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ORIGINAL RESEARCH

Temporal Trends and Drivers of Heart Team Utilization in Transcatheter Aortic Valve Replacement: A Population-Based Study in Ontario, Canada

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BACKGROUND: The multidisciplinary Heart Team (HT) is recommended for management decisions for transcatheter aortic valve replacement (TAVR) candidates, and during TAVR procedures. Empiric evidence to support these recommendations is limited. We aimed to explore temporal trends, drivers, and outcomes associated with HT utilization.

METHODS AND RESULTS: TAVR candidates were identified in Ontario, Canada, from April 1, 2012 to March 31, 2019. The HT was defined as having a billing code for both a cardiologist and cardiac surgeon during the referral period. The procedural team was defined as a billing code during the TAVR procedure. Hierarchical logistical models were used to determine the drivers of HT. Median odds ratios were calculated to quantify the degree of variation among hospitals. Of 10 412 patients referred for TAVR consideration, 5489 (52.7%) patients underwent a HT during the referral period, with substantial range between hospitals (median odds ratio of 1.78). Utilization of a HT for TAVR referrals declined from 69.9% to 41.1% over the years of the study. Patient characteristics such as older age, frailty and dementia, and hospital characteristics including TAVR program size, were found associated with lower HT utilization. In TAVR procedures, the procedural team included both cardiologists and cardiac surgeons in 94.9% of cases, with minimal variation over time or between hospitals.

CONCLUSIONS: There has been substantial decline in HT utilization for TAVR candidates over time. In addition, maturity of TAVR programs was associated with lower HT utilization.

Key Words: aortic stenosis ■ Heart Team ■ transcatheter aortic valve replacement

Over the last decade, transcatheter aortic valve replacement (TAVR) has evolved to become either the standard of care or a reasonable alternative for patients with severe aortic stenosis (AS) across the entire spectrum of patient risk.[1,2] Over this period, it has become recognized that collaborative, multidisciplinary care is important for appropriate decision making and is recommended as an important quality indicator.[3]

The multidisciplinary Heart Team (HT) concept, comprised at its minimum of an interventional cardiologist and a cardiac surgeon, has been conceptualized in two contexts of TAVR care. The first is during the work-up phase in order to determine the best treatment strategy for the patient,[1] specifically which of TAVR, surgical aortic valve replacement (SAVR) or neither is most appropriate. The second is the complement of the procedural team consisting of both a cardiac surgeon and cardiologist during the actual TAVR procedure.[4]

Although these applications of the HT are endorsed by professional societies,[1,2,4] there is a paucity

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CLINICAL PERSPECTIVE

What Is New?

- A substantial decline in Heart Team utilization for TAVR candidates was observed over time.
- This decline in TAVR use was associated with increasing maturity of TAVR programs, and it did impact treatment allocation—thus we believe reflects a more selective use of the Heart Team in cases where it is likely to affect treatment decisions.

What Are the Clinical Implications?

- These findings challenge the current recommendations to utilize a Heart Team for every TAVR candidate.

Nonstandard Abbreviations and Acronyms

AS	aortic stenosis
CIHI-DAD	the Canadian Institute for Health Information Discharge Abstract Database
HT	Heart Team
ICES	Institute for Clinical Evaluative Sciences
MOHLTC	Ministry of Health and Long-Term Care
MOR	median odds ratio
OHIP	Ontario Health Insurance Plan
SAVR	surgical aortic valve replacement
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
TAVR	transcatheter aortic valve replacement

of empiric evidence to support this recommendation; instead it is based on expert opinion. No evidence exists that patients who undergo a HT assessment post referral have a different pattern of treatment allocation compared to patients who do not. Similarly, regarding the procedural team, there is no evidence on differential post-hospitalization outcomes comparing procedures done by only cardiologists versus cardiac surgeons versus both.

Accordingly, we sought to address these gaps in knowledge through a population-based study in Ontario, Canada. Our specific objectives were to explore temporal trends and drivers of HT utilization in TAVR candidates in Ontario, Canada. In addition, we examined the relationship between HT utilization and treatment allocation. We hypothesize there would be wide variation in the utilization of the HT across hospitals, and that HT utilization during the decision-making phase would result in more appropriate TAVR candidates, while a full procedural team would have improved outcomes.

METHODS

This study was approved by the institutional research ethics board at Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada, before data collation and analysis. This retrospective cohort study utilized anonymized data of Ontario residents, held at ICES (previously known as the Institute for Clinical Evaluative Sciences). ICES is Canada's largest health services research institute and is a prescribed entity under Ontario's Personal Health Information Protection Act which allows for researchers to link together encoded population-based administrative databases and clinical registries for conducting approved research studies under strict privacy and security policies, procedures, and practices (see link to Data and Privacy at www.ices.on.ca). The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act; as such the need for individual patient consent was waived. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for the reporting of observational studies. Analytic methods and study materials will be available to other researchers for purposes of reproducing the results or replicating the procedure. Individual data will not be available in order to be compliant with privacy regulations in Ontario. Dr Wijeysundera will be responsible for maintaining the availability of analytic methods and study materials.

