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Original Article

Outcomes in Patients Undergoing Surgical Aortic Valve Replacement With vs Without a Preoperative Heart Team Assessment

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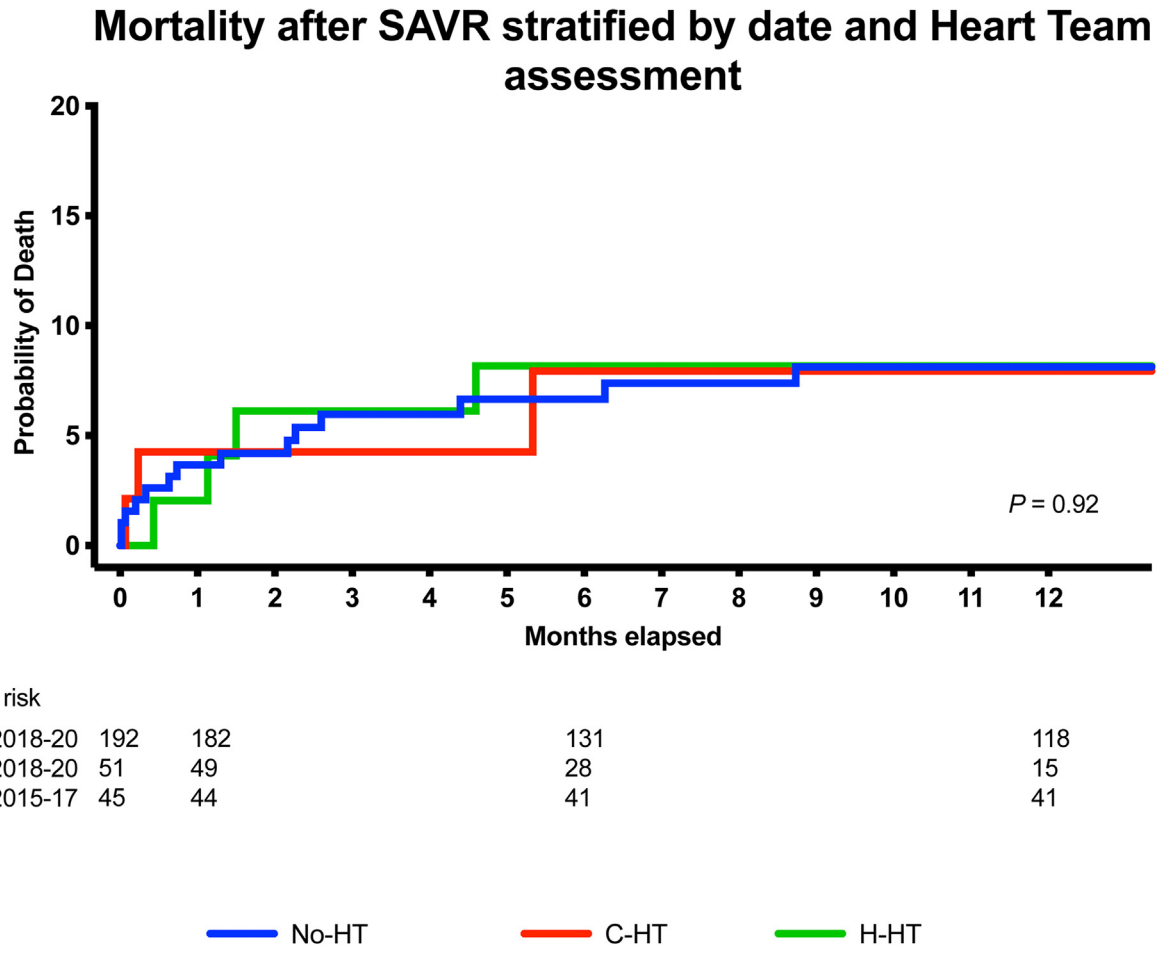

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ABSTRACT

Background: This study sought to compare characteristics and outcomes of patients who underwent surgical aortic valve replacement (SAVR) after being referred to a heart team (HT), to those of patients referred directly for SAVR.

Methods: An analysis of patients who underwent SAVR from 2015 to 2020 was conducted. Patients were categorized into 3 groups, as follows: (i) H-HT: patients referred to the HT from 2015 to 2017 (historical cohort); (ii) C-HT: patients referred to the HT from 2018 to 2020 (contemporary cohort); and (iii) No-HT: patients referred directly to cardiac surgery from 2018 to 2020. Two subanalyses were performed: H-HT vs C-HT patients, and C-HT vs No-HT patients. The primary outcome was a composite of in-hospital mortality, prolonged intubation, reoperation, sternal wound infection, and stroke.

Results: This study consisted of 288 patients, distributed as follows: H-HT (n = 45); C-HT (n = 51); and No-HT (n = 192). The mean ages of H-HT, C-HT, and No-HT patients was 76.3 ± 6.9 years, 73.3 ± 7.6 years, and 69.6 ± 9.7 years, respectively ($P = 0.0001$). H-HT, C-HT, and No-HT patients had average Society of Thoracic Surgeons scores of 4.8 ± 2.2, 3.2 ± 1.6, and 4.2 ± 2 ($P = 0.002$), respectively. The composite outcome rate was more than 5 times higher among H-HT patients compared to that among the C-HT patients (20.0 vs 3.9%, $P = 0.02$), and was numerically higher in No-HT compared to C-HT patients (13.0 vs 3.9%, $P = 0.07$).

Conclusions: Referral to an HT appears to be primarily driven by higher chronological age rather than overall risk profile. Patients assessed by the HT prior to undergoing SAVR have a low incidence of complications, comparable to that among patients referred directly to cardiac surgery.

RÉSUMÉ

Contexte : Cette étude visait à comparer les caractéristiques et le devenir de patients ayant subi une chirurgie de remplacement valvulaire aortique après avoir été orientés vers une équipe de cardiologie (EC) à ceux de patients orientés directement en chirurgie cardiaque pour une chirurgie de remplacement valvulaire aortique.

Méthodologie : Une analyse portant sur les patients ayant subi une chirurgie de remplacement valvulaire aortique de 2015 à 2020 a été effectuée. Les patients ont été divisés en trois groupes, à savoir : i) CH-POEC : patients orientés vers une EC de 2015 à 2017 (cohorte historique); ii) CC-POEC : patients orientés vers une EC de 2018 à 2020 (cohorte contemporaine); iii) PODC : patients orientés directement en chirurgie cardiaque de 2018 à 2020. Deux sous-analyses ont été effectuées : CH-POEC *vs* CC-POEC, et CC-POEC *vs* PODC. Le paramètre d'évaluation principal était composite. Il comprenait la mortalité hospitalière, l'intubation prolongée, la réopération, l'infection de la plaie sternale et l'accident vasculaire cérébral.

