



## Original Article

# One-Year Costs Associated with Hospitalizations Due to Aortic Stenosis in Canada

Jean-Eric Tarride, MA, PhD,<sup>a,b</sup> Sandra Lauck, PhD,<sup>c</sup> Madhu K. Natarajan, MD, MSc,<sup>d</sup> Anita W. Asgar, MD, MSc,<sup>e</sup> Trinh Luong, BScPhm, MSc,<sup>f</sup> and Gord Blackhouse, MBA<sup>a,b</sup>

<sup>a</sup> Department of Health Research Methods, Evidence, and Impact, McMaster University, Hamilton, Ontario, Canada

<sup>b</sup> Programs for Assessment of Technology in Health (PATH), The Research Institute of St Joe's, St Joseph's Healthcare Hamilton, Hamilton, Ontario, Canada

<sup>c</sup> Centre for Heart Valve Innovation, St Paul's Hospital, University of British Columbia, Vancouver, British Columbia, Canada

<sup>d</sup> Division of Cardiology, Department of Medicine, McMaster University, Hamilton, Ontario, Canada

<sup>e</sup> Department of Cardiology, Montreal Heart Institute, University of Montreal, Montreal, Quebec, Canada

<sup>f</sup> Edwards Lifesciences (Canada), Inc, Mississauga, Ontario, Canada

## ABSTRACT

**Background:** There is a lack of data on the burden of patients hospitalized with aortic stenosis (AS) in Canada. The primary study objective was to document the index and 1-year costs of hospitalized patients with AS in Canada. Secondary objectives were to explore results by treatment modality and Canadian provinces.

**Methods:** Hospitalized patients with a most responsible diagnosis (MRD) of AS during fiscal year 2014/2015 were identified using Canadian administrative databases. Costs were calculated for the index admission and for up to 1 year. For our secondary analyses, patients were classified

## RÉSUMÉ

**Contexte :** Les données sur le fardeau associé aux hospitalisations pour sténose aortique (SA) au Canada sont fragmentaires. L'étude avait pour principal objectif de déterminer le coût de référence et le coût d'une année d'hospitalisations pour SA au Canada. Les objectifs secondaires consistaient à étudier les résultats selon les modalités thérapeutiques ainsi que par province canadienne.

**Méthodologie :** Les patients hospitalisés pour un diagnostic principal de SA pendant l'exercice financier 2014-2015 ont été répertoriés à partir de bases de données administratives canadiennes. Les coûts ont

Due to its high prevalence,<sup>1</sup> associated mortality,<sup>2,3</sup> associated poor quality of life,<sup>4</sup> and high healthcare resource utilization,<sup>5,6</sup> severe aortic stenosis (AS) is a major public health issue.<sup>7</sup> Although surgical aortic valve replacement (SAVR) has been the standard of care for severe or symptomatic AS patients, the use of transcatheter aortic valve implantation (TAVI) has been steadily increasing in Canada<sup>8-10</sup> and elsewhere.<sup>11-13</sup> A few studies have been conducted in Canada to document the use of TAVI<sup>8,9</sup> and SAVR over time,<sup>10</sup> and the hospitalization costs associated with TAVI, SAVR, or SAVR with coronary artery bypass graft (CABG) in Ontario.<sup>14</sup> Although these studies provide important information, they are limited in scope (TAVI only vs all treatment modalities)<sup>8-10,15</sup> or geographical location (Ontario or Quebec

vs all Canada).<sup>10,14,15</sup> In addition, no studies have provided information on the costs and outcomes among those Canadians who were hospitalized for AS but did not receive an intervention. Thus, the full economic burden associated with AS hospitalizations in Canada is unknown. Finally, although the Canadian Cardiovascular Society national quality reports<sup>8,9</sup> showed differences in TAVI outcomes across Canadian provinces, patients' demographic and inpatient costs in Canada and across Canadian provinces have never been examined by AS treatment modalities (eg, SAVR, SAVR with CABG, TAVI, or no treatment). To fill a gap in the literature and to inform future research, the primary objective of this study was to document the 1-year costs associated with hospitalization due to AS in Canada. Secondary exploratory objectives were to describe patient demographics and outcomes by treatment modalities and selected provinces.

Received for publication June 23, 2020. Accepted September 15, 2020.

**Ethics Statement:** The study was approved by the Hamilton Integrated Research Ethics Board (HiREB) (HiREB project #3141).

Corresponding author: Dr Jean-Eric Tarride, Communication Research Lab (CRL) 227, McMaster University, 1280 Main Street West, Hamilton, Ontario L8K 4K1, Canada. Tel. +1-905-525-9140 ext. 20205.

E-mail: [tarride@mcmaster.ca](mailto:tarride@mcmaster.ca)

See page 88 for disclosure information.