Context

Ontario is the largest province in Canada, with a population of 14.6 million. All citizens have universal access to health care and hospital services through a publicly funded healthcare program administered by a single third-party payer, the Ontario Ministry of Health and Long-Term Care. TAVR has been publicly funded in Ontario since 2012. It is currently approved across the spectrum of patient risk, from inoperable, high, intermediate, and low-risk patients.

Data Sources

Our study used data from the CorHealth Ontario registry,[5] which contains information on AS patients referred for consideration for TAVR at the 11 tertiary cardiac hospitals with onsite cardiac surgery across the province, from the time of referral until they are off-listed. Off-list reasons are broadly categorized as an intervention for AS (TAVR or SAVR), conservative treatment recommended without intervention, or death while awaiting intervention. The registry contains information on patient demographics, comorbidities, and procedural variables. These data elements have been validated through selected chart abstractions and core laboratory analyses.[6] Data from the CorHealth registry were linked using encoded unique patient identifiers to population-based administrative databases housed at ICES for verification and supplementation of baseline characteristics.

We used billing data from the Ontario Health Insurance Plan (OHIP) registry to determine if a physician assessment was conducted, and the ICES physician database to determine their subspeciality (cardiology versus cardiac surgery). We used data from the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD) to verify and supplement patient characteristics from the CoreHealth registry, as well as in-hospital outcomes, and post-discharge rehospitalizations. This includes the non-age adjusted Charlson score, calculated from the CIHI-DAD. The Registered Persons Database was used for ascertainment of all-cause mortality.

Patient Selection

We included all patients who were referred for TAVR in Ontario from April 1, 2012 to March 31, 2019. The unit of analysis for our study was episode of care, defined as the period from referral to an offlist. As such, a single patient could have more than 1 referral and episode of care—for patients with more than one referral, all were included.

Heart Team Definition

The CorHealth registry contains a variable on the date of acceptance for TAVR; however, it does not explicitly have a variable designated for HT discussion. In a previous environmental scan done by CorHealth, all Ontario TAVR programs report having a HT process. In this study, our aim was to explore if patients were seen by a cardiac surgeon and cardiologist during the period between referral to the procedure. A full HT evaluation was defined as having both a cardiologist and cardiac surgeon evaluating the patient during the referral period. We determined a physician evaluation based on the presence of a billing code as captured in the OHIP database; the evaluations could be asynchronous with evaluations by cardiac surgery and cardiology on different days. This definition would not capture if the HT compromised solely of a team discussion without the patient reviewed individually (ie virtual/in person) by each member.

As a secondary definition, we defined the procedural team based on the presence of a cardiologist and cardiac surgeon billing for the actual TAVR procedure, in the subset of our cohort who underwent a TAVR.

Follow-Up and Treatment Allocations

To examine the effect of the HT consults on the allocations of AS patients considered for intervention, patients were followed up for the entire period they were on the waiting list. We were interested in the reason for allocation to the off-list, which could be (1) treatment allocation to TAVR/SAVR, (2) no intervention (conservative therapy), or (3) death.

Statistical Analysis

Differences in baseline characteristics between HT and non-HT patients were compared using t test for normally distributed continuous variables, the Mann-Whitney test for non-normally distributed continuous variables and χ^2 tests for categorical variables. Given the large sample size, we also calculated standardized differences when comparing baseline differences, with a standardized difference of >0.1 considered significant. To understand the drivers of a HT during the referral period, a series of hierarchical logistic models were developed, with a random hospital effect. We first created a null model, with only the random hospital effect. We then sequentially built 3 more models by adding patient characteristics, hospital characteristics, and finally, a temporal effect based on the year of referral. These patient and hospital variables were chosen based on clinical relevance (see Table 1 for candidate variables). To understand the degree of variation between hospitals, we calculated the median odds ratio (MOR) for each of these models. The MOR is a measure of the variation between different hospitals that is not explained by the modeled risks.[7]

To understand the impact of a HT on treatment allocation, we built a cause-specific Cox proportional hazards model, with time to TAVR as the dependent variable. This accounts for the competing risk of dying on the waitlist, being off-listed for other reasons, or having a SAVR.

As per privacy legislation in Ontario, any cell with <5 counts were suppressed. All data analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC). Statistical significance was considered to be two-sided *P* values of ≤0.05.