Résultats : L'étude regroupait 288 patients, répartis comme suit : CH-POEC, n = 45; CC-POEC, n = 51; PODC, n = 192. L'âge moyen dans les groupes CH-POEC, CC-POEC et PODC était respectivement de 76,3 ± 6,9 ans, 73,3 ± 7,6 ans et 69,6 ± 9,7 ans ($P = 0{,}0001$). Les groupes CH-POEC, CC-POEC et PODC présentaient des indices STS (Society of Thoracic Surgeons) moyens de 4,8 ± 2,2, 3,2 ± 1,6 et 4,2 ± 2 ($P = 0{,}002$), respectivement. Le taux composite d'événements au sein du groupe CH-POEC était plus de cinq fois supérieur à celui noté dans le groupe CC-POEC (20,0 *vs* 3,9 %, $P = 0{,}02$). Il était aussi plus élevé au sein du groupe PODC comparativement au groupe CC-POEC (13,0 *vs* 3,9 %, $P = 0{,}07$).

Conclusions : Le principal motif d'orientation vers une EC semble être un âge chronologique avancé plutôt que le profil de risque global. Chez les patients qui sont évalués par une EC avant de subir une chirurgie de remplacement valvulaire aortique, l'incidence de complications est faible et comparable à celle observée chez les patients orientés directement en chirurgie cardiaque.

The emergence of transcatheter aortic valve replacement (TAVR) has broadened patient eligibility for valve replacement. Over the past decade, the implementation of TAVR into clinical practice has resulted in an overall decrease in mortality for patients undergoing either TAVR or surgical aortic valve resplacement (SAVR).[1,2]

The considerations used to assess whether TAVR or SAVR should be pursued include procedural feasibility from an anatomic perspective (bicuspid aortic valve, size of the aortic root, diameter of the aortic annulus, mediastinal anatomy, etc.), as well as patient-specific variables, such as frailty, comorbidities, and age.[3,4] Specifically, for patients aged between 65 and 80 years, both procedures should be considered. Current American guidelines emphasize patient symptoms (or lack thereof), echocardiographic parameters, and the degree of aortic valve calcification, in addition to the aforementioned variables, for defining the severity of aortic stenosis (AS), and therefore, determining the optimal, patient-specific course of treatment.[5]

These recommendations will undoubtebly lead to a significant increase in heart team (HT) referrals. However, not all patients will be deemed eligible for TAVR, and a sizeable proportion will undergo SAVR. The clinical characteristics of these latter patients are currently unknown. Their outcomes, as compared to those of patients referred directly for SAVR, also have not been studied.

We therefore sought to compare the characteristics and outcomes of patients undergoing SAVR after being referred directly, without a HT assessment, to those of patients undergoing SAVR after being assessed by a HT. The temporal trends of patient characteristics were also considered.

Methods

Study design

An analysis of adults undergoing SAVR for severe AS at the McGill University Health Centre from January 1, 2015, to January 1, 2020, was performed. The typical referral process for aortic valve replacement begins with the general practitioner referring a patient for a transthoracic echocardiogram if symptoms are present or if a murmur is heard. Once the

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Ethics Statement: This study was registered and approved by the Research Ethics Board of the McGill University Health Centre.

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See page 33 for disclosure information.

presence of AS is confirmed, the patient is referred to a general cardiologist or internist for follow-up. Once the AS is believed to be severe, the patient is then referred to a HT or cardiac surgeon. At our institution, no single centre is designated for valvular disease; rather, the referring physician is free to send the patient to the specialist deemed most appropriate.

Patients were categorized into the following 3 groups: (i) historical HT (group H-HT), consisting of patients who underwent SAVR from 2015 to 2017, after an HT assessment; (ii) contemporary HT (group C-HT), consisting of patients who underwent SAVR from 2018 to 2020, after an HT assessment; (iii) group No-HT, consisting of patients who underwent SAVR from 2018 to 2020, after direct referral to cardiac surgery. After the publication of major randomized controlled trials pertaining to intermediate-risk patients in 2016[6] and 2017,[7] along with updated guideline recommendations in 2017,[8] we observed a change in the patterns of referral to our HT for TAVR or SAVR consideration in the beginning of 2018. In addition, the Canadian Cardiovascular Society proposed updated guidelines for the management of AS in 2019, whereby the decision to undergo TAVR became guided by several patient-specific factors, which include, but extend beyond, age.[3,4] Given this change, we chose to divide patients in our study into groups H-HT and C-HT for the purpose of observing temporal differences in physician referral patterns for TAVR. Groups C-HT and No-HT allowed us to evaluate exclusively the role of a HT in a contemporary cohort. For patients seen by the HT, including groups C-HT and H-HT, reasons for not proceeding with TAVR were recorded and are displayed in Figures 1 and 2, respectively. For all patients, data regarding comorbidities, echocardiographic data, procedural details, and postoperative outcomes were collected from medical records.

The predicted risk of mortality (PROM) was calculated using the Society of Thoracic Surgeons (STS) risk model for every patient. Two analyses were performed. The first was a temporal trend comparison of group H-HT vs group C-HT. The second analysis evaluated the role of the HT by comparing group C-HT vs group No-HT. The results of this study have been organized to reflect these 2 subanalyses. A point to note is that all cases of coronary artery bypass graft (CABG) + aortic valve replacement in group No-HT were assessed, in order to determine if these patients could have alternatively undergone TAVR + percutaneous coronary intervention (PCI). Cases in which TAVR + PCI were not feasible were excluded from the study. This study was registered and approved by the Research Ethics Board of the McGill University Health Centre.

Study population

Medical charts of patients undergoing SAVR from 2015 to 2020 were screened to determine if patients met the following inclusion criteria: (i) being adults with severe AS, with or without regurgitation, (ii) having been assessed for either TAVR or SAVR and having undergone SAVR; (iii) having undergone concomitant cardiac surgeries if these procedures were equally feasible percutaneously. Another point to note is that the severity of AS in this study was based on echocardiographic parameters, as opposed to symptom burden. Thus, although the majority of patients presented with notable symptoms, asymptomatic patients (class I) were included if they also presented with a reduced ejection fraction ($< 50\%$), or if they had undergone concomitant cardiac procedures, as this would qualify them to undergo TAVR or SAVR, according to recent guidelines.[9] Subgroup analyses excluding concomitant surgeries were performed. Patients were excluded if they had undergone valve replacement for reasons other than AS, such as pure aortic regurgitation or infective endocarditis, and therefore would not be a suitable candidate for TAVR.