## Materials and Methods

### Data source and identification of cases

This retrospective cohort study used health administrative data from the Canadian Institute for Health Information

according to the intervention received: surgical aortic valve replacement (SAVR), SAVR with coronary artery bypass graft, or transfemoral or transapical transcatheter aortic valve implantation. Hospitalized AS patients who did not undergo SAVR or transcatheter aortic valve implantation were classified as the untreated group. The data were also analyzed by Canadian provinces.

**Results:** During fiscal year 2014/15, a total of 7217 Canadians were hospitalized with an MRD of AS. The mean (standard deviation) age of our population was 74.2 (11.5) years, and 39% were female. The 1-year hospital costs associated with an MRD of AS in Canada were calculated at \$393 million. Our secondary analyses suggest that patient demographics (mean age ranging from 69 to 82 years) and outcomes (median length of stay ranging from 6 to 12 days) differ among treatment modalities and Canadian provinces.

**Conclusions:** AS hospitalizations result in a significant cost burden in Canada. Future research is needed to better understand variation among treatment modalities and Canadian provinces.

(CIHI)<sup>16</sup> Discharge Abstract Database to identify patients hospitalized with a most responsible diagnosis (MRD) of AS in fiscal year (FY) 2014/2015. Aligned with other studies,<sup>10,11</sup> potential cases were included if patients were hospitalized with an MRD of either I35.0 for aortic (valve) stenosis or I35.2 for aortic (valve) stenosis with insufficiency. For our secondary objectives, the following cohorts of patients who received an intervention were selected: (i) SAVR alone; (ii) SAVR with CABG; (iii) transfemoral TAVI (TF-TAVI); and (iv) transapical TAVI (TA-TAVI). The group of hospitalized AS patients who did not undergo TAVI or SAVR but had an MRD of AS were categorized as “untreated.” [Supplemental Table S1](#) presents the detailed codes used to determine the study cohorts. We accessed the Discharge Abstract Database data covering 2 fiscal years (FY 2014/2015 and FY 2015/2016), allowing us to evaluate follow-up admissions and hospital costs up to 1 year post index admission. The study was approved by the Hamilton Integrated Research Ethics Board.

### Patients' characteristics

We used demographics and clinical information recorded in CIHI databases to describe our population. The Charlson Comorbidity Index, which is based on 17 comorbidities, and the Elixhauser Comorbidity Index, based on 31 comorbidities, were calculated using the administrative data to characterize the populations. To capture surgical risk, we relied on information recorded in the databases to determine risk and comorbidity scores in the absence of hospital-level documentation of the Society for Thoracic Surgeons (STS) predicted risk-of-mortality score. Based on previous publications using administrative databases,<sup>17-19</sup> the predicted risk (probability) of mortality was calculated with the logistic EuroScore (European System for Cardiac Operative Risk Evaluation), a disease-specific risk score predicting the

été calculés pour l'admission de référence et pour une période maximale d'un an. Pour nos analyses secondaires, les patients ont été classés selon l'intervention reçue : chirurgie de remplacement valvulaire aortique, chirurgie de remplacement valvulaire aortique avec pontage aortocoronarien, ou implantation valvulaire aortique par cathéter par voie transfémorale ou transapicale. Les patients hospitalisés pour SA n'ayant subi aucune chirurgie de remplacement valvulaire aortique ni aucune implantation valvulaire aortique par cathéter ont été classés non traités.

**Résultats :** Pendant l'exercice financier 2014-2015, un total de 7 217 Canadiens ont été hospitalisés pour un diagnostic principal de SA. L'âge moyen (écart-type) de notre population était de 74,2 (11,5) ans; 39 % étaient des femmes. Les coûts des hospitalisations pour SA comme diagnostic principal pour une année au Canada ont été calculés à 393 millions de dollars. Nos analyses secondaires laissent croire que les données démographiques des patients (âge moyen variant de 69 à 82 ans) et les issues (durée médiane des séjours variant de 6 à 12 jours) diffèrent selon les modalités thérapeutiques et les provinces canadiennes.

**Conclusions :** Les hospitalisations pour SA constituent un important fardeau financier au Canada. D'autres recherches sont nécessaires pour mieux comprendre les variations en fonction des modalités thérapeutiques et des provinces canadiennes.

