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0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2021.12.057

Valve: Research

Outcomes of Surgical Bioprosthetic Aortic Valve Replacement in Patients Aged ≤65 and >65 Years

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ABSTRACT

BACKGROUND Implantation of a bioprosthetic valve is a reasonable choice for patients aged > 65 years. For middle-aged patients there is less certainty about whether a mechanical or bioprosthetic valve is best.

METHODS The Pericardial Surgical Aortic Valve Replacement (PERIGON) Pivotal Trial is evaluating the safety and efficacy of the Avalus bioprosthesis (Medtronic). We evaluated clinical and echocardiographic outcomes through 5 years of follow-up, stratified by age ≤ 65 and >65 years.

RESULTS Two hundred seventy-one patients (24.2%) were ≤65 years old and 847 (75.8%) >65 years old. Most patients in both groups were men (217 [80.1%] vs 623 [73.6%], respectively; $P = .031$). Younger patients had a lower Society of Thoracic Surgeons risk of mortality (1.1% ± 0.9% vs 2.2% ± 1.4%, $P < .001$), better baseline New York Heart Association class ($P = .004$), and fewer comorbidities than older patients. At 5 years mortality was lower among younger than older patients (5.3% vs 14.0%, $P < .001$) and no cases of structural valve deterioration occurred in either group. Effective orifice area was similar between age groups ($P = .11$), and mean gradient was 13.9 ± 5.4 vs 12.0 ± 4.1 mm Hg ($P < .001$). Multivariable linear regression identified several parameters associated with mean aortic gradient at 5 years, including baseline age and mean aortic gradient, discharge stroke volume index and EOA, and implanted valve size. Ninety-five percent of patients were in New York Heart Association class I/II through 5 years in both age groups ($P = .85$).

CONCLUSIONS Findings from this analysis demonstrate satisfactory safety, hemodynamic performance, and durability of the Avalus bioprosthesis through a 5-year follow-up in patients aged ≤ 65 and >65 years.

(Ann Thorac Surg 2023;116:483-91)

Patients who require aortic valve replacement (AVR) may undergo implantation with either a mechanical or bioprosthetic valve. The proportion of AVR patients receiving a bioprosthetic valve has

The Supplemental Tables and Supplemental Figure can be viewed in the online version of this article [10.1016/j.athoracsur.2021.12.057] on http://www.annalsthoracicsurgery.org.

Dr Kiaii discloses a financial relationship with Medtronic, Boston Scientific, Johnson & Johnson, and Edwards Lifesciences; Dr Moront with Medtronic, Edwards Lifesciences, and Atricure; Dr Patel with Medtronic; Dr Ruel with Medtronic and MIST Trial (Minimally Invasive Coronary Surgery Compared to STernotomy Coronary Artery Bypass Grafting Trial); Dr. Liu with Medtronic; Dr Klautz with Medtronic, LivaNova, and Edwards Lifesciences; Dr Sabik with PERIGON Pivotal Trial, Medtronic, Intuity Trial (Edwards Lifesciences), and EXCEL Trial (Abbott).

Accepted for publication Dec 14, 2021.

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increased substantially in recent years,[1,2] with the annual volume of transcatheter AVR procedures exceeding the volume of surgical AVR (SAVR) procedures performed in the United States in 2019.[3] Implantation of a bioprosthetic valve is a reasonable choice for patients aged >65 years.[4,5] For patients aged 50 to 65 years, there is less certainty about whether a mechanical or bioprosthetic valve is best.[4,5]

Choosing a surgical valve for middle-aged patients requires that the surgeon and patient weigh the risks and benefits of each valve type and consider patient preferences and lifestyle. Mechanical valves are associated with long-term durability and low rate of reintervention but also with thrombogenecity, need for lifelong anticoagulation, and risk of bleeding complications, which can substantially impact quality of life.[6,7] Bioprosthetic valves do not require lifelong anticoagulation and have much lower risks of thromboembolism and bleeding, but structural valve deterioration (SVD) may occur over time, necessitating reintervention.[9-14] Particularly in younger patients SVD seems to be accelerated.[7,15-17] The development of percutaneous bioprosthetic valves in recent years adds another dimension to a strategy for avoiding both anticoagulation and redo sternotomy.[16,17]

Several studies have reported outcomes achieved with bioprosthetic valves among various age groups.[11,18,19] However, data on outcomes achieved with newer surgical aortic valves in young patients are lacking. The Pericardial Surgical Aortic Valve Replacement (PERIGON) Pivotal Trial is evaluating the safety and efficacy of the Avalus bioprosthesis (Medtronic, Minneapolis, MN), a stented bovine pericardial aortic valve. This article compares clinical and hemodynamic outcomes at 5 years postimplant in patients aged ≤65 and >65 years.