Preoperative assessments

For patients seen by the HT, a multidisciplinary assessment was performed. This assessment consisted of a consultation with a nurse practitioner, a consultation with an interventional cardiologist, and a frailty evaluation. The role of the nurse practitioner was to take the patient's history, perform a clinical exam, and review any imaging, biochemical, or electrocardiogram reports from the referring centre, and present all relevant findings to the interventional cardiologist. Nurse practitioners also provided assistance for patient follow-up along the care continuum, both before and after the procedure. In addition, patients underwent a transthoracic echocardiogram, a coronary angiogram, and a cardiac computed tomography scan after having been seen by the multidisciplinary team at our centre. The results of these tests, as well as the impression of the multidisciplinary team were presented at HT rounds and discussed among interventional cardiologists and cardiac surgeons to determine whether the patient would benefit most from TAVR, SAVR, or medical management. Anatomic considerations included the following: aortic annulus diameter, aortic valve morphology (calcification, bicuspid, valve-in-valve), location of the coronary ostia, and size of the aortic sinuses. Reasons for which patients seen by the HT did not proceed with TAVR were recorded. In patients referred directly to cardiac surgery, only transthoracic echocardiogram and coronary angiogram were performed.

Frailty

In addition to analyzing clinical parameters and procedural outcomes, frailty was assessed by the healthcare team when possible. Among this small subset, frailty was measured using the essential frailty toolset (EFT), which uses the following 4 parameters to assess the risk of 1-year mortality in patients undergoing SAVR or TAVR: hemoglobin (g/dL), serum albumin (g/dL), chair rise time (time to complete 5 sit-to-stand chair rises without using arms), and cognitive impairment (determined using the mini-mental state examination).[10]

Outcomes

The primary outcome was a composite of postoperative complications prior to discharge, including in-hospital mortality, reoperation, sternal wound infection, stroke, and readmission.[4] The secondary outcome was 1-year all-cause mortality following SAVR. Vital status at 1 year was determined through data available in medical records.

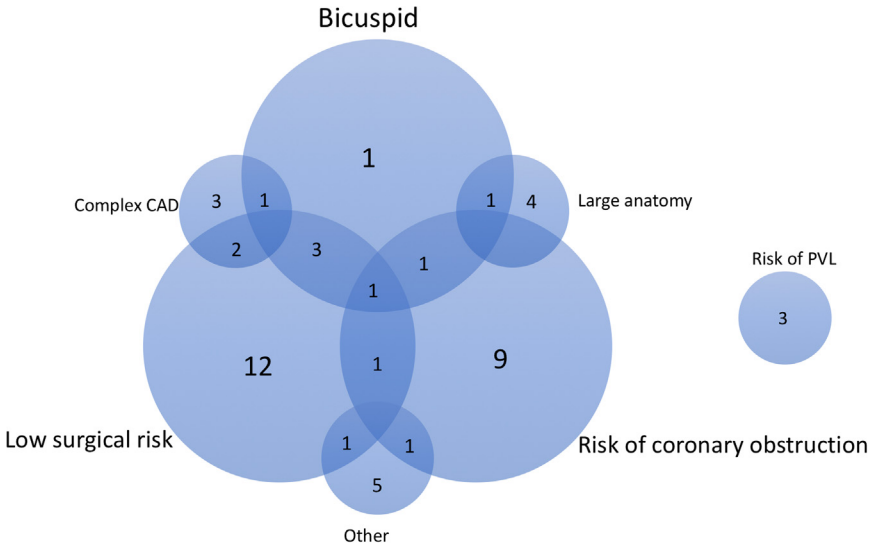

Figure 1. Reasons for surgical aortic valve replacement (SAVR) preference over transcatheter aortic valve replacement in patients considered for both approaches in the contemporary cohort (patients referred to the heart team from 2018 to 2020). The 3 main reasons for selection of surgical aortic valve replacement were the presence of a bicuspid aortic valve, small anatomy with increased risk of coronary obstruction, and low surgical risk. Less-common reasons included complex coronary artery disease (CAD; in addition to severe aortic stenosis) that would be better revascularized surgically, anatomy too large for available transcatheter aortic valve replacement devices, prohibitive calcium burden with increased risk of paravalvular leak (PVL), and other reasons as described in the text.

Statistical approach

Continuous data are reported as mean ± standard deviation or median (interquartile range), and categorical variables are reported as number of patients and percentages. Categorical data were compared using the χ^2 test, and continuous data were compared using 1-way analysis of variance or the Kruskal-Wallis test, as appropriate. The Student t test and Fisher's exact test were used for pairwise comparisons. Events are reported as counts of first occurrence per type of event. Data on 1-year survival were estimated using the Kaplan-Meier method and compared using the log-rank test. In order to identify the independent predictors of composite outcome and HT referral, variables with a P value < 0.10 on univariate analysis were included in stepwise multivariate logistic regression models.

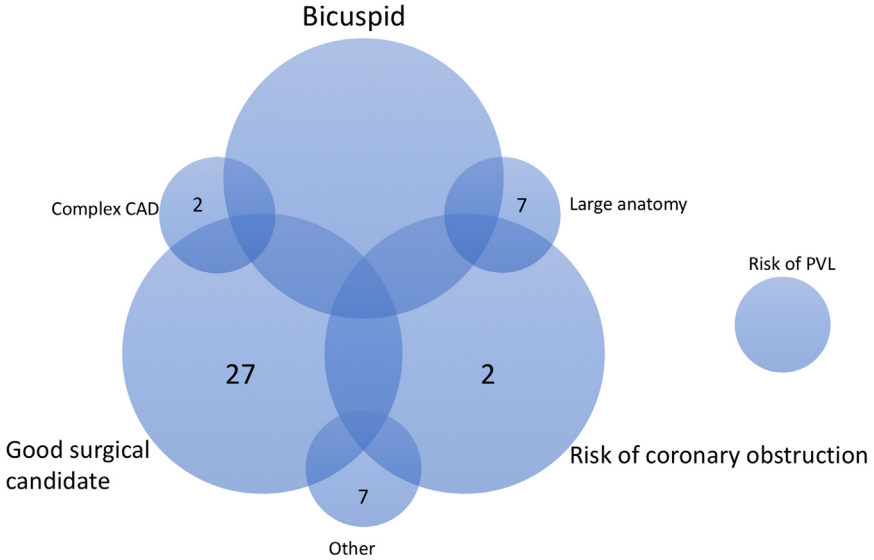

Figure 2. Reasons for surgical aortic valve replacement preference over transcatheter aortic valve replacement in patients considered for both approaches in the historical cohort (patients referred to the heart team from 2015 to 2017. The main reason for selection of surgical aortic valve replacement was good surgical candidacy in the majority of patients. Less-common reasons included large anatomy that could be treated surgically, increased risk of coronary obstruction, and other unspecified reasons. CAD, coronary artery disease; PVL, paravalvular leak.

