR 1.99 [95% CI: 1.37–2.88], *P* < 0.001; Table 3).

TAVR patients vs general population late survival

In the secondary analysis comparing TAVR to the general population of nonagenarians in the Canadian province of Quebec, the survival rate post-TAVR was higher than the expected survival rate for the general population when adjusted for year of procedure, age, and gender (Fig. 2), with a cumulative relative mortality of 0.86 (0.75–0.87). Thus, this difference represents the relative “excess” mortality

compared to general population, which is thereby < 1. The ratios of the estimated (ie, observed in TAVR patients) survival rate over the expected one (ie, for the general population) according to the years after TAVR are shown in Figure 3.

Improvements in quality of life of TAVR nonagenarian patients

In paired analyses, TAVR nonagenarian patients showed significant improvements from baseline to 1–3 months in functional status in the 6MWT (192 ± 84 vs 259 ± 102 m, *P* < 0.05), and in QoL, as assessed by the KCCQ (64 [52–73] vs 79 [68–91], *P* < 0.05), the DASI (13 ± 7 vs 16 ± 10, *P* < 0.05), and various aspects of the EuroQoL-5D questionnaire and the global health state scale (63% ± 16% vs 71% ± 15%,

Table 2. Procedural data and postoperative outcomes in the transcatheter aortic valve replacement (TAVR) population

Variable	TAVR (n = 171)
Access	
Transfemoral	123 (72)
Alternative	48 (28)
Predilatation	76 (51)
Postdilatation	21 (12)
TAVR valve-in-valve	4 (2)
Valve type	
Balloon-expandable	128 (75)
Self-expanding	43 (25)
Valve size, mm	
20–23	51 (30)
25–26	77 (45)
27–29	38 (22)
34	5 (3)
Hospital LOS, d	5 (3–7)
Postoperative echocardiographic data	
LVEF, %	53 ± 12
AVA, m ² (n = 137)	1.62 ± 0.51
Mean gradient, mm Hg	10 ± 5
Pulmonary systolic arterial pressure, mm Hg	45 ± 14
Complications at 30 d	
Death	11 (6)
Stroke/TIA	9 (5)
Surgical conversion	5 (3)
Significant periprosthetic insufficiency	5 (3)
Pacemaker implantation	7 (5)
Acute kidney insufficiency	14 (8)
Pulmonary embolus	3 (2)
Pleural effusion	4 (2)
Heart conduction deficits/arrhythmias	
Atrioventricular block	15 (9)
Atrial fibrillation de novo	11 (6)
Left bundle block	22 (13)

Values are mean ± standard deviation, median (25th–75th percentile), or n (%).

AVA, aortic valve area; LOS, length of stay; LVEF, left ventricular ejection fraction; TIA, transient ischemic attack.

$P < 0.05$; Table 4). These observations of functional status and QoL improvements were significantly maintained up to 1

year without being significantly different than those at the 1–3 month follow-up.

Discussion

TAVR improvements observed during the past decades have led to increasing use of this procedure in many subgroups of patients with severe AS. The survival benefit of TAVR in very elderly patients, such as nonagenarians, has been established previously, but questions remain, as advanced age inherently is related to a lower life expectancy, and current guidelines do not provide definitive recommendations regarding this specific population. Although previous studies have demonstrated superiority of TAVR compared to MT in nonagenarians, they were limited by small numbers and the inherent limitations of national databases. Other studies have shown that nonagenarians undergoing TAVR are at increased risk of mortality during hospital admission and at 30 days, compared with younger patients.^{5,17} Thus, the potential futility of TAVR in the very elderly has been a concern, even as iterative improvements in both TAVR technology and patients' postintervention outcomes continue to be noted.¹⁸ Moreover, QoL improvement and functional status of patients who undergo TAVR remain subjects of interest, especially in elderly patients.^{19–21} In fact, these patient-centred outcomes of health status are very important in this elderly population, sometimes as important as survival benefit, and thus could help guide clinicians in their preoperative evaluation.