PATIENTS AND METHODS

STUDY DESIGN AND PATIENTS. The PERIGON Pivotal Trial (www.clinicaltrials.gov, NCT02088554), a prospective, nonrandomized study, was designed and conducted in accordance with the Declaration of Helsinki and good clinical practice. The protocol was approved by the institutional review board/ethics committee at each center, and written informed consent was obtained from all patients. The trial is under way at 39 centers in Europe, Canada, and the United States.

The study design was previously described.[20,21] Patients with moderate or severe symptomatic aortic valve stenosis or chronic severe regurgitation and a clinical indication for SAVR were enrolled. Exclusion criteria included a preexisting prosthetic valve or annuloplasty device in another position, need for repair of another heart valve, active systemic infection, anatomic abnormality that increased surgical risk, life expectancy <2 years, or renal failure (defined as dialysis therapy or a glomerular filtration rate <30 mL/min/1.73 m^2). Concomitant procedures were limited (left atrial appendage ligation, coronary artery bypass grafting, patent foramen ovale closure, ascending aortic aneurysm/dissection repair not requiring circulatory arrest, and subaortic membrane resection not requiring myectomy).

Deaths and endpoint-related adverse events were adjudicated by an independent clinical events committee. Study oversight was provided by an independent data and safety monitoring board. An independent core laboratory (MedStar, Washington, DC) evaluated echocardiograms. An independent core lab (CV Path Institute, Gaithersburg, MD) analyzed all explanted study valves that were returned to the sponsor.

PROCEDURE AND VALVE DETAILS. Surgical approach and strategies for cardioplegia and cardiopulmonary bypass were left to the discretion of the surgeon. Valve sizes ranged from 17 to 29 mm; supraannular positioning was recommended. Postimplant anticoagulation followed local practice.

FOLLOW-UP AND ENDPOINTS. The first year after implant clinical and echocardiographic evaluations were performed annually. This analysis evaluated outcomes through 5 years of follow-up. Clinical outcomes were all-cause, cardiac, and valve-related death and valve-related thromboembolism, major bleeding, endocarditis, major paravalvular leak (PVL), SVD, non-SVD, severe hemodynamic dysfunction of indeterminate or evolving cause, reintervention, and explant.[20,21] The severe hemodynamic dysfunction endpoint was used to categorize potential safety events with conflicting or inconclusive information that did not meet the protocol-defined criteria for SVD or non-SVD. Echocardiographic outcomes were mean aortic gradient, effective orifice area (EOA), indexed EOA, cardiac index, left ventricular ejection fraction, and indexed stroke volume. New York Heart Association (NYHA) class was used to assess functional status.

STATISTICAL ANALYSIS. Outcomes were stratified by age ≤65 and >65 years at baseline. Categorical data are reported as frequencies and percentages and were compared using the χ^2 or Fisher exact test. Continuous data are reported as mean ± SD and were compared using the *t* test. The cumulative probabilities (ie, event rates) of mortality and valve-related events through 5 years were analyzed using the Kaplan-Meier method; outcomes were compared using the log-rank test. A Cox proportional hazard regression was performed to determine predictors of mortality at 5 years. The model included age (≤65 vs >65 years); male sex; previous cardiovascular surgery; NYHA at baseline (class I/II vs III/IV); moderate or severe prosthesis-patient mismatch (defined by Valve Academic Research Consortium 3 criteria); prior stroke/cerebrovascular accident; and

baseline atrial fibrillation, hypertension, coronary artery disease, renal dysfunction, and diabetes. A linear regression was performed to determine factors associated with aortic gradient at 5 years. This model included age (≤65 vs >65 years), male sex, baseline body surface area, hypertension, mean aortic gradient, primary indication for valve replacement (stenosis/mixed vs regurgitation/failed prosthesis), prior coronary artery bypass grafting, implanted valve size, and the following measures at the discharge/up to 30 days visit (henceforth called the discharge visit): NYHA class I/II vs III/IV, indexed stroke volume, left ventricular ejection fraction, and EOA. Missing hemodynamic values at the discharge visit were imputed separately for each age group using the median value. For both models stepwise selection was used with *P* set at 0.20 for model entry and 0.15 for remaining in the model. Analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

PATIENT CHARACTERISTICS AND PROCEDURAL INFORMATION. In total, 1288 patients were enrolled (Figure 1) from May 2014 through July 2017 (valve sizes 17-29 mm). An additional sample size for the 29-mm valve is required for U.S. Food and Drug Administration approval; therefore, enrollment was reopened for this valve size in June 2019 and continues. Among the 1118 patients who received an implant, 271 (24.2%) were ≤65 years old and 847 (75.8%) were >65 years old. Mean age was 58.4 ± 7.3 years in the group aged ≤65 and 73.9 ± 5.6 years in the group >65 years. Supplemental Figure 1 shows the distribution of age in 5-year increments. Most patients in both groups were men (≤65 years, 217 [80.1%]; >65 years, 623 [73.6%]; $P = .031$). Younger patients had a lower Society of Thoracic Surgeons risk of mortality ($P < .001$), better baseline NYHA functional class ($P = .004$), and fewer comorbidities than older patients (Table 1). The most common indication for SAVR was aortic stenosis in both groups. Procedural data are reported in Supplemental Table 1.