Table 1. Baseline characteristics

Variable	H-HT 2015−2017 (n = 45)	C-HT 2018−2020 (n = 51)	No-HT 2018−2020 (n = 192)	*P* (H-HT vs C-HT)	*P* (C-HT vs No-HT)
Age, y	76.3 ± 6.9	73.3 ± 7.6	69.6 ± 9.7	**0.045**	**0.01**
Male sex	25 (55.6)	26 (51.0)	121 (63.0)	0.67	0.15
STS-PROM, %	4.8 ± 2.2	3.2 ± 1.6	4.2 ± 2.5	**< 0.0001**	**0.007**
Obesity	5 (11.1)	9 (17.6)	65 (34.0)	0.40	**0.03**
Diabetes	16 (35.6)	18 (35.3)	65 (33.9)	1	0.87
Hypertension	34 (75.6)	41 (80.4)	121 (63.0)	0.63	**0.02**
Dyslipidemia	26 (57.8)	29 (56.9)	100 (52.1)	1	0.64
Active smoker	4 (8.9)	2 (3.9)	19 (10.6)	0.27	0.30
NYHA class 3 or 4	15 (40.5)	21 (53.8)	64 (58.2)	0.26	0.71
Known CAD	27 (60.0)	16 (31.4)	96 (50.3)	**0.007**	**0.02**
Atrial arrhythmia (flutter or fibrillation)	10 (22.2)	11 (21.6)	30 (15.6)	1	0.30
Previous PPM	2 (4.4)	2 (3.9)	11 (5.8)	1	1
Previous SAVR	1 (2.2)	1 (2.0)	9 (4.7)	1	0.69
Previous stroke or TIA	4 (8.9)	5 (9.8)	15 (7.8)	1	0.58
Peripheral vascular disease	2 (4.4)	3 (5.9)	8 (4.2)	1	0.70
Chronic obstructive pulmonary disease	12 (26.7)	5 (9.8)	27 (14.1)	**0.04**	0.49
LVEF, %	57.7 ± 15.7	57.8 ± 12.2	57.2 ± 12.1	0.97	0.75
LVEF ≤ 30%	4 (9.3)	3 (5.9)	10 (5.6)	0.67	1
Mean aortic gradient, mm Hg	58.2 ± 16.0	55.2 ± 20.3	46.1 ± 20.0	0.43	0.06
AVA, cm^2	0.75 ± 0.24	0.77 ± 0.20	0.96 ± 0.64	0.65	**0.04**
Aortic insufficiency greater than mild	5 (11.1)	7 (13.7)	31 (16.1)	0.76	0.83
Creatinine, umol/L	87.5 ± 27.5	94.9 ± 47.4	94.7 ± 50.6	0.36	0.98
Dialysis	1 (2.2)	0 (0.0)	2 (1.0)	0.47	1
Essential Frailty Toolset score*	1.21 ± 1.10	1.20 ± 1.01	1.13 ± 1.06	0.96	0.87

Values are mean ± standard deviation, or n (%), unless otherwise indicated. Boldface indicates significance ($P < 0.05$).

AVA, aortic valve area; CAD, coronary artery disease; C-HT, contemporary HT group (patients referred to the HT from 2018 to 2020); H-HT, historical HT group (patients referred to the HT from 2015 to 2017); HT, heart team; LVEF, left ventricular ejection fraction; No-HT, no HT group (patients referred directly to cardiac surgery from 2018 to 2020); NYHA, New York Heart Association; PPM, permanent pacemaker; SAVR, surgical aortic valve replacement; STS-PROM, Society of Thoracic Surgeons Predicted Risk of Mortality; TIA, transient ischemic attack.

*Frailty was assessed in the following number of patients in each group: n = 28, 20, and 23 in groups H-HT, C-HT, and No-HT, respectively.

A P value < 0.05 was considered significant. Statistical analyses were performed with SPSS version 23 (IBM Corp, Armonk, NY).

Results

Overall baseline characteristics

This study consisted of 288 patients with AS, who were treated surgically at the McGill University Health Centre from 2015 to 2020. Of these patients, 45 were seen by the HT from 2015 to 2017 (group H-HT), 51 were seen by the HT from 2018 to 2020 (group C-HT), and 192 were referred directly to cardiac surgery from 2018 to 2020 (group No-HT). In the 2015-2017 period, an additional 182 patients underwent TAVR after being assessed by the HT, and in the 2018-2020 period, an additional 194 did so. Therefore, the proportion of patients undergoing SAVR after being considered for TAVR remained stable, at about 20%, over the study period.

Temporal trend analysisgroup H-HT vs group C-HT

Baseline characteristics. The mean ages among patients in groups H-HT and C-HT were 76.3 and 73.3 years, respectively ($P = 0.045$), with the proportion of male patients being similar across the 2 groups: H-HT, 55.6%; C-HT, 51.0% ($P = 0.67$; Table 1). Furthermore, a significantly greater proportion of H-HT patients had known coronary artery disease (CAD), compared to the proportion of C-HT patients (60.0% vs 31.4%, $P = 0.007$). A similar trend was observed regarding the prevalence of chronic obstructive pulmonary disease, with 26.7% of H-HT patients having the disease, compared to 9.8% of C-HT patients ($P = 0.04$). These differences were reflected in the respective STS-PROM scores of each group, with H-HT patients having a mean score of 4.8 ± 2.2, which was significantly higher than the 3.2 ± 1.6 seen in C-HT patients ($P < 0.0001$). Lastly, frailty was measured in a subset of H-HT and C-HT patients using the EFT. Using this scale, patients were found to be equally frail, with H-HT patients having a mean score of 1.21 ± 1.10, as compared to 1.20 ± 1.01 in C-HT patients ($P = 0.96$). Other baseline characteristics were similar between the 2 groups.