chances of dying during or shortly after undergoing heart surgery.<sup>20</sup>

### Length of stay (LOS), resource intensity weight, and hospitalization costs

For the purpose of the analyses, the index date used to calculate LOS and costs was defined as the first day of hospitalization for AS. Index and 1-year hospital-related costs were documented according to CIHI methodology-based resource intensity weight (RIW).<sup>21</sup> Briefly, RIW is a relative resource number assigned to each hospitalization for which an RIW of 1.0 equals an average cost of stay. RIWs are determined based on the case-mix group (CMG) to which an individual is assigned based on their MRD at discharge, as well as other factors used to reflect variation in intensity of care among patients within a same CMG (eg, patients' age, health status, certain types of intervention to identify more-complex patients, such as those requiring invasive ventilation or dialysis). For each patient, the hospitalization cost was derived by multiplying the RIW for that patient by the national average cost per RIW (eg, \$6098 in 2017).<sup>22</sup> Given that physician billings are not included in the RIW value, surgeon/cardiologist, surgical assistant, and anesthetist fees associated with each AS intervention (SAVR, SAVR plus CABG, TAVI) were added based on assumptions used in Tam et al.<sup>23</sup> along with the intervention durations observed in the index hospitalizations. The device costs of TAVI and SAVR were assumed to be \$25,000 and \$6000 based on the manufacturers' list price of the balloon-expandable TAVI device and a recent Canadian cost-effectiveness study comparing TAVI with SAVR,<sup>23</sup> respectively. In addition to the costs associated with the index hospitalization, the cohorts were followed to document the costs associated with any hospital readmissions within 1 year following the index hospitalization.

## Statistical analysis

The primary analyses involved all individuals hospitalized with an MRD of AS. Mean and median values along with standard deviations (SDs) and interquartile ranges (IQRs) were used to summarize continuous variables (eg, age, LOS, RIWs, and costs). Discrete variables were represented using percentages. For our secondary analyses by treatment modalities, statistical tests (Student *t* test and  $\chi^2$  test) were conducted to determine statistically significant differences in baseline characteristics between treatment modalities. To explore variation among Canadian regions, data were first presented for Canada and then for the provinces of British Columbia (BC), Ontario, Quebec, and for all the other Canadian provinces combined to reflect approximately equal case volumes. Given the likely impact of unobserved confounders (eg, STS scores, frailty index, physician/patient preferences) and the absence of statistical methods<sup>24,25</sup>) to match our 5 cohorts, our analyses by treatment modalities were exploratory and descriptive in nature. To comply with CIHI requirements, cells for which less than 6 individuals contributed to the data were not disclosed.

## Results

### Number of AS hospitalizations and procedures

During FY 2014/2015, a total of 7217 Canadians were hospitalized with an MRD of AS. More than 6000 individuals received either TAVI or SAVR: 2808 (46%) procedures were SAVR, 2072 (34%) were SAVR with CABG, 1072 (18%) were TF-TAVI, and 109 (2%) were TA-TAVI. We also identified 1156 individuals hospitalized with an MRD of AS but who did not receive either SAVR or TAVI (ie, the untreated group).

### Primary analyses: burden of hospitalization due to AS in Canada

The mean (SD) age of our population was 74.2 (11.5); approximately 40% were female; and the value of the logistic EuroScore was 16%. The median (IQR) LOS and RIW associated with the index AS hospitalization were 8 (6, 17) and 3.9 (3.5, 6.2), respectively. Based on the RIW value, the median (IQR) cost associated with the index hospitalization was \$23,936 (\$21,593, \$37,589). The addition of the procedure and device costs resulted in an overall median (IQR) cost of \$40,445 (\$33,173, \$54,821) per AS hospitalization in Canada. Within 1 year following the index AS hospitalization, 36.5% of individuals were readmitted. Approximately one-third (32%) of these readmissions were cardiac related, and 2% were stroke related. The median (IQR) cost associated with these readmissions was \$10,934 (\$5234, \$23,602).

When both the AS index hospitalizations and 1-year readmissions were considered, AS was associated with 12,025 hospitalizations, 148,985 hospital days, and \$392.5 million in hospitalization costs. Among these costs, \$341.8 million were for the index hospitalizations. [Table 1](#) presents these data.

### Secondary analyses by treatment modality

As shown in [Table 2](#), presenting the patient characteristics for the entire population and by treatment modality, differences in age, gender, risk scores, or medical conditions were observed between treatment modalities (all *P* values <0.001). For example, the 2 SAVR cohorts were approximately 10-15 years younger than the TAVI and the untreated cohorts. Patients undergoing SAVR had the lowest logistic EuroScore (13%) compared to the other groups (ranging from 17% to 19%). However, the untreated group had the highest Charlson Comorbidity Index, and almost twice as many patients in the untreated group than in the other groups had a history of congestive heart failure (40% vs 12%-22% in the other groups).

