



## Original Article

# The Impact of Preoperative Frailty on the Clinical and Cost Outcomes of Adult Cardiac Surgery in Alberta, Canada: A Cohort Study

Carmel L. Montgomery, RN, PhD,<sup>a</sup> Nguyen X. Thanh, PhD,<sup>b,c</sup> Henry T. Stelfox, MD, PhD,<sup>b,d,e</sup>  
Colleen M. Norris, RN, PhD,<sup>b,c,f</sup> Darryl B. Rolfson, MD,<sup>g</sup> Steven R. Meyer, MD, PhD,<sup>h</sup>  
Mohamad A. Zibdawi, MD,<sup>a</sup> and Sean M. Bagshaw, MD, MSc<sup>a,b,c</sup>

<sup>a</sup> Department of Critical Care Medicine, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada

<sup>b</sup> Strategic Clinical Networks, Alberta Health Services, Edmonton, Alberta, Canada

<sup>c</sup> School of Public Health, University of Alberta, Edmonton, Alberta, Canada

<sup>d</sup> Department of Critical Care Medicine, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada

<sup>e</sup> Department of Community Health Sciences, University of Calgary, Calgary, Alberta, Canada

<sup>f</sup> Faculty of Nursing, University of Alberta, Edmonton, Alberta, Canada

<sup>g</sup> Division of Geriatric Medicine, Department of Medicine, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada

<sup>h</sup> Division of Cardiac Surgery, Department of Surgery, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada

## ABSTRACT

**Background:** There is limited information about the impact of frailty on public payer costs in cardiac surgery. This study aimed to determine quality-adjusted life-years (QALYs) and costs associated with preoperative frailty in patients referred for cardiac surgery.

**Methods:** We retrospectively compared costs of frailty in a cohort of 529 patients aged  $\geq 50$  years who were referred for nonemergent cardiac surgery in Alberta. Patients were screened preoperatively for frailty, defined as a score of 5 or greater on the Clinical Frailty Scale. The primary outcome measure was public payer costs attributable to frailty, calculated in a difference-in-difference (DID) model.

**Results:** The prevalence of frailty was 10% ( $n = 51$ ; 95% confidence interval [CI], 7%–12%). Median (interquartile range) costs for frail patients were higher in the first year postsurgery (\$200,709 [\$146,177–\$486,852] vs \$147,730 [\$100,674–\$177,025];  $P < 0.001$ ) compared

## RÉSUMÉ

**Contexte :** Il existe peu de renseignements concernant les répercussions de la fragilité sur les coûts pour les payeurs publics en chirurgie cardiaque. Cette étude visait à déterminer les années de vie pondérées par la qualité (QALY, pour Quality-Adjusted Life-Years) et les coûts associés à la fragilité préopératoire chez les patients dirigés vers un service de chirurgie cardiaque.

**Méthodologie :** Nous avons comparé de façon rétrospective les coûts de la fragilité dans une cohorte de 529 patients âgés de 50 ans ou plus qui ont été dirigés vers un service de chirurgie cardiaque pour une intervention non urgente en Alberta. Un dépistage de la fragilité, définie comme un score de 5 ou plus à l'échelle CFS (*Clinical Frailty Scale*), a été effectué avant l'intervention. Le principal critère d'évaluation était le coût attribuable à la fragilité pour les payeurs publics, calculé selon un modèle d'écart des différences.

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**Ethics Statement:** Health research ethics approval was obtained from the University of Alberta Research Ethics Board (File #Pro00074770). Each patient provided written informed consent prior to participation.

Corresponding author: Dr Carmel Montgomery, Department of Critical Care Medicine, Faculty of Medicine and Dentistry, University of Alberta, 2-124 CSB, 11350-83 Ave, Edmonton, Alberta T6G 2G3, Canada. Tel.: +1-780-248-1256; fax: +1-780-492-1500.

E-mail: [carmelm@ualberta.ca](mailto:carmelm@ualberta.ca)

See page 60 for disclosure information.