Reasons for not undergoing TAVR. The primary reason for undergoing SAVR over TAVR among H-HT patients was "acceptable surgical candidacy—low or intermediate risk" in 27 of 45 patients. In 9 patients, TAVR was technically not feasible due to large anatomy (n = 7) or an increased risk of coronary obstruction (n = 2). For 2 patients, SAVR was preferred due to the presence of complex CAD that would be best treated through surgical revascularization techniques. SAVR was preferred in the 7 remaining patients, for other unspecified reasons. The primary reason for undergoing SAVR over TAVR among C-HT patients was "low surgical risk" in 20 of 51 patients. TAVR was technically not feasible

Table 2. Procedural characteristics

Variable	H-HT 2015−2017 (n = 45)	C-HT 2018−2020 (n = 51)	No-HT 2018−2020 (n = 192)	*P* (H-HT vs C-HT)	*P* (C-HT vs No-HT)
Isolated SAVR	18 (40.0)	30 (58.8)	81 (42.2)	0.10	**0.04**
Concomitant procedure				0.67	0.47
CABG (≥ 1)	16 (35.6)	16 (31.4)	83 (43.2)		
Root	10 (22.2)	8 (15.7)	29 (15.1)		
Mitral valve	3 (6.7)	2 (3.9)	4 (2.1)		
Other	3 (6.7)	2 (3.9)	3 (1.6)		
Concomitant CABG no.				0.81	0.74
1	10 (22.2)	8 (15.7)	35 (18.2)		
2	29 (8.9)	4 (7.8)	25 (13.0)		
3	2 (4.4)	3 (5.9)	16 (8.3)		
4	0 (0.0)	1 (2.0)	6 (3.1)		
5	0 (0.0)	0 (0.0)	1 (0.5)		
Device size, mm				0.38	**0.02**
Small, ≤ 21	14 (31.1)	22 (44.0)	48 (25.1)		
Medium, 23−25	25 (55.6)	21 (42.0)	119 (62.3)		
Large, ≥ 27	6 (13.3)	7 (14.0)	24 (12.6)		
Cross-clamp time, min	78.7 ± 28.9	89.8 ± 32.2	91.4 ± 33.8	0.19	0.76
CPB time, min	99.6 ± 34.6	110.1 ± 41.7	112.8 ± 43.8	0.08	0.70

Values are mean ± standard deviation, or n (%), unless otherwise indicated. Boldface indicates significance ($P < 0.05$).

CABG, coronary artery bypass graft; C-HT, contemporary HT group (patients referred to the HT from 2018 to 2020); CPB, cardiopulmonary bypass; H-HT, historical HT group (patients referred to the HT from 2015 to 2017); HT, heart team; No-HT, no HT group (patients referred directly to cardiac surgery from 2018 to 2020); SAVR, surgical aortic valve replacement.

in 18 patients, due to an increased risk of coronary obstruction (n = 13) or large anatomy (n = 5). In addition, 8 patients within this group had a bicuspid aortic valve. For 6 patients, SAVR was the preferred approach due to the presence of complex CAD. In 3 patients, SAVR was also preferred due to an increased risk of paravalvular leak. Finally, SAVR was preferred in the 7 remaining patients for other unspecified reasons.

Procedural characteristics. Patients in groups H-HT and C-HT underwent similar procedures, with 40% of H-HT patients undergoing an isolated SAVR, compared to 58.8% of C-HT patients ($P = 0.10$; Table 2). In addition, no significant difference was observed between groups H-HT and C-HT in the proportion of patients who underwent concomitant procedures ($P = 0.67$), or in the number of bypassed vessels when patients underwent concomitant coronary artery bypass graft procedures ($P = 0.81$). Also, the device sizes used were similar for the 2 groups, with 31% of H-HT patients requiring a device less than 21 mm, compared to 44% in group C-HT ($P = 0.38$). The cross-clamp times were similar among patients in group H-HT (78.7 minutes) vs group C-HT (89.8 minutes; $P = 0.19$). No significant difference was observed in time spent on cardiopulmonary bypass in H-HT patients (99.6 minutes) vs C-HT patients (110.1 minutes; $P = 0.08$).

Outcomes

The results of the primary composite outcome demonstrated that H-HT patients were more likely to experience at least one of the endpoints of the composite, compared to patients in group C-HT; the incidence was 20.0% among H-HT patients and 3.9% in C-HT patients ($P = 0.02$; Table 3). No significant differences were observed between groups H-HT and C-HT regarding individual in-hospital outcomes, such as major bleeding, tamponade, new-onset arrythmias, new pacemaker implantation, and acute kidney injury. Length of stay in the intensive care unit and total hospital length of stay were similar for groups H-HT and C-HT.

At 1 year, no statistically significant difference in outcomes was observed between H-HT and C-HT patients, with 5 deaths occurring in group H-HT, and 3 deaths occurring in group C-HT ($P = 0.69$). No endocarditis was observed in either group, and the rates of readmission were similar, with 17 patients (37.8%) being readmitted in group H-HT, and 12 patients (23.5%) readmitted in group C-HT ($P = 0.18$). Postoperative echocardiographic findings were similar across the 2 groups and are displayed in Table 3.

HT analysis: C-HT vs No-HT

Baseline characteristics. Patients seen by the HT were significantly older than those who were referred directly to cardiac surgery, as the mean ages among patients in groups C-HT and No-HT were 73.3 and 69.6 years, respectively ($P = 0.01$; Table 1). The proportion of males was similar across the 2 groups: C-HT, 51.0%; No-HT, 63.0%; $P = 0.67$). A significantly greater proportion of patients in group No-HT were obese, compared to that in group C-HT (34.0% vs 17.6%, $P = 0.03$). Similarly, a greater proportion of patients in group No-HT had known CAD (50.3% vs 31.4%, $P = 0.007$). Patients in group No-HT also had a higher overall surgical risk than those in group C-HT, as determined by their respective STS-PROM scores (4.2 ± 2.5 vs 3.2 ± 1,6, $P = 0.007$). Significant differences were also observed between the 2 groups in echocardiographic parameters, with a mean aortic valve area for patients in group C-HT of 0.77 cm^2, compared to 0.96 cm^2 in group No-HT ($P = 0.04$). Finally, both groups of patients were found to be equally frail using the EFT, with C-HT patients having a mean score of 1.20 ± 1.01, compared to 1.13 ± 1.06 in group No-HT ($P = 0.96$).