Survival with TAVR vs MT

This study demonstrated that TAVR is associated with improved survival among nonagenarians, compared to MT, after multivariate adjustment. These results observed in a “real-life” single-centre cohort are consistent with those of previous studies of TAVR in high-risk surgical patients and nonagenarians.^{6,7,22,23} Nevertheless, nonagenarians remain at higher risk of complications than younger patients, reinforcing the need for a careful patient selection process,^{7,17,24–28} including preoperative frailty assessment.^{29–31}

Survival with TAVR vs in the general population

When comparing survival of TAVR nonagenarian patients with the life expectancy of the general population of the same age, gender, and according to the year the TAVR was performed, we demonstrated a survival benefit of up to 12.5% at approximately 3 years. These results suggest that TAVR may confer an improvement in cardiovascular health status that translates into better long-term functional capacity and survival. Zadrozny et al. previously showed similar 2-year survival in the general population vs nonagenarians, but they used an average mortality and not a direct age-, sex-, and year of referral-matched comparison.³² This difference is a potential explanation for the current results, as improvements in TAVR technology during the years may have contributed to creating this survival benefit. Another possible explanation for these results may be related to the fact that the nonagenarians undergoing TAVR are highly selected and are those with few life expectancy-limiting comorbidities in addition to the AS. As shown by a number of studies, nonagenarians undergoing

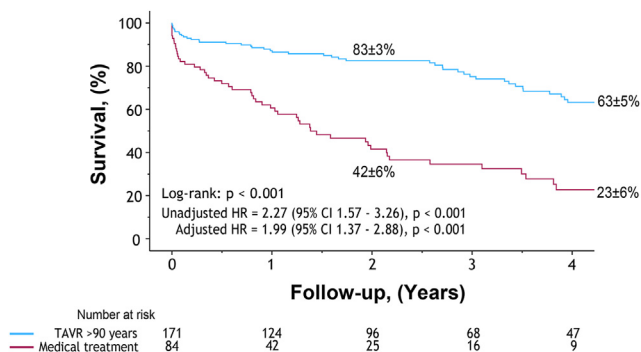


Figure 1. Survival benefit of transcatheter aortic valve replacement (TAVR), compared with medical treatment, in nonagenarian patients. Kaplan-Meier survival curves of nonagenarian patients who underwent TAVR (blue), compared to medical treatment (burgundy). CI, confidence interval; HR, hazard ratio.

Table 3. Cox proportional hazard models

Variable	Univariable analysis		Multivariable analysis	
	HR (95% CI)	P	HR (95% CI)	P
Medical treatment vs TAVR, age ≥ 90 y	2.27 (1.57–3.26)	< 0.001	1.99 (1.37–2.88)	< 0.001
Age, increment 2 y	1.29 (1.10–1.52)	0.002	1.32 (1.10–1.57)	0.002
Female sex	0.92 (0.64–1.32)	0.64	0.98 (0.67–1.42)	0.90
NYHA class III/IV vs I/II	1.34 (0.89–2.00)	0.16	—	—
History of stroke/TIA	1.26 (0.81–1.96)	0.30	—	—
Dyslipidemia	1.26 (0.86–1.85)	0.23	—	—
Diabetes	1.75 (1.14–2.69)	0.011	2.06 (1.29–3.29)	0.003
Arterial hypertension	1.61 (1.03–2.52)	0.038	1.89 (1.17–3.03)	0.009
COPD	1.41 (0.88–2.26)	0.16	—	—
Coronary artery disease	1.07 (0.73–1.54)	0.75	—	—
Atrial fibrillation/flutter	0.94 (0.65–1.36)	0.73	—	—
Creatinine clearance < 60 mL/min	0.86 (0.43–2.01)	0.86	—	—
Carotid stenosis	0.83 (0.39–1.80)	0.64	—	—
SPAP, increment 5 mm Hg	0.96 (0.90–1.02)	0.20	—	—

Text in bold highlights the statistically significant associations.

CI, confidence interval; COPD, chronic obstructive pulmonary disease; HR, hazard ratio; NYHA, New York Heart Association; SPAP, systolic pulmonary artery pressure; TAVR, transcatheter aortic valve replacement; TIA, transient ischemic attack.