Other data indicated that the median (IQR) RIW values associated with the index AS hospitalization ranged from 1.5 (1.0, 3.2) for the untreated group to 4.8 (3.9, 7.6; SAVR with CABG). Given that hospitalizations with SAVR and TF-TAVI shared the same CMGs (ie, 98% to 99% of patients who underwent SAVR or TF-TAVI were assigned to CMG 162, ie, cardiac valve procedure), the median (IQR) RIW associated with SAVR (3.9 [3.5, 6.0]) and TF-TAVI (3.9 [3.5, 6.4]) were very close in value. Consistent with the RIW values, the median [IQR] cost associated with the index hospitalization was quite similar between SAVR (\$23,936 [\$21,593, \$36,492]) and TF-TAVI (\$23,936 [\$21,593, \$38,749]). Overall, when the procedure and device costs were added to the RIW-hospitalization costs, the median (IQR) cost per AS hospitalization ranged from \$9160 (\$5879, \$19,331) for the untreated group to \$56,513 (\$51,775, \$72,021) for TA-TAVI. [Figure 1](#) presents the median (IQR) costs associated with the index hospitalization for the entire population, and by treatment modality, and [Supplemental Table S2](#) presents the detailed costing (eg, mean/SDs and median/IQR values of LOS, RIWs, and procedure and device costs).

As shown in [Table 3](#), the proportion of readmissions within 1 year following the index hospitalization ranged from 31% (SAVR) to 62% (TA-TAVI), and between 29% (SAVR) and 45% (untreated group) of these rehospitalizations were cardiac related. The median (IQR) cost associated with these readmissions ranged from \$7920 (\$4007, \$17,312) for SAVR to \$14,726 (\$7550, \$37,506) for TA-TAVI. [Supplemental Table S3](#) presents the detailed reasons for these readmissions and associated costs for the entire population and by treatment group.

**Table 1. Burden of aortic stenosis hospitalizations in Canada (fiscal years (FYs) 2014/2015 and 2015/2016)**

Variable	Index hospitalization (FY 2014/2015)	All-cause hospitalizations during 1-year follow-up (FY 2014/2015 and FY 2015/2016)	
			Total
Number of hospitalizations	7217	4808	12,025
Number of hospital days	104,788	44,197	148,985
Hospitalization costs, \$	341,847,046	50,660,312	392,507,358

**Table 2. Baseline characteristics of individuals hospitalized for aortic stenosis and per treatment modality (fiscal year 2014/2015)**

Variable name	All individuals (N = 7217)	SAVR (n = 2808)	SAVR with CABG (n = 2072)	TF-TAVI (n = 1072)	TA-TAVI (n = 109)	Untreated (n = 1156)	P for treatment comparison
Age, y	74.2 (11.5)	68.6 (11.2)	72.9 (8.4)	82.3 (7.4)	79.2 (7.9)	81.4 (12.4)	< 0.001
Female	38.5	39.4	24.3	47.8	53.2	52.2	< 0.001
EuroScore1	16	13	19	18	19	17	< 0.001
Elixhauser Comorbidity Index	3.4 (1.7)	3.1 (1.5)	3.7 (1.6)	3.2 (1.7)	3.8 (2.1)	3.6 (1.9)	< 0.001
Charlson Index	1.1 (1.1)	0.8 (0.9)	1.2 (1.1)	1.1 (1.1)	1.3 (1.3)	1.5 (1.2)	< 0.001
Medical comorbidities							
Chronic obstructive pulmonary disease	10.7	7.9	9.6	10.1	20.2	19.2	< 0.001
Cerebrovascular disease	3.5	2.7	4.6	3.4	7.3	3.1	< 0.001
Peripheral vascular disease	14.0	16.2	15.6	9.1	26.6	9.0	< 0.001
Obesity	8.0	9.6	10.1	3.2	9.2	4.9	< 0.001
Renal failure	11.0	5.7	9.9	14.7	22.0	21.6	< 0.001
Coagulopathy	5.0	4.5	7.8	4.5	7.3	1.7	< 0.001
Cardiac risk factors							
Diabetes with and without complications	30.2	25.7	37	30.1	25.7	28.2	< 0.001
Hypertension	56.4	50.0	69.5	54.1	56.0	50.8	< 0.001
Cardiac history							
Previous cardiac surgery	15.7	15.4	18.6	16.0	20.2	10.9	< 0.001
Recent myocardial infarction	6.4	2.4	13.2	2.7	ND	7.4	< 0.001
Congestive heart failure	19.4	12.0	16.6	21.8	19.3	40.3	< 0.001
Left ventricular dysfunction	2.7	1.2	1.7	1.8	ND	9.2	< 0.001
Valvular disease	100	100	100	100	100	100	0.247
Cardiac arrhythmia	46.2	48.2	52.9	41.2	45.9	33.8	< 0.001
Other							
Neurological dysfunction	12.4	10.2	17.7	7.6	11.0	12.9	< 0.001
Extracardiac arteriopathy	6.3	3.7	8.3	6.1	20.2	7.9	< 0.001
Pulmonary circulation disorders	3.2	2.6	2.9	3.1	7.3	5.1	0.001

Values are mean (standard deviation) or %, unless otherwise indicated.

CABG, coronary artery bypass grafting; IQR, interquartile range; ND, not disclosable as cell size is less than 6; SAVR, surgical aortic valve replacement; TA-TAVI, transcatheter aortic valve implantation; TF-TAVI, transfemoral transcatheter aortic valve implantation.