Table 3. In-hospital and 1-year outcomes

In-hospital outcome	H-HT 2015−2017 (n = 45)	C-HT 2018−2020 (n = 51)	No-HT− 2018−2020 (n = 192)	*P* (H-HT vs C-HT)	*P* (C-HT vs No-HT)
Composite endpoint	9 (20.0)	**2 (3.9)**	25 (13.0)	**0.02**	0.07
Death	4 (8.9)	2 (3.9)	12 (6.3)	0.41	0.74
Stroke	1 (2.2)	1 (2.0)	5 (2.6)	1	1
Myocardial infarction	0 (0.0)	0 (0.0)	2 (1.0)	1	1
Major bleeding	10 (22.2)	5 (9.8)	30 (15.6)	0.16	0.37
Tamponade	1 (2.2)	0 (0.0)	7 (3.6)	0.47	0.35
Sternal wound infection	1 (2.2)	0 (0.0)	5 (2.6)	0.47	0.59
New-onset atrial arrhythmia	11 (24.4)	15 (29.4)	41 (21.4)	0.65	0.26
New pacemaker implantation	3 (6.7)	0 (0.0)	6 (3.1)	0.10	0.35
Acute kidney injury	3 (6.7)	1 (2.0)	5 (2.6)	0.34	1
ICU stay, median days (IQR)	2 (2−4)	2 (2−3)	2 (1−3)	0.20	0.47
Hospital stay, median days (IQR)	10 (7−14.5)	9 (7−14)	9 (6.25−13)	0.34	0.96
1-year outcome					
1-year death*	5 (11.4)	3 (7.9)	16 (10.0)	0.69	0.74
Readmission	17 (37.8)	12 (23.5)	**23 (12.0)**	0.18	**0.045**
Valve endocarditis	0 (0.0)	0 (0.0)	1 (0.5)	1	1
LVEF, %	58.0 ± 9.0	54.7 ± 13.7	54.0 ± 12.2	0.35	0.80
AVA, cm^2	1.61 ± 0.50	1.84 ± 0.59	1.86 ± 0.73	0.30	0.94
Mean gradient > 20 mm Hg	0 (0.0)	2 (11.1)	6 (6.8)	0.23	0.62
Mean gradient, mm Hg	11.7 ± 3.7	13.6 ± 10.2	11.1 ± 5.2	0.45	0.12
Paravalvular regurgitation > mild	0 (0.0)	0 (0.0)	0 (0.0)	1	1

Values are mean ± standard deviation, or n (%), unless otherwise specified. Acute kidney injury was defined as a > 2-fold increase in serum creatinine within 48 hours of surgery. Boldface indicates significance ($P < 0.05$).

AVA, aortic valve area; C-HT, contemporary HT group (patients referred to the HT from 2018 to 2020); H-HT, historical HT group (patients referred to the HT from 2015 to 2017); ICU, intensive care unit; IQR, interquartile range; LVEF, left ventricular ejection fraction; No-HT, no HT group (patients referred directly to cardiac surgery from 2018 to 2020).

*Kaplan-Meier estimate; log-rank *P* values.

Procedural characteristics. A greater proportion of patients seen by the HT (58.8%) underwent isolated SAVR, compared to the proportion referred directly to cardiac surgery (42.2%; $P = 0.04$; Table 2). More specifically, 31.4% of patients in group C-HT underwent a CABG procedure, compared to 43.2% in group No-HT ($P = 0.47$), with no difference between groups in number of bypassed vessels ($P = 0.74$). Smaller devices (< 21 mm) were used more often in group C-HT than group No-HT (44% vs 25%, respectively; $P = 0.02$). Cross-clamp times were similar between patients in group C-HT (89.9 minutes) and group No-HT (91.4 minutes; $P = 0.76$). No significant difference was observed for time spent on cardiopulmonary bypass in group C-HT (110.1 minutes) and group No-HT (112.8 minutes; $P = 0.08$).

Outcomes. The incidence of experiencing the composite endpoint was more than tripled in patients referred directly to cardiac surgery vs those seen by the HT during the same period; however, this difference did not reach statistical significance (group No-HT: n = 25; 13.0% vs group C-HT: n = 2; 3.9%; $P = 0.07$; Table 3). Similarly, in-hospital death was numerically higher in patients referred directly to cardiac surgery (n = 12; 6.3%), compared to those seen by the HT (n = 2; 3.9%; $P = 0.74$). In addition, postoperative tamponade (group C-HT: n = 0; group No-HT: n = 7 (3.6%); $P = 0.36$), sternal wound infection (group C-HT: n = 0; group No-HT: n = 5 (2.6%); $P = 0.59$), and the implantation of a permanent pacemaker (group C-HT: n = 0; group No-HT: n = 6 (3.6%); $P = 0.35$) occurred exclusively in patients referred directly to cardiac surgery. All patients had a median intensive care unit stay of 2 days ($P = 0.47$) and a mean overall hospital length of stay of 9 days ($P = 0.96$).

Overall outcomes across groups H-HT, C-HT, and No-HT

Similar survival patterns were observed across all 3 groups, although the highest incidence of mortality was seen in group No-HT (Fig. 3). In the total cohort, 2 independent predictors of the composite outcome were identified: surgery involving the aortic root (odds ratio 3.4 (1.5-7.8); $P = 0.004$) and STS score (odds ratio 1.2 (1.1-1.4) per 1-point increase; $P = 0.001$). Aside from these 2 predictors, no other clinical variable reached the level of univariate statistical significance needed to be included in the mulvariate model. For patients undergoing a concomitant aortic root procedure in groups H-HT and C-HT, TAVR was considered unsuitable because of the risk of coronary obstruction in 4 of 18 cases.

Outcomes based on procedure type

A supplemental analysis was performed in which patients undergoing concomitant valve, left atrial appendage closure, and septal myomectomy procedures were excluded. Patients

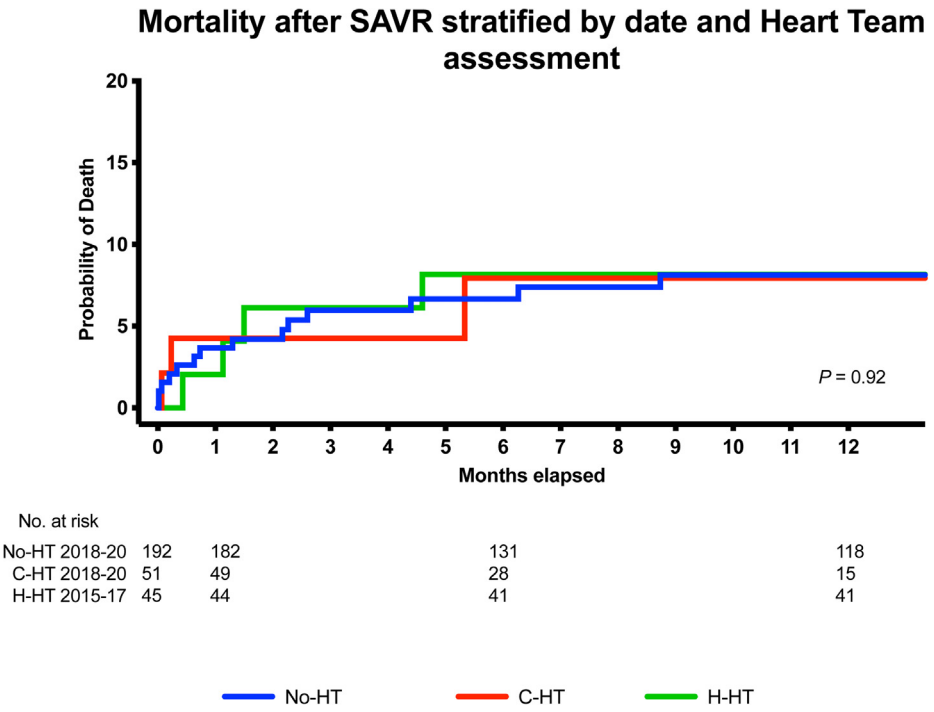

Figure 3. Kaplan-Meier curves comparing the 1-year incidence of mortality across patients seen by the heart team (HT) from 2015-2017 (H-HT), or from 2018-2020 (C-HT), and those referred directly to cardiac surgery (no-HT). C-HT, contemporary HT group (patients referred to the HT from 2018 to 2020); H-HT, historical HT group (patients referred to the HT from 2015 to 2017); No-HT, no heart team group (patients referred directly to cardiac surgery from 2018 to 2020; SAVR, surgical aortic valve replacement.