Frailty is the most common condition leading to death among community-dwelling elderly persons.<sup>1</sup> It is described as a multidimensional syndrome resulting from accumulation of deficits over time, and characterized by exaggerated vulnerability to adverse outcomes, especially following conditions of stress.<sup>2,3</sup> Rapid growth in the older demographic and concomitant increased prevalence of cardiovascular disease and frailty have been linked to prolonged duration of hospital stay, major morbidity, loss of independence, decline in overall

to nonfrail; the difference-in-difference attributable cost of frailty was \$57,836 (95% CI, \$-28,608-\$144,280). At 1 year, frail patients had fewer QALYs realized compared to nonfrail patients (0.71 [0.57-0.77] vs 0.82 [0.75-0.86],  $P < 0.001$ ), whereas QALYs gained were similar (0.02 [-0.02-0.05] vs 0.02 [0.00-0.04],  $P = 0.58$ , median difference 0.003 [95% CI, -0.01-0.02]) in frail and nonfrail patients.

**Conclusions:** Frailty screening identified a population with greater impairment in quality-of-life and greater healthcare costs. Costs attributable to frailty represent opportunity costs that should be considered in future cardiac surgical services planning in the context of our aging population and the growing prevalence of frailty.

quality-of-life, and high costs related to health services use near the end of life.<sup>4,6</sup> Despite frailty adding discriminative value to explain observed variances in costly adverse events, it is not routinely assessed prior to cardiac surgery.<sup>7</sup> With the Canadian population aged over 65 years expected to increase to 25% by 2038,<sup>8</sup> the number of people living with chronic conditions (eg, diabetes mellitus, hypertension, coronary artery disease) and frailty is anticipated to rise, as will demand for cardiac surgery.

Previous studies have focused on established preoperative risk stratification models, age,<sup>9</sup> and postoperative complications (eg, infection,<sup>10</sup> bleeding,<sup>11</sup> atrial fibrillation,<sup>12</sup> and acute kidney injury<sup>13</sup>) to predict costs associated with cardiac surgery. Although noncardiac surgical procedures have been the focus of cost prediction in the presence of preoperative frailty, only one study focused on proximate hospital costs following cardiac surgery.<sup>7</sup> This current study extends beyond the previous study as it explores both perioperative and longer-term costs associated with frailty.

In Canada, cardiac surgery (ie, coronary artery bypass graft and valve replacement) is the most frequent surgical procedure among patients admitted to intensive care units (ICUs), responsible for at least 21,000 annual admissions to one of the most resource-intensive and costly hospital services.<sup>14</sup> Preoperative screening for frailty may provide an opportunity to intervene to better manage costs and improve clinical outcomes in this population.<sup>15</sup> Accordingly, we aimed to describe clinical outcomes, health services use, and costs associated with patients living with frailty undergoing cardiac surgery. Our hypothesis was that preoperative frailty in cardiac surgery patients would be associated with greater morbidity, utilization of health services, and higher costs in the year prior to surgery and subsequent years following surgery.

## Methods

Health research ethics approval was obtained from the University of Alberta Research Ethics Board (File #Pro00074770).

**Résultats :** La prévalence de la fragilité a été de 10 % ( $n = 51$ ; intervalle de confiance [IC] à 95 % : 7 à 12 %). Les coûts médians (écart interquartile) dans la première année suivant l'intervention chirurgicale ont été plus élevés chez les patients fragiles que chez les patients non fragiles (200 709 \$ [146 177 \$ à 486 852 \$] contre 147 730 \$ [100 674 \$ à 177 025 \$];  $p < 0,001$ ); le coût attribuable de la fragilité selon le modèle d'écart des différences a été de 57 836 \$ (IC à 95 % : -28 608 \$ à 144 280 \$). À 1 an, les patients fragiles avaient moins de QALY réalisées que les patients non fragiles (0,71 [0,57 à 0,77] contre 0,82 [0,75 à 0,86];  $p < 0,001$ ), alors que le nombre de QALY gagnées était similaire (0,02 [-0,02 à 0,05] contre 0,02 [0,00 à 0,04];  $p = 0,58$ ; différence médiane : 0,003 [IC à 95 % : -0,01 à 0,02]) chez les patients fragiles et non fragiles.