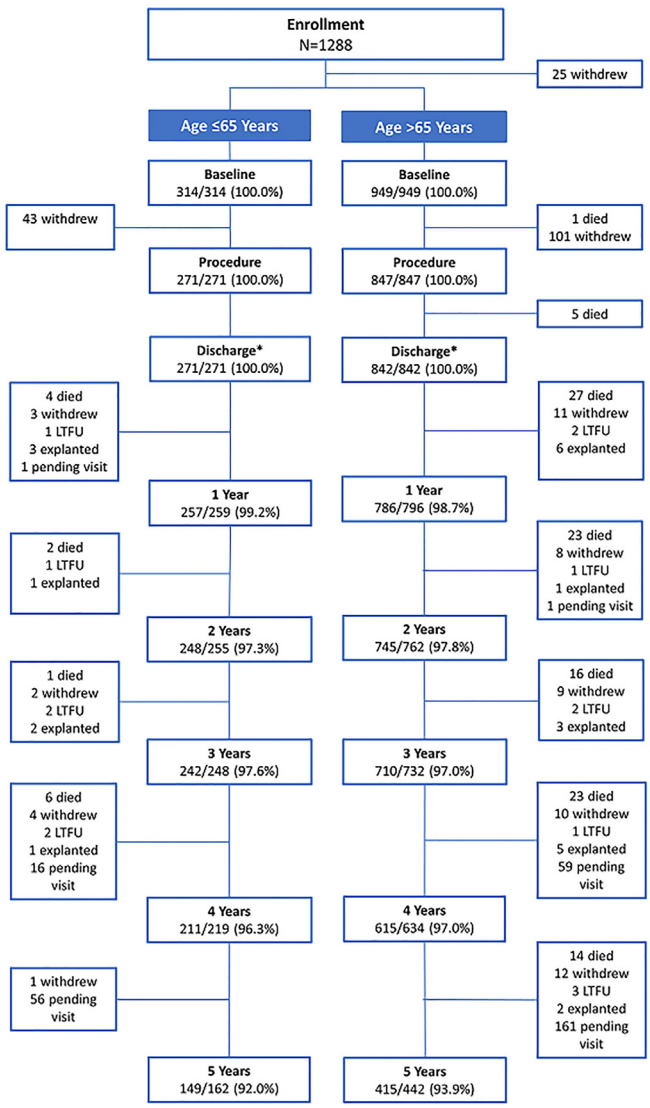

FIGURE 1 Patient disposition through 5 years by ages ≤ 65 and >65 years. Denominators are the number of patients expected at each visit; numerators are the number of patients who completed each visit. Completion of follow-up visits and details on reasons for leaving the study are reported. *Discharge/up to 30 days. (LTFU, long-term follow-up.)

MORTALITY AND VALVE-RELATED ADVERSE EVENTS. The Kaplan-Meier event rate of all-cause mortality at 5 years was 5.3% (3.1%-9.0%) in patients ≤65 years and 14.0% (11.6%-16.8%) in patients >65 years ($P < .001$). Cardiac-related mortality at 5 years was also lower in younger patients ($P = .032$), whereas valve-related mortality was not significantly different between groups ($P = .66$) (Table 2). In patients ≤65 years there were 3 valve-related deaths (1 due to cardiogenic shock, 1 to major hemorrhage, and 1 to valve endocarditis). Twelve deaths in patients >65 years were valve-related (5 due to endocarditis, 3 to anticoagulant-related major hemorrhages, and 1 each to embolic stroke, confirmed sepsis, congestive heart failure, and other). Older age ($P = .005$), preoperative atrial fibrillation ($P < .001$), hypertension ($P = .12$), and renal dysfunction ($P = .001$) were associated with mortality at 5 years of follow-up; moderate or severe prosthesis-patient mismatch at 5 years was not (Supplemental Table 2).

Rates of most valve-related adverse events were similar between groups, including thromboembolism, endocarditis, and reintervention (Figure 2, Table 2). Twenty-seven patients (7 younger, 20 older) underwent redo surgery with explant. The primary reason in both groups was endocarditis (4 patients ≤65 years, 18 patients >65 years).