RESULTS

HT Utilization in TAVR Consideration Referrals

After exclusions, our cohort included 10 412 patients who were referred for TAVR consideration between

Table 1. Baseline Characteristics of Patient Referred for TAVR According to Heart Team Utilization

Variable	Total Cohort	Heart Team: Yes	Heart Team: No	*P* Value	Standardized Difference
No.	10 412	5489	4923		
Demographic characteristics					
Age, median (IQR), y	83 (77–87)	82 (76–86)	84 (78–88)	<0.001	0.25
Sex, female, n (%)	4757 (45.7)	2442 (44.5)	2315 (47.0)	0.01	0.05
Income quintile, n (%)					
1	2120 (20.4)	1101 (20.1)	1019 (20.7)	0.19	0.02
2	2273 (21.8)	1170 (21.3)	1103 (22.4)		0.03
3	2096 (20.1)	1093 (19.9)	1003 (20.4)		0.01
4	1889 (18.1)	1030 (18.8)	859 (17.4)		0.03
5	2018 (19.4)	1089 (19.8)	929 (18.9)		0.02
Rural residence	1214 (11.7)	698 (12.7)	516 (10.5)	<0.001	0.07
Medical comorbidities					
Charlson score, mean±SD	1.53±1.82	1.52±1.82	1.55±1.83	0.45	0.01
Frailty, n (%)	2170 (20.8)	1063 (19.4)	1107 (22.5)	<0.001	0.08
Diabetes mellitus, n (%)	4532 (43.5)	2448 (44.6)	2084 (42.3)	0.02	0.05
Hypertension, n (%)	9564 (91.9)	5027 (91.6)	4537 (92.2)	0.28	0.02
Dyslipidemia, n (%)	5906 (56.7)	3090 (56.3)	2816 (57.2)	0.35	0.02
Congestive heart failure, n (%)	5804 (55.7)	2987 (54.4)	2817 (57.2)	0.004	0.06
COPD, n (%)	3656 (35.1)	1917 (34.9)	1739 (35.3)	0.67	0.01
Interstitial lung disease, n (%)	122 (1.2)	60 (1.1)	62 (1.3)	0.43	0.02
Dementia, n (%)	805 (7.7)	367 (6.7)	438 (8.9)	<0.001	0.08
Malignancy, n (%)	704 (6.8)	363 (6.6)	341 (6.9)	0.53	0.01
Liver disease, n (%)	188 (1.8)	84 (1.5)	104 (2.1)	0.03	0.04
Renal disease, n (%)	768 (7.4)	393 (7.2)	375 (7.6)	0.37	0.02
Dialysis, n (%)	349 (3.4)	188 (3.4)	161 (3.3)	0.66	0.01
Coronary artery disease, n (%)	4367 (41.9)	2378 (43.3)	1989 (40.4)	0.003	0.06
Cardiac arrhythmia/AF, n (%)	2125 (20.4)	1049 (19.1)	1076 (21.9)	<0.001	0.07
Cerebrovascular disease, n (%)	461 (4.4)	243 (4.4)	218 (4.4)	1.00	0
PVD, N (%)	309 (3.0)	172 (3.1)	137 (2.8)	0.29	0.02
Previous cardiac procedure, n (%)					
PCI	1771 (17.0)	925 (16.9)	846 (17.2)	0.65	0.01
CABG	1701 (16.3)	973 (17.7)	728 (14.8)	<0.001	0.08
Valve surgery	911 (8.7)	494 (9.0)	417 (8.5)	0.34	0.02
Fiscal year, n (%)					
2012	438 (4.2)	306 (5.6)	132 (2.7)	<0.001	0.15
2013	909 (8.7)	572 (10.4)	337 (6.8)		0.13
2014	1296 (12.4)	846 (15.4)	450 (9.1)		0.19
2015	1583 (15.2)	996 (18.1)	587 (11.9)		0.17
2016	1780 (17.1)	895 (16.3)	885 (18.0)		0.04
2017	2052 (19.7)	907 (16.5)	1145 (23.3)		0.17
2018	2354 (22.6)	967 (17.6)	1387 (28.2)		0.25
Number of TAVR done by hospital, median (IQR)	686 (398–771)	651 (398–771)	698 (582–771)	<0.001	0.28

AF indicates atrial fibrillation; CABG, coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; IQR, interquartile range; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; and TAVR, transcatheter aortic valve replacement.

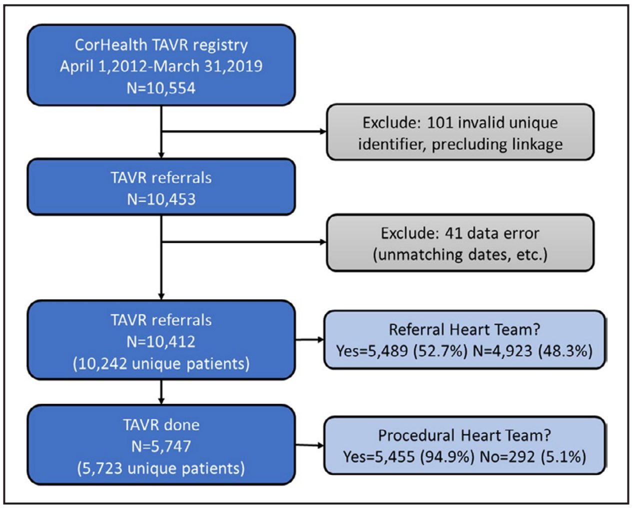

Figure 1. Data flow.
Cohort creation flow chart, with proportions of Heart Team utilization for patients referred for TAVR consideration, and for patients undergoing TAVR, in Ontario, between 2012 and 2019. TAVR indicates transcatheter aortic valve replacement.