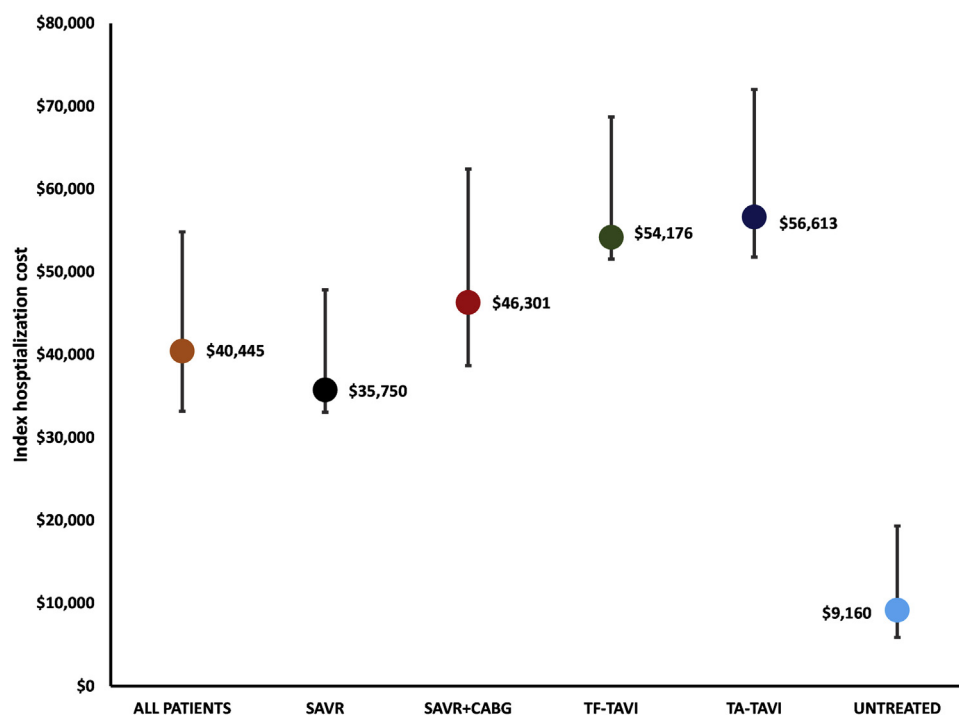
### Secondary analyses by Canadian provinces

Analysis of data by Canadian regions (BC, Quebec, Ontario, and all the other provinces) illustrated some variation in the median LOSs (Fig. 2) and RIWs (Fig. 3) associated with the index hospitalization for the entire population and by treatment modalities. For example, the median (IQR) LOS associated with the index hospitalization varied from 7 (5, 15) in BC to 10 (6, 19) in Quebec for the entire population (Fig. 2). In contrast to the LOS, the median RIW associated with the AS hospitalization was almost the same across the 4 regions for the entire population and for SAVR at 3.9. Variation in RIW values was seen for the other treatment modalities (Fig. 3). Differences among Canadian regions were also observed in terms of patient characteristics (eg, logistic EuroScore value) and mean hospitalization costs. Supplemental Table S4 presents the details.

### Discussion

To the best of our knowledge, our study is the first to provide a national estimate of the hospital costs associated with AS in Canada. As such, our study contributes to the literature in several ways. First, the results highlight the significant economic and human burden of hospitalization due to AS in Canada. Our 1-year results indicated that the total acute care costs following a hospitalization with an MRD of AS in Canada in FY 2014/2015 were \$393 million. Second, we described for the first time in Canada the patient characteristics, healthcare resource utilization, and costs per

treatment modalities, including those individuals hospitalized with an MRD of AS but who did not undergo SAVR or TAVI. Third, an important finding of our study highlights potential limitations associated with the RIW methodology when trying to compare the index hospitalization costs associated with TF-TAVI and SAVR in Canada. At the Canadian level (and also for Ontario and the provinces other than BC and Quebec), individuals who underwent TF-TAVI and SAVR had similar mean/median RIW values, despite differences of 15 years in the mean age between the SAVR and TF-TAVI cohorts. This is mostly due to a change in the RIW methodology when several age groups were rolled together for certain CMGs in 2014, including CMG 162. Fourth, our regional analyses also highlight important differences across the country, which need to be taken into consideration to better inform health services planning for AS patients. Although this study fills an important gap in the Canadian literature on AS, our analyses precede the recent rapid changes in TF-TAVI, with the accelerated adoption of a minimalist approach, the avoidance of critical care admission, and the increasingly adopted target of next-day discharge.<sup>26-28</sup> The latest Canadian data indicated a median LOS of 2 for TF-TAVI in 2017/2018 in Quebec, whereas a recent evaluation of the Vancouver 3M (multidisciplinary, multimodality, but minimalist) clinical pathway<sup>26</sup> found that 80% of patients could be discharged after 1 day, and 90% could be discharged within 2 days. In addition to improving outcomes, these changes to processes of care and health service utilization are associated with significant cost savings.<sup>29</sup> This evolution of



**Figure 1.** Median (interquartile range) cost associated with the index aortic stenosis hospitalization and per-treatment modality (fiscal year 2014/2015). The data include resource intensity weight admission costs as well as procedure and device costs. CABG, coronary artery bypass grafting; SAVR, surgical aortic valve replacement; TA-TAVI, transapical transcatheter aortic valve implantation; TF-TAVI, transfemoral transcatheter aortic valve implantation.