TABLE 1 Baseline Patient Characteristics by Age ≤65 or >65 Years

Characteristic	Age ≤ 65 Years (n = 271)	Age > 65 Years (n = 847)	P
Age, y	58.4 ± 7.3	73.9 ± 5.6	<.001
Sex			.031
Male	217 (80.1)	623 (73.6)	
Female	54 (19.9)	224 (26.4)	
Body surface area, m^2	2.07 ± 0.22	1.96 ± 0.21	<.001
New York Heart Association class			.004
I	39 (14.4)	84 (9.9)	
II	136 (50.2)	387 (45.7)	
III	91 (33.6)	359 (42.4)	
IV	5 (1.8)	17 (2.0)	
Society of Thoracic Surgeons risk of mortality, %	1.1 ± 0.9	2.2 ± 1.4	<.001
Atrial fibrillation	21 (7.7)	96 (11.3)	.09
Dyslipidemia	136 (50.2)	554 (65.4)	<.001
Hypertension	173 (63.8)	679 (80.2)	<.001
Coronary artery disease	74 (27.3)	413 (48.8)	<.001
Renal dysfunction/insufficiency	19 (7.0)	100 (11.8)	.026
Primary indication			<.001
Aortic stenosis	205 (75.6)	737 (87.0)	
Aortic regurgitation	32 (11.8)	32 (3.8)	
Mixed	33 (12.2)	73 (8.6)	
Failed prosthesis	1 (0.4)	5 (0.6)	

Values are n (%) or mean ± SD.

In patients ≤65 years other reasons for explant were major PVL (n = 1), severe hemodynamic dysfunction of indeterminate/evolving cause (n = 1), and septal myectomy (n = 1). Among patients > 65 years other reasons for explant were major PVL (n = 1) and procedural bleeding (n = 1). Major bleeding was 3.2% (1.6%-6.2%) in younger patients and 6.9% (5.3%-8.9%) in older patients ($P = .028$). Valve thrombosis occurred in 2 patients ≤ 65 years of age; both were treated with oral anticoagulation. Valve thrombosis was reported in 1 patient >65 years old. Severe hemodynamic dysfunction of indeterminant/evolving cause occurred in 2 patients >65 years; both underwent a valve-in-valve procedure. No cases of SVD have occurred in either group (Table 2). Most patients (≥97%) had none/trace PVL through 5 years (Figure 3).

ECHOCARDIOGRAPHIC DATA. At early time points and the 5-year follow-up younger patients had higher mean aortic gradients ($P < .001$), whereas EOA, indexed EOA, cardiac index, left ventricular ejection fraction, and indexed stroke volume did not differ between groups (Table 3). Mean gradients were durable over time in both groups (Supplemental Table 3). Supplemental Tables 4 through 6 provide additional details about echocardiographic outcomes. Several parameters were associated with mean gradient at 5 years: baseline age and mean aortic gradient, discharge stroke volume index and EOA, and implanted valve size (Supplemental Table 7). Prosthesis-patient mismatch at 30 days and 1 year did not differ between groups (Supplemental Table 8).

FUNCTIONAL STATUS. At discharge 48.5% of patients ≤65 years were in NYHA class I and 61.9% of patients >65 years were in class II. At least 95% of patients in both groups were in class I/II at 5 years (Figure 4).

COMMENT

The PERIGON Pivotal Trial is a large prospective series evaluating a new surgical aortic bioprosthesis. Outcomes through 5 years of follow-up among patients aged ≤65

TABLE 2 Mortality and Valve-related Event Rates Through 5 Years

	Kaplan-Meier Event Rate[a]				
	Age ≤ 65 Years (n = 271)		Age > 65 Years (n = 847)		
Event	30 Days	5 Years	30 Days	5 Years	P
No. of patients completing visit	271	149	842	415	
All-cause death	0.0 (NA; 0)	5.3 (3.1-9.0; 13)	1.2 (0.6-2.2; 10)	14.0 (11.6-16.8; 105)	<.001
Cardiac death	0.0 (NA; 0)	2.9 (1.4-6.0; 7)	0.7 (0.3-1.6; 6)	6.8 (5.2-9.0; 49)	.032
Valve-related death	0.0 (NA; 0)	1.3 (0.4-3.9; 3)	0.0 (NA; 0)	1.5 (0.9-2.7; 12)	.66
Thromboembolism	1.1 (0.4-3.4; 3)	5.0 (2.9-8.5; 13)	1.4 (0.8-2.5; 12)	5.8 (4.3-7.7; 44)	.73
Major bleeding	0.0 (NA; 0)	3.2 (1.6-6.2; 8)	1.3 (0.7-2.3; 11)	6.9 (5.3-8.9; 54)	.028
Major paravalvular leak	0.4 (0.1-2.6; 1)	0.4 (0.1-2.6; 1)	0.0 (NA; 0)	0.1 (0.0-0.9; 1)	.4
Endocarditis	0.0 (NA; 0)	4.8 (2.6-8.6; 11)	0.2 (0.1-0.9; 2)	4.3 (3.0-6.1; 31)	.84
Nonstructural valve dysfunction	0.4 (0.1-2.6; 1)	2.9 (1.3-6.6; 6)	0.1 (0.0-0.8; 1)	1.1 (0.5-2.3; 7)	.07
Structural valve deterioration	0.0 (NA; 0)	0.0 (NA; 0)	0.0 (NA; 0)	0.0 (NA; 0)	NA
Severe hemodynamic dysfunction, indeterminate/evolving cause	0.0 (NA; 0)	0.4 (0.1-2.8; 1)	0.0 (NA; 0)	0.3 (0.1-1.1; 2)	.75
Reintervention[b]	0.4 (0.1-2.6; 1)	2.7 (1.3-5.6; 7)	0.4 (0.1-1.1; 3)	3.4 (2.3-5.1; 24)	.76
Explant[b]	0.4 (0.1-2.6; 1)	2.7 (1.3-5.6; 7)	0.4 (0.1-1.1; 3)	2.7 (1.7-4.2; 20)	.90