April 2012 and March 2019 in Ontario, Canada (Figure 1).

After referral, 5489 (52.7%) patients underwent a HT before they were off-listed and 4923 had no HT before off-listing. Baseline characteristics of patients according to HT utilization status are presented in Table 1. For the overall cohort, the median age was 83 years (interquartile range [IQR] 77–87), and 45.7% were women. Compared with patients who underwent a HT, those who did not, were older, more frequently women, and had greater comorbidity burden, including heart failure, cardiac arrhythmias, dementia and frailty. At the hospital level, more established programs, as reflected by greater total number of TAVRs performed over the study period, had a lower utilization of a HT. There was decreasing HT utilization over time as seen in Figure 2, from 69.9% in 2012 to 41.1% in 2018.

Variation in HT Use

There was substantial variation in HT utilization across Ontario (Figure 3) from 35.2% to 77.0%. This is represented by a MOR for the null model of 1.78 (Table 2). To put this value in context, in comparison with the majority of the ORs that predict HT in Table 3, this MOR was of greater magnitude. This suggests that the unexplained between hospital variation in HT utilization was as relevant as the majority of patient- and hospital-level characteristics. When patient and hospital level factors were incorporated, the MOR did not decrease, suggesting that the between hospital variation was not accounted for by the factors in our model (full model MOR 1.83, Table 2).

Predictors of HT Use

Our multivariable model for identifying significant drivers of a HT in the referral period are presented in Table 3. Patients who were older (for each 1-year increase: odds ratio [OR] 0.97, 95% confidence interval [CI] 0.96–0.97, *P*<0.001) with greater comorbidities including frailty, or dementia were less likely to have a HT.

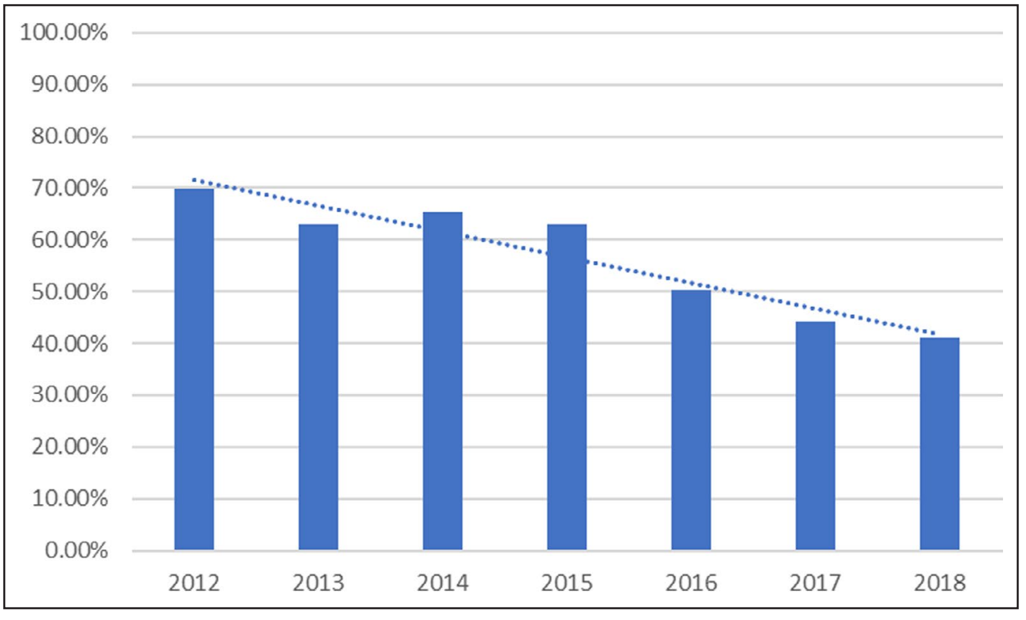

Figure 2. Temporal trend of Heart Team utilization 2012 to2018.
A statistically significant decline in Heart Team utilization for TAVR referrals was seen over the years of the study. See Table 3 for full multivariable logistic model. TAVR indicates transcatheter aortic valve replacement.