TAVR have lower surgical risk scores (EuroSCORE II and Society of Thoracic Surgery Predicted Risk of Mortality [STS-PROM]) than younger patients undergoing TAVR.^{7,17} Nonagenarians undergoing TAVR have a lower prevalence of lung disease, diabetes, coronary artery disease, and obesity than younger patients, but they have a higher rate of heart failure and slightly more severe echocardiographic criteria for AS.^{7,17} Further studies are required to confirm these observations in other populations, but nonetheless, nonagenarians seem to have reasonable survival with TAVR if selected appropriately by a multidisciplinary heart team.

QoL improvements

We have shown an improvement in QoL objective indices among nonagenarians undergoing TAVR. Few studies have demonstrated an improvement in either KCCQ score or an adapted version of the EuroQol-5D questionnaire, but these were performed in smaller numbers of patients.^{21,33} Moreover,

as suggested in a study on cardiac resynchronization therapy,³⁴ older patients should not be refused an optimal therapy based solely on their age and the limited potential survival benefit associated with advanced age. For nonagenarians, QoL and functional status improvements may result in a longer time period with autonomy. Improvements in mobility and general state of health, as demonstrated in our study, are therefore of foremost importance in nonagenarians. Frailty in nonagenarians remains a concern because TAVR complications can have a devastating impact on the ability of these patients to perform daily living activities. Thus, careful consideration prior to TAVR referral needs to address the potential futility of the procedure in a given patient. Even though, in the present study, we demonstrate survival benefit and improvement in QoL indices, in some other cases, the preoperative cognitive impairments, comorbidities, and frailty status may outweigh the potential benefit of TAVR, in terms of symptoms improvement. Moreover, potential new-onset arrhythmias/conduction deficits or other complications (eg, stroke, acute kidney injury) related to TAVR could lead to a rapid decline in functional and

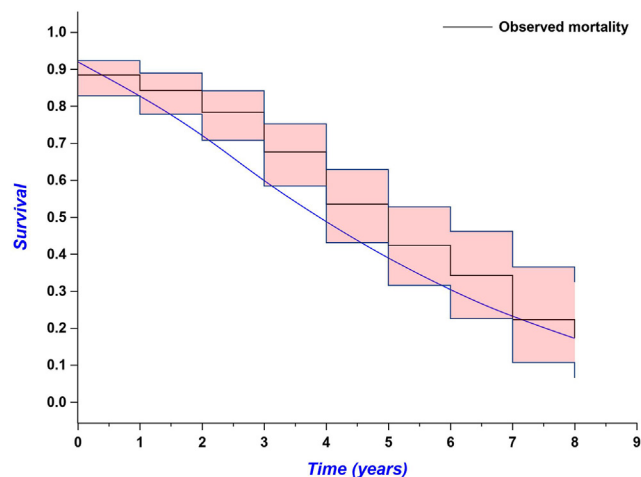


Figure 2. Survival comparison of nonagenarian patients undergoing transcatheter aortic valve replacement with the age- and sex-matched general provincial population. Observed survival (black) after the procedure, compared to the expected mortality (blue) of the general population.

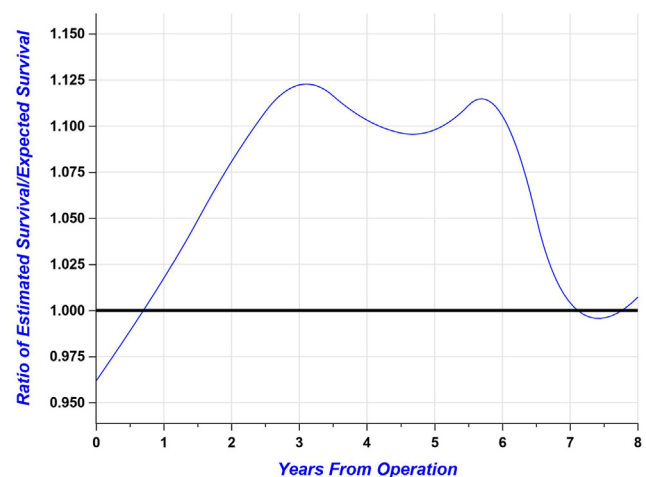


Figure 3. Survival ratio of the observed survival (TAVR treated patients) over expected survival (age- and sex-matched provincial general population) in severe AS patients.