[a]Subjects may have had >1 event; [b]All events, not only valve-related, are included. Values in parentheses are 95% confidence interval; no. of patients). NA, not applicable.

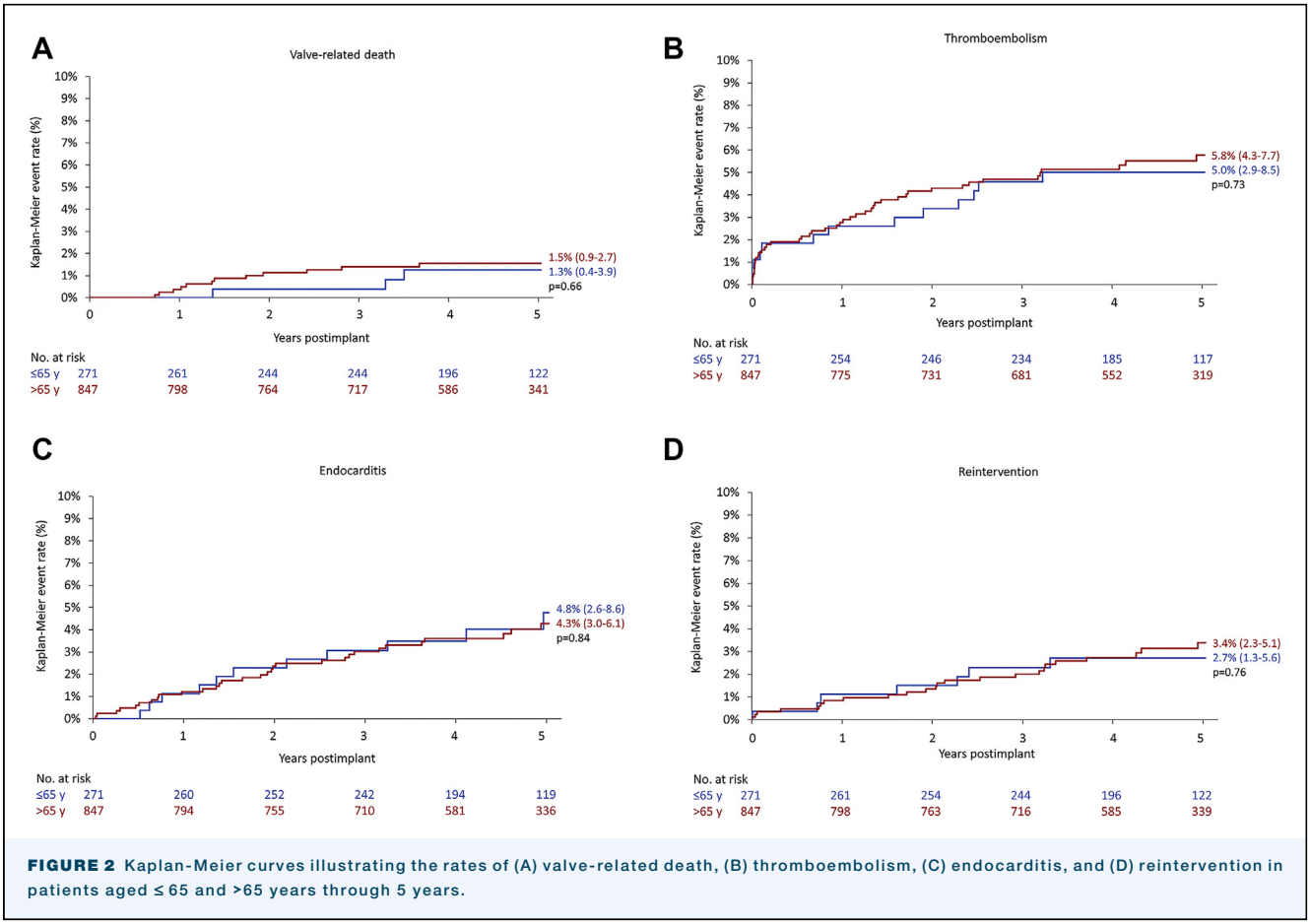

FIGURE 2 Kaplan-Meier curves illustrating the rates of (A) valve-related death, (B) thromboembolism, (C) endocarditis, and (D) reintervention in patients aged ≤ 65 and >65 years through 5 years.