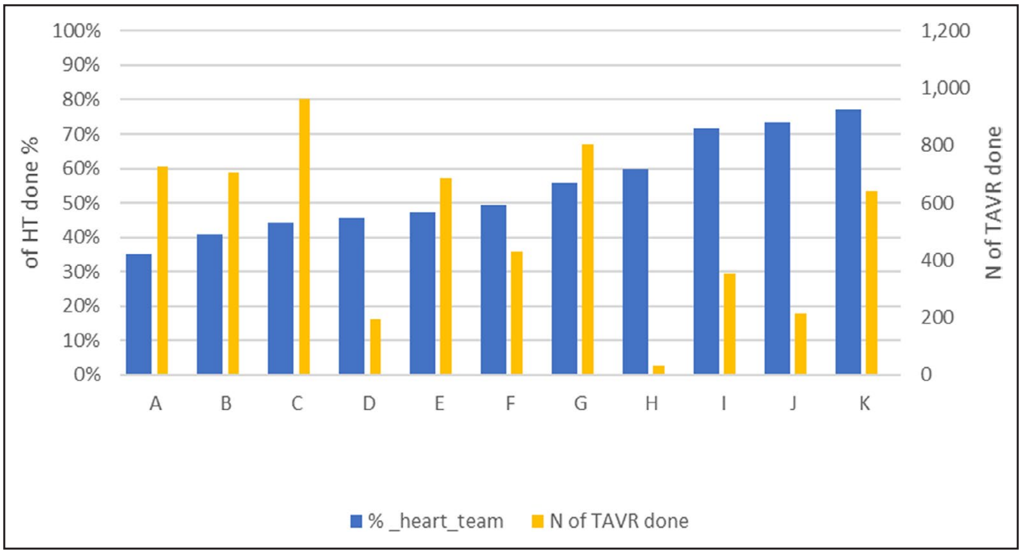

Figure 3. Heart Team utilization and number of TAVR done across hospitals in Ontario.
The percentage of Heart Team utilization had a wide variation across the 11 TAVR sites, with larger programs having less Heart Team use. TAVR done from 2012 to 2019 (see Table for model). HT indicates Heart Team; TAVR, transcatheter aortic valve replacement.

Larger hospitals based on bed count were more likely to have a HT (for each increase in 50 beds: OR 1.12; 95% CI 1.06–1.16, *P*=0.001). That said, larger TAVR programs based on TAVR completed, had a lower likelihood of a HT assessment (for any increase by 100 TAVR done—OR 0.81, 95% CI 0.68–0.96, *P*=0.02). There was a strong temporal impact, with patients referred in 2018 having an OR of 0.20 compared to those referred in 2012, even having accounted for baseline patient differences (Figure 2, Table 3).

Procedural Team Presence During TAVR Procedure

The subset of 5747 patients who underwent TAVR in our cohort had a median age of 83 years (IQR 78–87), and 44.5% of them were women. In 5455 (94.9%) of TAVR procedures, both a cardiologist and a cardiac surgeon (defined as a HT in the procedure) were present, with minimal variation observed between hospitals (Figure S1). Baseline characteristics of TAVR patients according to HT presence during the procedure are presented in Table S1.

Table 2. Multi-Level Model of Heart Team With Hospital as Random Effect

Model	Median Odds Ratio
Null	1.78
Patient level	1.82
Patient+hospital	1.74
Full (patient+hospital+year)	1.83

Treatment Allocation

As seen in Table 4, overall, patients undergoing a HT were more likely to undergo invasive treatment (TAVR or SAVR, 76.7% versus 55.6%). However, after adjusting for baseline characteristics and the competing risk of death, we did not find a significant relationship between HT and treatment allocation in an adjusted time to TAVR Cox model (Table S2, hazard ratio 1; *P*=0.93).

DISCUSSION

In our study of all TAVR referrals in Ontario, we found substantial variation in the use of HT between hospitals, and a strong temporal effect with decreasing HT utilization in more recent years. In contrast, we found that the procedural team for TAVR has remained consistent with both cardiologists and cardiac surgeons present during TAVR in most cases, without any significant variation between hospitals.

A previous survey by Mesana and colleagues from 2018 provided an overview on the utilization of the HT in Canada. They found that 47.6% of the hospitals did not have a HT currently, with half of the remaining hospitals stating they were planning to create one.[8] To our knowledge, ours is the first study that has looked at the HT in detail from the point of referral and contrasting the HT involved in treatment allocation decisions to the procedural team involved in the procedure. The hospital variation in the use of HT is striking, and merits further consideration. In TAVR candidates, factors that seem to reflect programmatic maturity, such as higher volumes of TAVR