TAVI as a mature, minimally invasive treatment option will continue to narrow the gap with more-invasive approaches, and it is projected to become economically dominant by providing greater quality-adjusted life expectancy and lower long-term costs than SAVR.<sup>30</sup> Future research is warranted to determine if the change in technology and practice associated with TF-TAVI will result in decreased costs and improved outcomes associated with AS hospitalizations in Canada.

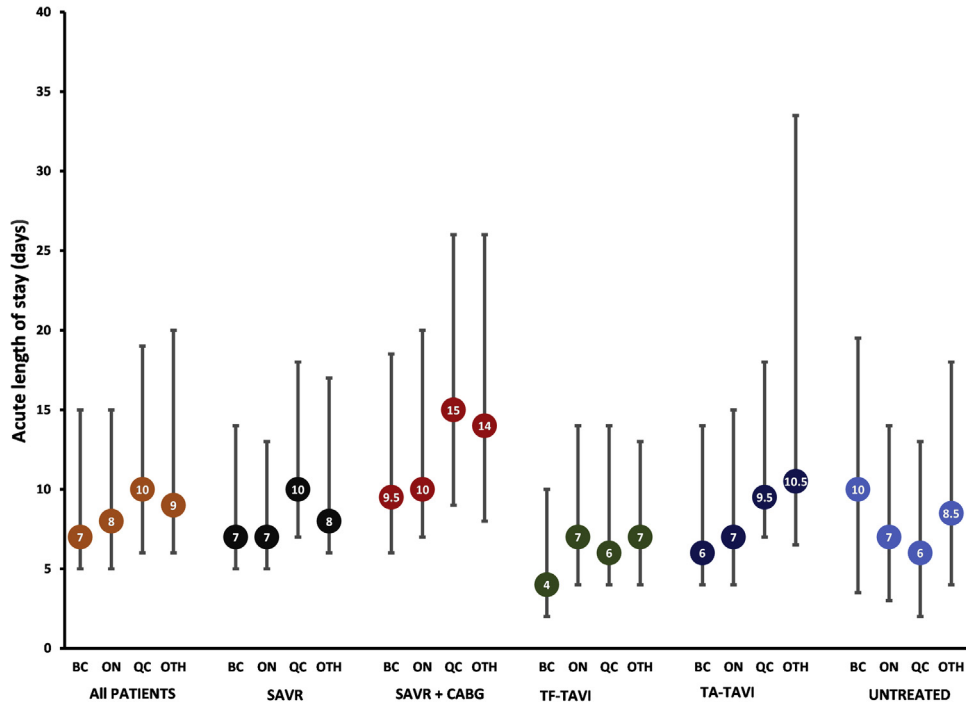
Due to varying methodologies or data, it is difficult to directly compare our results with those of other Canadian studies. However, the characteristics of our SAVR, SAVR with CABG, and TAVI study populations were relatively similar to

those of other Canadian<sup>8,9</sup> or Ontario<sup>10,14</sup> data in terms of age, sex, and comorbidity profile. Our TF-TAVI results were relatively comparable with Canadian Cardiovascular Society data<sup>9</sup> in terms of LOS, in-hospital stroke, and 1-year readmission for FY 2014/2015 and FY 2015/2016. In terms of costs, our cost estimates of the initial hospitalization (eg, median cost of \$54,176 and \$35,750 for TF-TAVI and SAVR, respectively) were higher than those estimated by Ailawadi et al.<sup>31</sup> in their study of Ontario AS-related hospitalizations (median costs of \$42,742 and \$21,811 for TAVI and SAVR, respectively). The difference is mostly due to costing methodologies, as Wijeyesundera et al.<sup>14</sup> based their estimates on the Ontario Case Costing Initiative, whereas our