Table 4. Functional status and quality of life during follow-up in nonagenarians who underwent TAVR.

Variable	Baseline	1–3 mo	1 y
Functional status			
6-min walk test distance, m	192 ± 84 (n = 96)	259 ± 102* (n = 63)	252 ± 97* (n = 56)
Quality of life			
KCCQ score	64 (52–73) (n = 109)	79 (68–91)* (n = 74)	81 (70–94)* (n = 53)
DASI score	13 ± 7 (n = 131)	16 ± 10* (n = 101)	16 ± 9* (n = 108)
Euro Quality of Life - 5 Dimensions questionnaire	(n = 131)	(n = 103)	(n = 101)
Mobility ≥ 2	51 (39)	46 (45)	52 (52)*
Self-care ≥ 2	22 (17)	18 (17)	21 (21)
Activities ≥ 2	76 (58)	44 (43)*	42 (42)*
Pain ≥ 2	47 (36)	39 (38)	38 (38)
Anxiety ≥ 2	28 (21)	26 (25)	16 (16)
Health state scale, %	63 ± 16	71 ± 15*	74 ± 15*

Values are mean ± standard deviation, median (25th–75th percentile), or EuroQoL-5D score (n).

DASI, Duke Activity Status Index; KCCQ, Kansas City Cardiomyopathy Questionnaire.

*Significant paired difference vs baseline, $P < 0.05$.

QoL status in a nonagenarians patient treated with TAVR. Nonetheless, our study suggests that TAVR can be performed safely in well-selected and mildly frail nonagenarians, with a low incidence of procedural complications.

Limitations

Due to the retrospective nature of the study, a selection bias for nonagenarian patients undergoing TAVR cannot be entirely ruled out, as the patients who were more likely to survive were probably directed to TAVR after referral to the heart team, compared to patients directed to MT. However, a near-60% survival rate at 5 years among nonagenarian TAVR patients, and improved survival compared to an age- and gender-matched general population of nonagenarians, suggests that the selection process of an expert heart team is associated with excellent outcomes in this specific patient subgroup. Frailty assessment was available only for TAVR patients and was accomplished mostly by the “eyeball” test, which limits our assessment of the differences in risk profile between MT and TAVR patients in this specific population, but further studies should make a direct comparison of frailty between these 2 groups and observe the evolution of frailty status during follow-up. Although the Rockwood Clinical Frailty Scale was also available in ~50% of our patients, future studies should use more accurate and reliable quantitative frailty measures, given the known limitations of the “eyeball” assessment.³⁵ Measures of QoL significantly improved post-TAVR, but unfortunately, these were not available for all patients. Nonetheless, paired analyses were used to assess evolution between follow-ups. However, the completeness of the follow-up varies between questionnaires. Patients whose QoL improved the most have a higher probability of participating in such evaluations, which could have artificially enhanced the observed benefit with TAVR. Also, the provincial life-expectancy curves were able to be adjusted for only age and gender. Thus, some important comorbidities, frailty, and potential terminal diseases in the general population were not accounted for in the latter analysis.

Conclusion

Among mildly frail nonagenarians, TAVR is associated with a significant survival benefit, compared with MT, as well as significant improvement in several QoL indices and

function (ie, 6MWT score). These patients experience a slightly better survival rate, compared to that of an age- and sex-matched general population. On the basis of these data and previous reports, nonagenarians should not be denied TAVR based solely on age.

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Ethics Statement

The study was approved by our institutional research ethics board who waived individual patient consent due to the retrospective nature of the study (approval number 2021–3627, 22050).

Patient Consent

Waived due to retrospective nature of this study.

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