Table 3. Multi-Level Logistic Model for Heart Team

Parameter	Odds Ratio	95% CI Lower	95% CI Upper	*P* Value
Patient level				
Age	0.97	0.96	0.97	<0.001
Charlson score	0.98	0.94	1.02	0.25
Frailty score	0.98	0.97	0.99	<0.001
Female sex	0.94	0.86	1.02	0.16
Rural residency	0.82	0.71	0.94	0.004
Hypertension	1.03	0.88	1.21	0.69
Diabetes mellitus	1.10	1.00	1.22	0.05
Dyslipidemia	1.03	0.94	1.12	0.54
Congestive heart failure	0.93	0.85	1.03	0.15
COPD	0.96	0.88	1.05	0.41
Interstitial lung disease	1.10	0.74	1.62	0.65
Malignancy	1.06	0.87	1.29	0.56
Atrial arrhythmia	0.89	0.79	0.99	0.03
Coronary artery disease	1.03	0.93	1.13	0.61
Cerebrovascular disease	1.15	0.93	1.43	0.19
Peripheral vascular disease	1.11	0.86	1.43	0.42
Dementia	0.80	0.69	0.94	0.007
Renal disease	1.07	0.87	1.30	0.53
Dialysis	1.05	0.81	1.35	0.72
Liver disease	0.62	0.45	0.87	0.01
Previous PCI	0.97	0.86	1.09	0.60
Previous CABG	0.95	0.84	1.08	0.47
Previous valve surgery	0.96	0.82	1.12	0.63
Hospital level				
Teaching hospital	0.79	0.24	2.57	0.67
Hospital size by bed count (per 50)	1.12	1.06	1.19	<0.001
Number of TAVR done (per 100)	0.81	0.68	0.96	0.020
Year level				
2012	Reference			
2013	0.56	0.43	0.72	<0.001
2014	0.62	0.48	0.80	<0.001
2015	0.59	0.46	0.75	<0.001
2016	0.33	0.26	0.42	<0.001
2017	0.24	0.19	0.30	<0.001
2018	0.20	0.16	0.26	<0.001

CABG indicates coronary artery bypass graft; COPD, chronic obstructive pulmonary disease; PCI, percutaneous coronary intervention; and TAVR, transcatheter aortic valve replacement.

completed, were associated with a lower HT utilization. Thus, our findings may reflect that mature programs have more comfort in determining patient eligibility for TAVR without requiring a full HT approach on all patients, given their experience in understanding which patients are most appropriate for each procedure. Indeed, reassuringly, despite the observed decline in HT utilization in TAVR candidates, we did not find evidence that treatment allocation was influenced by this change. Our findings are consistent with a study by Costa et al in which 383 TAVR candidates all underwent a HT. They found that 55.9% underwent TAVR, 20.9% underwent SAVR, and 23.2% were treated conservatively.[9] Somewhat surprisingly, we found that larger hospitals, as reflected by overall beds, had an inverse relationship with overall TAVR volume and maturity. The reasons for this are unclear and require further research.

Counterintuitively, the characteristics we found associated with a lower utilization of HT specifically older

Table 4. Unadjusted Treatment Allocation According to Heart Team Utilization

No. of referrals	Total Cohort	Heart Team: Yes	Heart Team: No	*P* Value
Referral outcomes				
n	10 412	5489	4923	
TAVR, n (%)	5747 (55.2)	3448 (62.8)	2299 (46.7)	<0.001
SAVR, n (%)	1201 (11.5)	762 (13.9)	439 (8.9)	
No intervention (medical treatment), n (%)	2860 (27.5)	1067 (19.4)	1793 (36.4)	
Death while waiting for intervention, n (%)	550 (5.3)	186 (3.4)	364 (7.4)	

SAVR indicates surgical aortic valve replacement; and TAVR, transcatheter aortic valve replacement.

age and frailty, are traditionally those for which the HT is considered most pertinent.[10,11] However, the variation between hospitals was not explained by these patient factors. Reinforcing this more selective approach, a recent editorial by Reardon et al suggests an evolution of the HT to a "Heart Team 2.0," recognizing a needed shift in the focus and composition of the HT to accommodate to the rapid evolution in transcatheter valve disease treatment.[12] We would argue that this does not reflect inappropriate care, as the allocation of treatments has not been impacted. Instead, it represents more efficient use of human resources to activate a HT only in those cases where it is likely to impact care decisions.

Several limitations must be considered in the interpretation of our findings. First, our definition of a HT was based on encounters with a cardiologist and a cardiac surgeon within a timeframe, not necessarily on the same day. This limitation, however, may lead to an overestimation of the occurrence of a HT and therefore bias to the null. Indeed, the true variance may be even greater than we found. Balanced against this, some may have had a consult from the "missing half" of the HT before the official referral date as documented in the CorHealth registry. In such cases, our analysis would have misclassified them as not having HT. Second, an important part of the data source, the billing done by the cardiologist and by the cardiac surgeon, is subject to under-reporting. This limitation may have led to an underestimation of HT utilization in our analysis. Third, our dataset lacked granular information that precluded the calculation of risk scores such as the Euroscore or Society for Thoracic Surgeons. Finally, our analysis was done on a cohort of patients who were referred for TAVR consideration. As such, our findings may not be fully generalizable to all AS patients, for which the guidelines recommend the HT approach.