in group C-HT had a significantly lower incidence of the composite outcome (n = 1; 2.2%), compared to group H-HT (n = 7; 17.1%; $P = 0.02$) and group No-HT (n = 24; 12.9%; $P = 0.03$; Supplemental Table S1). Similar results were observed when aortic root procedures were excluded from the analysis (group C-HT: n = 0; 0%, vs group H-HT: n = 4; 12.9%; $P = 0.03$; and vs group No-HT: n = 17; 10.7%; $P = 0.03$; Supplemental Table S2). Excluding procedures with more than 2 bypasses demonstrated similar results, with no patients in group C-HT (n = 0; 0%) experiencing the composite outcome (vs group H-HT: n = 3; 10.3%; $P = 0.08$; and vs group No-HT: n = 13; 9.6%; $P = 0.07$; Supplemental Table S3). Lastly, no significant differences were observed in either the composite or death, when isolated SAVR procedures were compared across all 3 groups (Supplemental Table S4).

Predictors of HT referral

Univariate and multivariate analysis of predictors of HT referral are displayed in Table 4. Independent predictors include the following: age, STS-PROM, obesity, hypertension, and mean aortic gradient. Of note, although hypertension, mean gradient, and age are positive predictors (ie, older age increases the likelihood of HT referral), obesity and STS-PROM inversely predict HT referral (higher STS-PROM decreases the likelihood of referral).

Discussion

This study analyzed temporal trends among patients with severe AS who were preoperatively assessed by the HT and ultimately underwent SAVR from 2015-2017 (group H-HT) and from 2018-2020 (group C-HT). The outcomes of patients considered but refused for TAVR were also compared to patients not assessed for TAVR (group No-HT).

The key findings of this study can be summarized as follows: (i) more patients with AS are now being seen by an HT prior to undergoing SAVR, although the majority continue to be directly referred to surgery; (ii) current referral patterns suggest that age is the primary factor for determining direct referral to cardiac surgery, whereas other relevant patient-specific factors are less-often considered; and (iii) the HT assessment is associated with favourable outcomes in patients undergoing SAVR. These findings are reassuring for patients who are assessed by an HT but refused for TAVR.

Temporal trends: H-HT vs C-HT

Temporal trends demonstrate that more patients with AS undergoing SAVR are being assessed by the HT at our institution, compared to the number in previous years. In addition, these same patients are at lower surgical risk, compared to patients in the past. This finding was determined by comparing the STS-PROM scores of group H-HT vs those of group C-HT. Factors that may have contributed to a lower STS score include the following: (i) an increased proportion of

Table 4. Univariate and multivariate predictors of heart team (HT) referral

Parameter	Univariate analysis		Multivariate analysis		
	OR	*P* (crude)	OR	95% CI	*P* (adjusted)
Age,* per 5-year increment	1.43	< 0.001	**1.43**	**1.15−1.78**	**0.001**
Female sex*	1.50	0.11	1.57	0.83−2.96	0.16
STS-PROM,* per 1% increment	0.96	0.45	**0.70**	**0.58−0.83**	**< 0.001**
Obesity	0.33	0.001	**0.37**	**0.18−0.78**	**0.009**
Hypertension	2.10	0.01	**2.34**	**1.17−4.68**	**0.02**
Known CAD	0.80	0.38	—	—	—
Chronic obstructive pulmonary disease	1.32	0.42	—	—	—
LVEF,* per 5% increment	1.02	0.73	0.89	0.29−1.00	0.06
Mean aortic gradient, per 5 mm Hg increment	1.15	< 0.001	**1.17**	**1.08−1.28**	**< 0.001**
AVA, per 0.1 cm^2 increment	0.86	0.003	—	—	—
Creatinine, per 5 umol/L increment	0.99	0.58	—	—	—

Boldface indicates significance ($P < 0.05$)

AVA, aortic valve area; CAD, coronary artery disease; CI, confidence interval; LVEF, left ventricular ejection fraction; OR, odds ratio; STS-PROM, Society of Thoracic Surgeons predicted risk of mortality.

*Age, sex, STS-PROM, and LVEF were forced into the model.

C-HT patients undergoing isolated SAVR as opposed to concomitant procedures; (ii) a lower mean age among C-HT patients, compared to that among H-HT patients; and (iii) a smaller proportion of C-HT patients having a left ventricular ejection fraction less than or equal to 30% vs that in group H-HT. TAVR was reserved for high-risk patients in the 2015-2017 period in our institution; therefore, those of intermediate risk would undergo SAVR, which also explains the higher risk profile in group H-HT. Since then, TAVR has been expanded to intermediate-risk patients (and even some low-risk patients), meaning that proportionately fewer intermediate-risk patients are undergoing SAVR.

Overall, contemporary patients experienced more favourable outcomes, compared to the historical cohort. The composite endpoint was 5 times higher in group H-HT vs group C-HT, and this result may be attributed to H-HT patients being significantly older than C-HT patients, having the highest mean STS score, having a higher prevalence of CAD, and being the group that underwent more concomitant surgeries, including root procedures.

Only when isolated SAVR was considered did the differences between the groups disappear. Remarkably, the multivariable logistic regression analysis demonstrated that the need for root procedures was found to be an independent predictor for the composite endpoint. Aortic root replacement is inherently linked with high mortality and morbidity rates.[11,12] Despite improved protection to the brain and myocardium as a result of technical advancements in thoracic surgery, mortality and morbidity rates remain elevated.[13,14]

Stamou et al. demonstrated an elevated incidence of operative mortality in patients with AS undergoing aortic root surgery (6.5%,) compared to that among those without AS (3.5%). Additionally, increased rates of acute renal failure and prolonged length of stay were observed.[15] This finding may be explained by the technical challenges encountered in such combined procedures, the need for procedural expertise, and the effects on patient outcomes when cardiopulmonary bypass time is increased. Whether these patients can be considered for TAVR as an alternative option remains unclear. In at least one-fifth of cases, TAVR was contraindicated specifically for aortic root reasons.