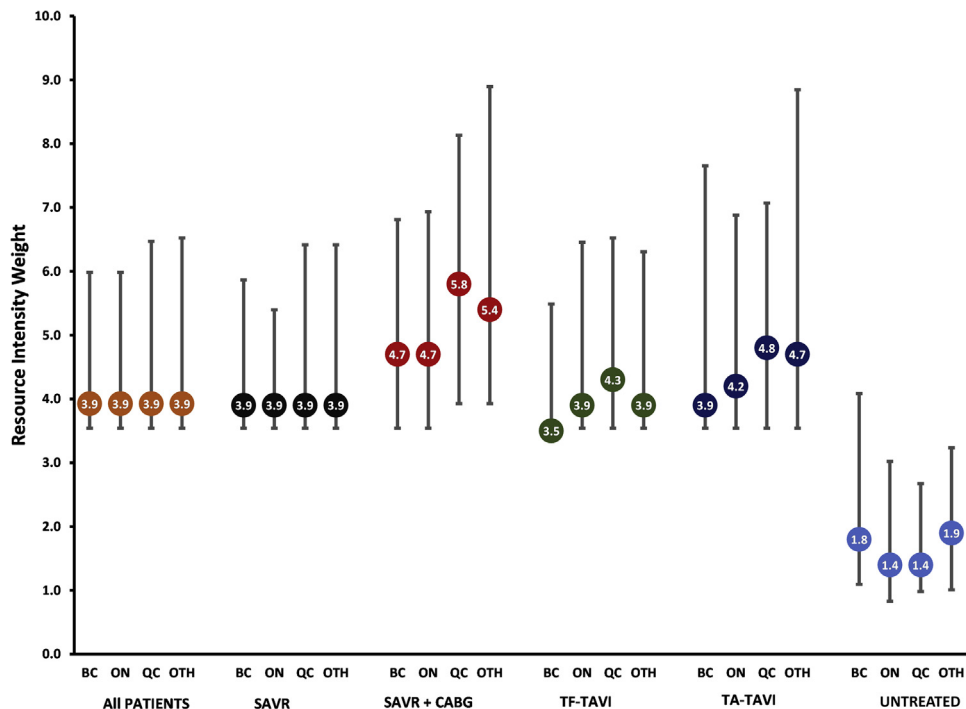
**Table 3.** Readmissions at 1 year following index aortic stenosis admission and per treatment modality (fiscal years 2014/2015 and 2015/2016)

Variable	All individuals (N = 7217)	SAVR (n = 2808)	SAVR with CABG (n = 2072)	TF-TAVI (n = 1072)	TA-TAVI (n = 109)	Untreated (n = 1156)
Patients with any readmission, %	36.5	30.6	31.6	45.2	62.4	48.8
Number of readmissions, mean (standard deviation)	0.70 (1.2)	0.51 (0.97)	0.56 (1.10)	0.90 (1.33)	1.19 (1.38)	0.97 (1.43)
Cardiac readmissions, %	32	29.0	24.8	28.9	36.9	45.2
Readmissions related to stroke, %	2.0	2.1	2.0	2.1	ND	2.0
1-year readmission costs (among those readmitted), mean (standard deviation), \$	20,354 (27,714)	15,748 (23,963)	18,166 (26,781)	22,781 (35,516)	25,413 (28,335)	21,778 (23,833)
1-year readmission costs (among those readmitted), median (interquartile range), \$	10,934 (5234, 23,602)	7920 (4007, 17,312)	8706 (4041, 19,474)	12,512 (5622, 27,234)	14,726 (7550, 37,506)	13,572 (5836, 28,973)

CABG, coronary artery bypass grafting; ND, not disclosable as size of cell size is less than 6; SAVR, surgical aortic valve replacement; TA-TAVI, transapical transcatheter aortic valve implantation; TF-TAVI, transfemoral transcatheter aortic valve implantation.



**Figure 2.** Median (interquartile range) length of stay associated with the index aortic stenosis hospitalization per province and treatment modality (fiscal year 2014/2015). BC, British Columbia; CABG, coronary artery bypass grafting; ON, Ontario; OTH, all other Canadian provinces; QC, Quebec; SAVR: surgical aortic valve replacement; TA-TAVI: transapical transcatheter aortic valve implantation; TF-TAVI, transfemoral transcatheter aortic valve implantation.



**Figure 3.** Median (interquartile range) resource intensity weight values associated with index aortic stenosis hospitalization per province and treatment modality (fiscal year 2014/2015). BC, British Columbia; CABG: coronary artery bypass grafting; ON: Ontario; OTH: all other Canadian provinces; QC: Quebec; SAVR, surgical aortic valve replacement; TA-TAVI, transapical transcatheter aortic valve implantation; TF-TAVI, transfemoral transcatheter aortic valve implantation.

estimates were based on applying a cost per resource intensity weight. Compared to the RIW methodology based on CMG (eg, TAVI and SAVR have the same RIW value), micro-costing may provide a more precise assessment of the index hospitalization costs associated with TAVI and SAVR. Unfortunately, the Ontario study<sup>14</sup> did not provide a detailed breakdown of the costs to better understand the difference in cost estimates between the 2 studies (eg, device costs, procedural costs). This highlights the need to use consistent approaches when measuring costs and outcomes associated with hospitalization due to AS.