CONCLUSIONS

In conclusion, we found a substantial decline over time in the utilization of the HT for TAVR candidates. Further study is needed to understand the implications of these observations so as to better inform best practice recommendations.

ARTICLE INFORMATION

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The corresponding author affirms that he has listed everyone who contributed significantly to the work. The authors had access to all the study data, take responsibility for the accuracy of the analysis, and had authority over manuscript preparation and the decision to submit the manuscript for publication. The corresponding author confirms that all authors read and approve the manuscript.

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Disclosures

None.

Supplementary Material

Tables S1–S2
Figure S1

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SUPPLEMENTAL MATERIAL

Table S1. Baseline characteristics of patients who underwent TAVR according to heart team during the procedure.

Variable	Total cohort	Heart Team: Yes	Heart Team: No	P-value	Standardized difference
N	5,747	5,455	292		
Demographic characteristics					
Age, median (IQR), y	83 (78-87)	83 (78-87)	83 (78-87)	0.76	0.02
Sex, female, N (%)	2,559 (44.5%)	2,445 (44.8%)	114 (39.0%)	0.05	0.12
Income quintile, N (%)					
1	1,117 (19.4%)	1,072 (19.7%)	45 (15.4%)	0.08	0.11
2	1,247 (21.7%)	1,190 (21.8%)	57 (19.5%)		0.06
3	1,190 (20.7%)	1,123 (20.6%)	67 (22.9%)		0.06
4	1,029 (17.9%)	961 (17.6%)	68 (23.3%)		0.14
5	1,154 (20.1%)	1,099 (20.1%)	55 (18.8%)		0.03
Rural residence	649 (11.3%)	612 (11.2%)	37 (12.7%)	0.62	0.04
Medical comorbidities					
Charlson score, mean±SD	1.43±1.74	1.43±1.73	1.43±1.84	0.99	0
Frailty, N (%)	1,004 (17.5%)	946 (17.3%)	58 (19.9%)	0.27	0.06
Diabetes, N (%)	2,458 (42.8%)	2,330 (42.7%)	128 (43.8%)	0.71	0.02
Hypertension, N (%)	5,289 (92.0%)	5,025 (92.1%)	264 (90.4%)	0.29	0.06
Dyslipidemia, N (%)	3,386 (58.9%)	3,218 (59.0%)	168 (57.5%)	0.62	0.03
Congestive heart failure, N (%)	3,105 (54.0%)	2,949 (54.1%)	156 (53.4%)	0.83	0.01
COPD, N (%)	1,960 (34.1%)	1,861 (34.1%)	99 (33.9%)	0.94	0
Interstitial lung disease, N (%)	56 (1.0%)	50-55*	<=5	0.93	0.01
Dementia, N (%)	351 (6.1%)	330 (6.0%)	21 (7.2%)	0.43	0.05
Malignancy, N (%)	368 (6.4%)	345 (6.3%)	23 (7.9%)	0.29	0.06
Liver Disease, N (%)	87 (1.5%)	80-89*	<=5	0.78	0.02
Renal Disease, N (%)	355 (6.2%)	334 (6.1%)	21 (7.2%)	0.46	0.04
Dialysis, N (%)	152 (2.6%)	140 (2.6%)	12 (4.1%)	0.11	0.09
Coronary artery disease, N (%)	2,539 (44.2%)	2,415 (44.3%)	124 (42.5%)	0.55	0.04
Cardiac arrhythmia/AF, N (%)	1,119 (19.5%)	1,050 (19.2%)	69 (23.6%)	0.07	0.11
Cerebrovascular disease, N (%)	234 (4.1%)	224 (4.1%)	10 (3.4%)	0.57	0.04
PVD, N (%)	164 (2.9%)	155 (2.8%)	9 (3.1%)	0.81	0.01
Pervious cardiac procedure, N (%)					
PCI	1,062 (18.5%)	1,011 (18.5%)	51 (17.5%)	0.65	0.03
CABG	1,111 (19.3%)	1,047 (19.2%)	64 (21.9%)	0.25	0.07
Valve surgery	511 (8.9%)	479 (8.8%)	32 (11.0%)	0.20	0.07
Fiscal year, N (%)					
2012	363 (6.3%)	340 (6.2%)	23 (7.9%)	0.03	0.06
2013	499 (8.7%)	468 (8.6%)	31 (10.6%)		0.07
2014	688 (12.0%)	669 (12.3%)	19 (6.5%)		0.2
2015	849 (14.8%)	810 (14.8%)	39 (13.4%)		0.04
2016	899 (15.6%)	844 (15.5%)	55 (18.8%)		0.09
2017	1,060 (18.4%)	1,000 (18.3%)	60 (20.5%)		0.06