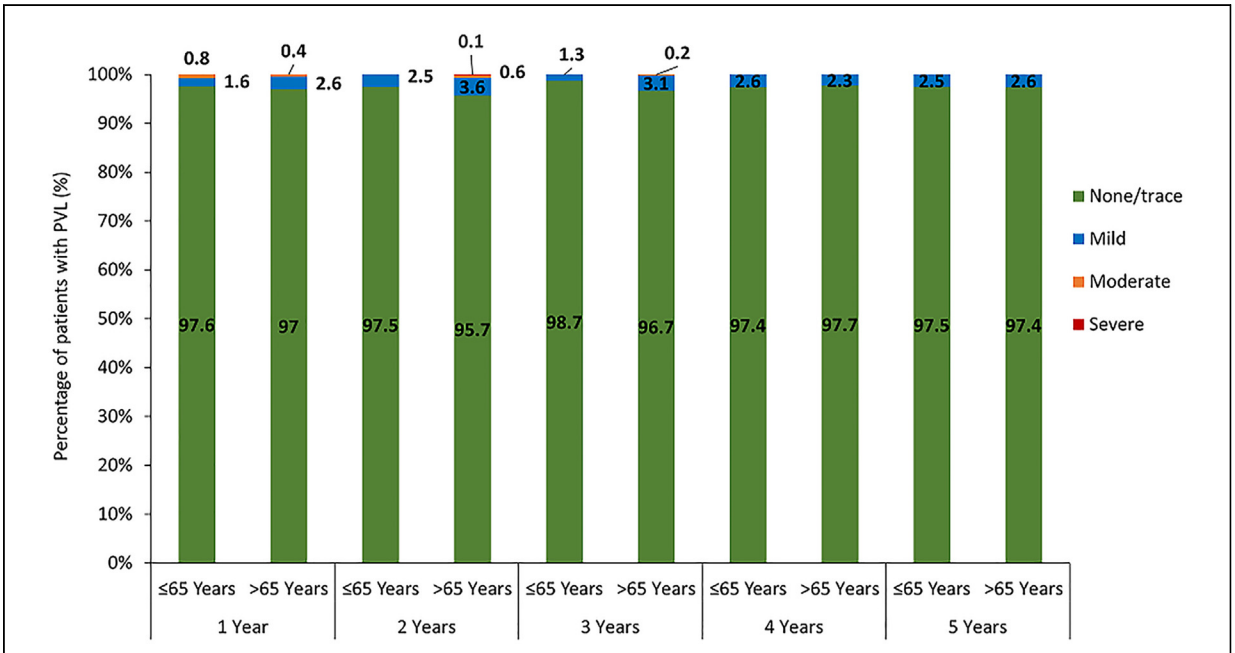

FIGURE 3 Paravalvular leak in patients aged ≤65 and >65 years through 5 years. (PVL, paravalvular leak.)

TABLE 3 Echocardiographic Data at Baseline, Discharge, and 5 Years in Patients ≤ 65 or >65 Years

Measure	Baseline	Discharge	5 Years
Mean aortic gradient, mm Hg			
≤65 y	43.1 ± 19.3 (262)	14.5 ± 4.8 (262)	13.9 ± 5.4 (123)
>65 y	41.8 ± 16.3 (827)	12.7 ± 4.5 (812)	12.0 ± 4.1 (306)
Effective orifice area, cm^2			
≤65 y	1.02 ± 0.70 (244)	1.64 ± 0.39 (240)	1.48 ± 0.40 (100)
>65 y	0.86 ± 0.45 (772)	1.58 ± 0.38 (710)	1.41 ± 0.33 (256)
Indexed effective orifice area, cm^2/m^2			
≤65 y	0.49 ± 0.34 (244)	0.80 ± 0.20 (240)	0.72 ± 0.17 (100)
>65 y	0.44 ± 0.23 (772)	0.81 ± 0.20 (710)	0.73 ± 0.17 (256)
Cardiac index, $L/min/m^2$			
≤65 y	2.7 ± 0.8 (244)	2.6 ± 0.6 (241)	2.3 ± 0.4 (100)
>65 y	2.6 ± 0.7 (774)	2.6 ± 0.7 (717)	2.3 ± 0.5 (262)
Left ventricular ejection fraction, %			
≤65 y	57.8 ± 10.2 (224)	56.5 ± 10.5 (193)	60.2 ± 8.3 (51)
>65 y	59.9 ± 9.2 (661)	58.4 ± 10.0 (533)	60.3 ± 8.8 (105)
Indexed stroke volume			
≤65 y	40.3 ± 11.7 (245)	34.1 ± 7.7 (241)	36.6 ± 6.7 (100)
>65 y	39.4 ± 10.0 (774)	33.8 ± 8.6 (717)	35.9 ± 8.2 (262)

Values in parentheses are no. of patients.

and >65 years are encouraging. The rates of all-cause and cardiac mortality were lower in younger than older patients, and the rates of most valve-related adverse events were similar between age groups. Hemodynamic performance improved substantially in both groups after SAVR, and the improvements were durable through 5 years.