There are a few limitations that should be considered when interpreting the results of our study. First, due to extensive delays in accessing the data from Quebec, our national data are relatively dated, and the findings, especially those associated with the TAVI group, may no longer be representative of the current situation, as previously discussed. Second, and consistent with the descriptive approach taken in the Canadian Cardiovascular Society reports on TAVI,<sup>8,9</sup> statistical comparisons of outcomes (eg, costs) between treatment modalities were not conducted, due to the absence of a validated risk-adjustment model, as well as differences in reimbursement criteria and funding allocation across Canada for TAVI. In addition, although propensity score-matching methods have been used to compare 2 matched cohorts of TAVI and SAVR patients, as of yet, these methods have not been developed to compare more than 3 treatments.<sup>24,25</sup> Furthermore, many important variables were not available in our datasets (eg, STS score, frailty index, physician and patient preferences), thus limiting our ability to adjust between cohorts to make meaningful comparisons. For these reasons (eg, unobserved confounders<sup>32</sup> and absence of statistical methods to match our 5 cohorts), our secondary analyses were exploratory and descriptive in nature, and direct comparisons by treatment modalities should not be made. In addition, any statistical methods to compare the different groups of patients by treatment modalities would also have to take into consideration regional differences, as shown by our data. This area is important for future research. Another important limitation of our study is that we did not have access to outpatient healthcare resource utilization associated with AS (eg, physician visits, prescribed medications) or mortality data in the community. Thus, the true burden of AS is likely to be larger than the hospital-related estimates presented in this paper. We also did not have information on the severity of AS and relied on an MRD of AS as a proxy. It is possible that some of the patients hospitalized with an MRD of AS but who did not undergo TAVI or SAVR may have had moderate AS. Finally, as in any study using administrative databases, we relied on diagnosis or coding information contained in the administrative databases and did not have access to detailed chart data (eg, body mass index, smoking status). As a result, some conditions may be underreported. For example, those with a diagnosis code of obesity (8% of our sample) may represent individuals with morbid obesity, as opposed to less-morbidly obese individuals. The fact that only 3% of the individuals undergoing TF-TAVI were considered obese in our data, vs 9%-10% for the other treatment modalities, may reflect treatment selection bias in a context of limited

reimbursement for TAVI in Canada. In comparison, US registry data indicated that 5% of all patients who underwent TAVI between 2011 and 2015 had class III obesity (body mass index  $\geq 40$  kg/m<sup>2</sup>), whereas 25% had class 1 or 2 obesity (body mass index from 30.0 to 39.9 kg/m<sup>2</sup>).<sup>33</sup>

Despite these limitations, our study has several strengths, including the access to all hospitalizations for AS in Canada. Thus, our results reflect real-world use and outcomes associated with the management of Canadian patients hospitalized due to an MRD of AS. Although the data are 4-5 years old, partly due to timely data availability, this study provides for the first time in Canada an estimate of the economic burden of hospitalization due to AS in Canada, which can be used as a benchmark for future studies. In the current economic times, clinicians must be sensitized to the economic burden of hospitalization due to AS and must work with administrators and policymakers to establish methods and trajectories of care that are efficacious for patients but also take into account associated costs. This approach is extremely important, as our results indicate that hospitalization due to AS is expensive. Thus, future research or initiatives should also focus on earlier awareness and options for treatment to avoid hospitalizations for symptomatic aortic stenosis. In addition, the paper describes the demographics, healthcare resource utilization, and costs per treatment modality (including those who did not receive an intervention) and province. Although descriptive and exploratory in nature, these analyses identified several important areas for future research to better understand variation in outcomes between treatment groups or provinces (eg, need for statistical methods to compare several treatment groups while incorporating regional variation in estimates).

## Conclusions

The study presenting the first comprehensive portrait of the burden of hospitalization due to aortic stenosis (AS) in Canada indicates that AS hospitalizations result in a significant cost burden. Several areas for future research were identified to better understand variation in outcomes between treatment modalities and Canadian provinces, and to decrease the burden of hospitalization due to AS.

## Acknowledgements

Parts of this material are based on data and information provided by CIHI; however the analyses, conclusions, opinions, and statements expressed herein are those of the authors and not those of CIHI.

## Funding Sources

The study was funded by Edwards Lifesciences (Canada), Inc.

## Disclosures

Dr Tarride has received honoraria from Edwards Lifesciences to participate on advisory boards. Dr Lauck has received consulting fees from Edwards Lifesciences. Dr Natarajan is a TAVI proctor for Edwards Lifesciences and has received honoraria for participation in an advisory role.

Dr Asgar has received consulting fees from Edwards Lifesciences and Medtronic. Ms Luong is an employee of Edwards Lifesciences. Mr Blackhouse has no funding sources to declare.

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### **Supplementary Material**

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