2018	1,389 (24.2%)	1,324 (24.3%)	65 (22.3%)		0.05
Number of TAVR done by hospital, median (IQR)	686 (582-771)	686 (582-771)	698 (651-771)	<0.001	0.23
TAVR procedure characteristics, N (%)					
Valve in Valve	446 (7.8%)	415 (7.6%)	31 (10.6%)	0.06	0.1
Access site: Non-transfemoral	950 (16.5%)	927 (17.0%)	23 (7.9%)	<0.001	0.28
Procedure status: urgent/emergent	550 (9.6%)	511 (9.4%)	39 (13.4%)	0.02	0.13

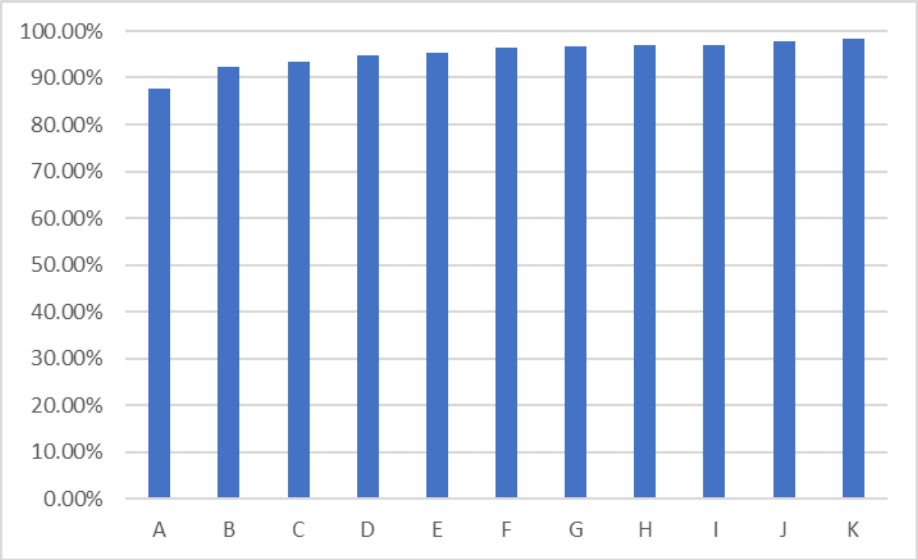
CABG – coronary artery bypass graft; COPD – chronic obstructive pulmonary disease; IQR – interquartile range; PCI – percutaneous coronary intervention; PVD – peripheral vascular disease; SD – standard deviation; TAVR - transcatheter aortic valve replacement.

Table S2. Adjusted Cox model of time to TAVR from referral according to heart team.

parameter	Hazard ratio	95%CI lower	95%CI upper	P-value
Heart team	1.00	0.95	1.06	0.93
age	1.01	1.00	1.01	0.00
Charlson score	1.02	1.00	1.05	0.11
Frailty score	0.99	0.98	1.00	0.01
Female sex	0.96	0.91	1.02	0.19
Rural residency	1.02	0.93	1.10	0.71
Hypertension	0.94	0.85	1.04	0.23
Diabetes	0.95	0.90	1.02	0.15
Dyslipidemia	1.05	0.99	1.11	0.09
Congestive heart failure	1.20	1.14	1.27	<0.001
COPD	0.89	0.84	0.94	<0.001
Interstitial lung disease	0.80	0.61	1.06	0.12
Malignancy	1.02	0.89	1.17	0.78
Atrial arrhythima	0.97	0.90	1.05	0.48
Coronary artery disease	1.27	1.20	1.35	<0.001
Cerebrovascular disease	0.97	0.84	1.12	0.67
Peripheral vascular disease	0.87	0.73	1.04	0.13
Dementia	0.80	0.71	0.89	<0.001
Renal diseas	1.03	0.89	1.19	0.68
Dialysis	0.79	0.65	0.95	0.01
Liver disease	0.87	0.69	1.11	0.26
Previous PCI	1.03	0.95	1.11	0.52
Previous CABG	1.11	1.03	1.20	0.01
Previous valve surgery	1.45	1.29	1.63	<0.001
Teaching hospital	1.09	1.01	1.18	0.03
Hospital size by bed count (per 50)	0.95	0.94	0.96	<0.001
Income quintile 1	0.89	0.82	0.97	0.01
Income quintile 2	0.87	0.80	0.95	0.00
Income quintile 3	0.95	0.88	1.04	0.25
Income quintile 4	1.02	0.94	1.12	0.63

CABG – coronary artery bypass graft; CI – confidence interval; COPD – chronic obstructive pulmonary disease; PCI – percutaneous coronary intervention; TAVR - transcatheter aortic valve replacement.

Figure S1. Heart team during TAVR procedures across hospitals in Ontario.



Minimal variation was seen between hospitals in Ontario in the presence of a heart team, i.e. a heart surgeon and a cardiologist, during TAVR procedures.