Outcomes data stratified by age at implant are important because the choice of valve requires balancing the risks of lifelong anticoagulation with the risks of reintervention. Although it was once widely accepted that mechanical valves were more appropriate for younger patients because of their longer durability, reports of improved durability for bioprosthetic valves have led to an increase in their use.[22] However conflicting data for middle-age patients make the choice between mechanical and bioprosthetic valves challenging.[8,22-25]

In this study the Avalus valve was safe and effective in patients ≤65 and >65 years, as demonstrated by low mortality, low rates of valve-related adverse events, and satisfactory hemodynamic performance and durability through 5 years. There was a difference in mortality rate between age groups (5.3% vs 14.0%, $P < .001$), which is unsurprising given that age is the most important predictor of mortality in any cohort, besides the greater comorbidity burden and surgical risk of older patients. Major bleeding was also lower in younger patients (3.2% vs 6.9%, $P = .028$).

Our outcomes are in line with those of some studies reporting outcomes by age through 5 years of follow-up. Our 5.3% 5-year mortality rate for patients ≤65 years of age (which corresponds to a survival rate of 94.7%) is in line with Wang and colleagues[26] and Riess and coworkers,[19] who reported 5-year survival rates of 96.3% and 94.1%, respectively, among patients aged <60 years. However, Forcillo and colleagues[27] (patients <60 years) and Huckaby and associates[25] (median age, 65 years; range, 60-68) reported 5-year survival rates of 89% and 84.4%, respectively, among patients who received a bioprosthetic valve. The reasons for the differences in survival rates between these (and other) studies is uncertain, because studies with conflicting data included patients who received older-generation valves[21,30] and patients who received newer-generation valves.[28,29] Huckaby and associates[25] suggested the driver of lower survival rates in younger patients observed in some studies might be the early (30-day) mortality rate associated with reoperation, which was 7.1% in a 2017 analysis of patients aged 45 to 64 years.[22]

Similarly valve-related adverse events in our younger patients were comparable with those reported by others. Five-year freedom from reintervention rates range from 91.5% to 96.3% for middle-aged patients,[19,25-27] compared with a freedom from reintervention rate of 97.3% observed in our patients ≤65 years. Freedom from thromboembolism in our younger group was 95.0%, compared with 5-year freedom from thromboembolic events rates of 95% and 98.1% reported by others.[26,27] In the current study freedom from endocarditis through 5 years was 95.2%, compared with 5-year freedom from endocarditis rates of 97% and 95.8% reported for middle-aged patients by others.[25,27] The occurrence of major PVL in this study has remained low throughout follow-up (1 patient in each age group), and 95% of patients in both age groups had a NYHA class of I or II through 5 years.

The hemodynamic performance of the Avalus valve in patients ≤65 and >65 years has been very good. Mean aortic gradient was substantially improved after implantation. Although slightly higher in younger patients, it has remained durable in both groups through 5 years. A linear regression model demonstrated that several factors are likely associated with gradients at 5 years, including baseline age and mean aortic gradient, discharge stroke volume index and EOA, and implanted valve size. In younger patients the surgeon should implant the largest valve size possible without oversizing in case a valve-in-valve procedure is later needed. Patients with a smaller valve potentially may require redo surgery.

Measures of valve durability are also encouraging, with no cases of SVD, 13 cases of non-SVD, and 3 cases of severe hemodynamic dysfunction. The Avalus valve has