The incidence of in-hospital all-cause mortality in group C-HT was 3.9%, which is comparable to that in previously published trials of patients following SAVR with preoperative HT assessment (**Su**rgical **R**eplacement and **T**ranscatheter **A**ortic **V**alve **I**mplantation [SURTAVI] and **P**lacement of **Aor**tic **Tran**scathe**ter** Valves 2 [PARTNER 2]), which showed a mortality rate of 1.7% and 4.1%, respectively.[6,7] Other in-hospital outcomes, including but not limited to myocardial infarction, major bleeding, acute kidney injury, and new-onset atrial fibrillation, showed no significant difference among our 3 groups, similar to results seen in the PARTNER 2 trial of intermediate-risk patients who underwent SAVR.[6]

No difference was observed when comparing all-cause mortality at 1 year across all 3 groups, which ranged from 7.9% to 11.4%. This percentage is lower than that in other studies consisting of intermediate-risk patients as determined by STS score, who showed 1-year mortality rates between 13.6% and 16.9%.[6,16-19] Studies demonstrating higher 1-year mortality rates may be explained by an older patient population with mean STS scores on the upper limit of the intermediate STS-score range.

The effects of the HT: C-HT vs No-HT

Although more patients with AS undergoing SAVR are being assessed by the HT, compared to the number in previous years, the majority continue to be directly referred to cardiac surgery. Referral to the HT was observed to be primarily driven by chronological age in a multivariable model, despite patients having a lower mean STS score, having comparable frailty scores, and undergoing fewer concomitant procedures. In fact, once adjusted for age, higher STS scores actually predicted direct referral to surgery rather than to the HT. These findings could be attributed to incomplete assessment of patients by the referring physician prior to referral. In addition, variations and complexities in coronary anatomy may have influenced the need for a concomitant CABG procedure, as opposed to percutaneous revascularization, thereby increasing the STS-PROM score. This information, along with the STS-PROM score itself, would not have been known by physicians at the time of referral in most

cases. In addition, variables in the statistical model could be affected by multicollinearity.

Of note, no significant difference across in-hospital outcomes was observed among patients seen by the HT, compared to those directly referred to surgery. These results are aligned with those of other studies.[6] Similarly, all-cause mortality at 1 year was similar for group C-HT vs group No-HT patients, a finding comparable to those in other studies of intermediate-risk STS-score patients, which showed 1-year mortality rates between 13.6% and 16.9%.[6,16-19] However, the incidence of readmission after 1 year was higher among patients referred directly to surgery (23.5% vs 12% among those seen by the HT; $P = 0.045$), indicating that a more thorough patient baseline assessment potentially improves long-term outcomes to a greater degree than in-hospital outcomes.

Moving forward, we argue in favour of having a single, designated referral centre for valvular disease, such that referring physicians do not need to decide which intervention is best for each patient with the limited information known at the time of referral. For example, the referring physician would be unable to compute the STS score accurately, as many elements would be unavailable to do so, most importantly, the extent of CAD. Having a single referral centre also offers the opportunity to thoroughly assess frailty for all patients, which would also contribute to an enhanced screening process. Therefore, having a single referral centre would allow more patients to have the opportunity to be seen by an HT, regardless of age.

Role of the HT: now and in the future

Benefits and challenges are associated with a HT assessment. Multidisciplinary approaches and discussions, optimal treatment options, risk-score adjustments, increased patient satisfaction, and a sense of "shared" responsibility are among the strengths of the HT approach. An HT also offers the opportunity to integrate new modalities and innovative approaches for complex cases, all while enhancing patient risk-stratification. For example, the HT could provide input in situations in which concomitant CABG could be avoided in high-risk patients at a progressed stage of the disease (for example, by suggesting PCI + TAVR when feasible). This thorough assessment process may very well explain why patients assessed by the HT in our cohort experienced improved postoperative outcomes, despite presenting at an older age. Essentially, the presence of an HT ultimately serves to create a more robust selection process for both surgical and nonsurgical candidates.

Despite the numerous advantages and opportunities the HT approach offers, some challenges remain. The role of an HT inherently involves increased discussion among surgeons and interventionists. For the benefits of an HT to be realized, these discussions and ensuing decisions must be done in a timely fashion so as to avoid delays in treatment, especially for patients who are already at an advanced stage of the disease. In addition, large discussion groups can make it easier for the voice of the patient to be lost. Essentially, although the expertise of surgeons and interventionists is imperative, final decision-making should always include and accommodate (when possible) patient preferences. Lastly, cost effectiveness and clinical efficiency must be considered when deciding if a preoperative "health team" assessment would benefit an individual patient.[20]

In the future, as TAVR continues to be expanded to younger and lower-risk patients, the involvement of an HT will become increasingly important, as discussions will be centred around valve durability, future coronary access, and pacemaker rates, among other factors. Current guidelines clearly outline treatment protocols for only the extreme ends of the age and risk spectra. A large proportion of patients fall somewhere in the middle, meaning that their optimal course of care is not as obvious and requires a more in-depth discussion.[1]

Fundamentally, although an HT is challenging to organize, its implementation offers tremendous opportunities for experts to collectively discuss and decide how to provide the best care on a patient-specific level. The results of such discussions currently provide better patient outcomes in SAVR patients and will become increasingly critical as TAVR expands to younger cohorts.

Limitations

The main limitation to our study is its retrospective nature, with the inherent biases this entails. However, a randomized trial of HT assessment in patients undergoing SAVR is not practical. In addition, given the low number of patients per group, adjustment for baseline characteristics was not possible. The generalizability and representativeness of the findings are limited, owing to the study having been conducted at a single centre. In addition, this study relied on medical records data, which may mean some information was missing. Finally, although the participants in this study consisted almost entirely of older adults, frailty data were available for only a select number of participants. Only 1 frailty evaluator is currently available at our institution, making assessment of the frailty status of all patients seen in a given clinic difficult. As a result, few conclusions can be drawn from this information alone. The lack of frailty data among patients undergoing cardiac surgery at our institution may reflect our own inherent bias regarding patient age. In the future, the incorporation of frailty assessments should be extended to all patients with severe-AS, so that we can offer a more thorough patient workup, to ultimately improve both short- and long-term patient outcomes.

Conclusion

Patients assessed by an HT prior to undergoing SAVR have a low incidence of complications, comparable to that of patients referred directly to cardiac surgery. Although patients referred directly to cardiac surgery are younger, their surgical risks are not significantly lower, and their frailty status is equivalent to that of patients who are seen and assessed by a HT. An integrated approach to patients with severe AS should be considered when deciding upon the optimal course of care.

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Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at https://www.cjcopen.ca/ and at https://doi.org/10.1016/j.cjco.2022.10.003.