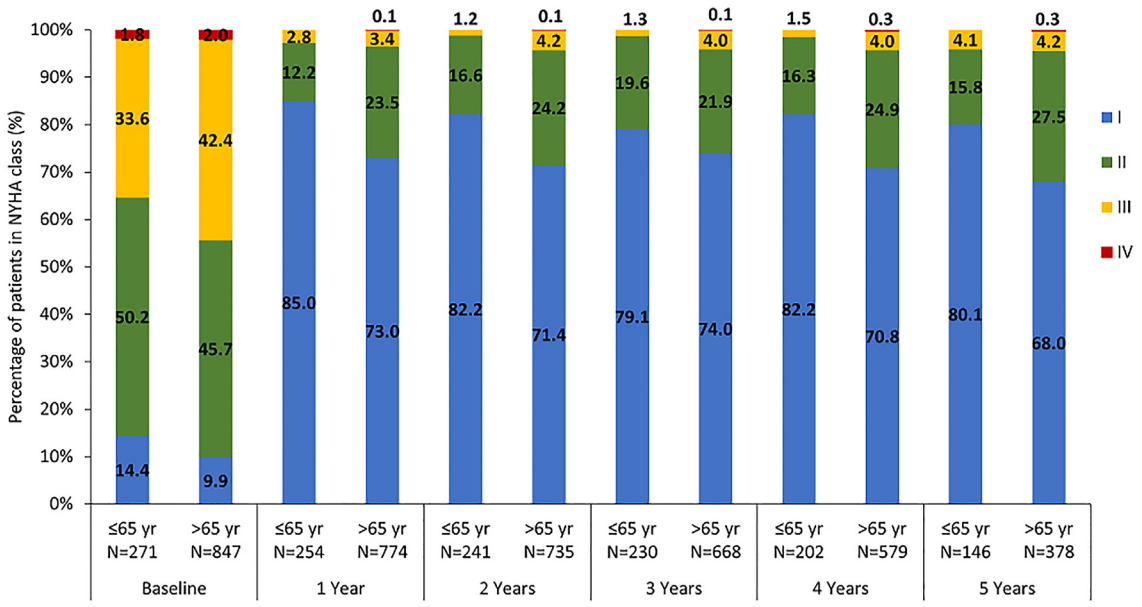

FIGURE 4 New York Heart Association class in patients aged ≤65 and >65 years through 5 years. (NYHA, New York Heart Association.)

the same antimineralization treatment as the Mosaic valve,[28,29] which is a durability workhorse.[19,30] In a cohort of 797 patients who had a Mosaic valve implanted in the aortic position, Riess and coworkers[19] reported rates of freedom from death at 17 years postimplant of 54.0% in patients <60 years old and 24.0% in patients aged ≥60 years; freedom from reoperation was 36.4% and 81.2%, respectively, and freedom from explant due to SVD was 47.5% and 89.1% ($P < .01$). Celiento and associates[30] reported an actuarial survival rate of 34% ± 7% at 15 years and freedom from SVD rates of 97% ± 2% at 15 years and 96% ± 2% at 20 years among patients who received a Mosaic aortic valve. Similar long-term performance with the Avalus bioprosthesis could be an important breakthrough for SAVR. Follow-up through 12 years is planned in a subset of centers to evaluate the long-term safety, hemodynamic performance, and durability of this device.

LIMITATIONS. This trial is a nonrandomized single-arm study, limiting comparisons with other surgical valves and the generalizability of the data to other populations. Follow-up for this analysis was 5 years. Longer follow-up is needed to better characterize the study valve in younger and older patients.

CONCLUSION. Findings from this analysis demonstrate satisfactory safety, hemodynamic performance, and durability of the Avalus aortic bioprosthesis in patients aged ≤65 and >65 years through 5 years of follow-up. These findings will help inform decision-making for middle-aged patients who require AVR.

The authors wish to acknowledge Julie A. Linick, who assisted with manuscript preparation under the direction of the lead author, and Elizabeth Gearhart, MS, who performed the initial analyses for this manuscript. Both are employees of Medtronic. Funding for the PERIGON Pivotal Trial was provided by Medtronic.

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0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2022.01.012

Long Enough to Predict Durability in Young Patients?

INVITED COMMENTARY:

Lifetime management of aortic valve disease changed dramatically with the introduction of transcatheter aortic valve replacement (TAVR). Soon, surgical aortic valve replacement (SAVR) will be offered to only young, healthy patients. Mechanical prostheses have superior durability; however, data comparing mechanical and bioprosthetic valves suggest similar long-term stroke and mortality risk.[1,2] The ability to perform TAVR-in-SAVR—valve-in-valve (VIV)—has resulted in increased biologic valve use and promises of future VIV.

In this issue of *The Annals of Thoracic Surgery*, Kiaii and colleagues[3] report 5-year durability data of the Avalus (Medtronic), a new stented bovine pericardial valve. Stratifying by age (≤65 or >65 years), the authors found the younger cohort had lower predicted risk of mortality and fewer comorbidities. Those ≤65 years had lower mortality (5.3% vs 14.0%), with no difference in valve-related deaths or adverse events (thromboembolism, endocarditis, valve thrombosis, or valve reintervention). Echocardiographic end points were similar, except the mean gradient was slightly increased in the younger group. No occurrences of structural valve dysfunction and similar rates of nonstructural valve dysfunction were reported.

This study has several limitations. Namely, 5-year durability can at best be labeled "midterm." Long-term SAVR durability must be held to the standard of TAVR with 10-year data and beyond, currently in ongoing trials.[4,5]

Second, values sized ≤21 mm were implanted in 22.7% of patients, 16.9% in the younger cohort. No subgroup analysis was completed to understand implications of an initial small prosthesis as it applies to prosthesis-patient mismatch and potentially early failure. The small annulus outcomes are particularly important, because Avalus cannot be fractured, which may preclude future VIV options.