**Conclusions :** Le dépistage de la fragilité a permis de repérer une population associée à une perte plus importante de qualité de vie et à des coûts plus élevés en soins de santé. Les coûts attribuables à la fragilité représentent des coûts de renonciation qui doivent être considérés dans la planification future des services de chirurgie cardiaque, dans le contexte du vieillissement de notre population et de la prévalence croissante de fragilité.

Each patient provided written informed consent prior to participation.

## Study design and setting

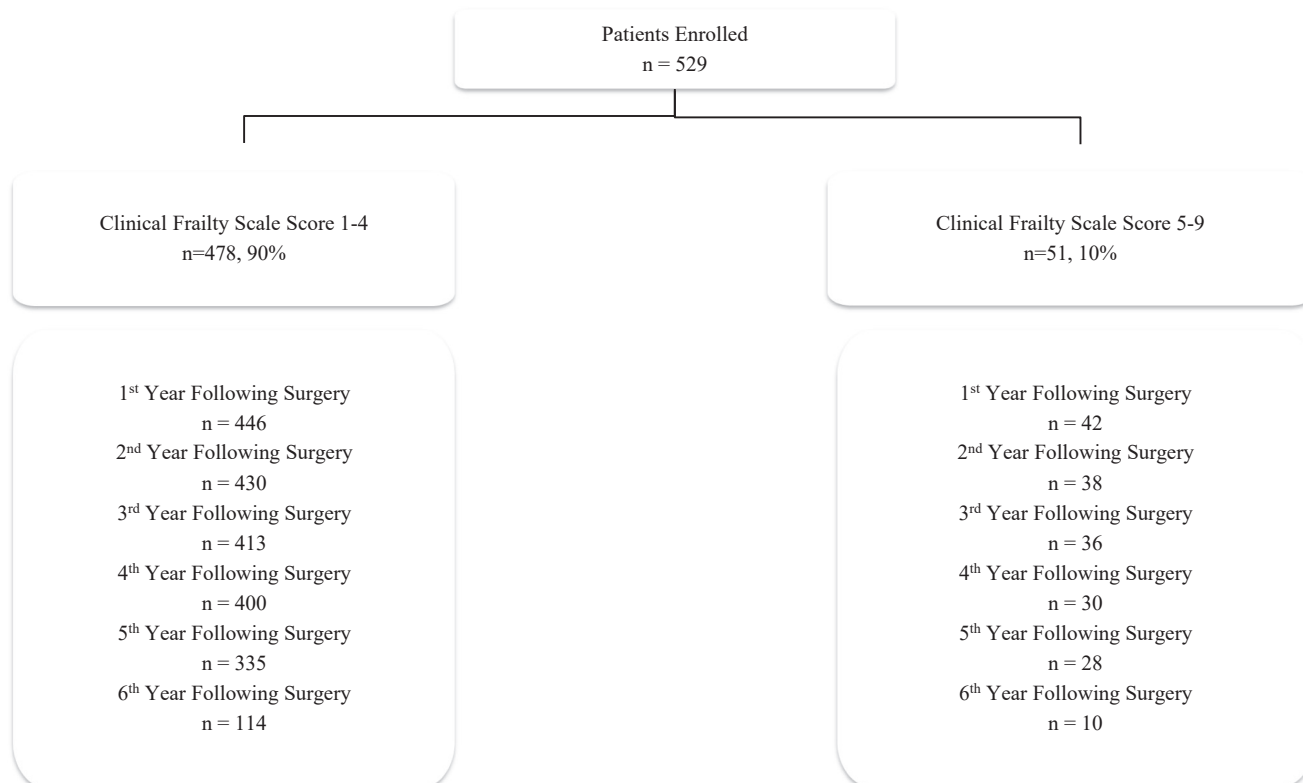
A retrospective comparative cost analysis of frailty within a prospective observational cohort of 529 patients aged  $\geq 50$  years referred for nonemergent surgery at the 2 academic centers where all cardiac surgical procedures are performed in Alberta, Canada enrolled between November 2011 and March 2014. Trained research coordinators assessed patients for frailty using the validated Clinical Frailty Scale (CFS) with frailty defined as a CFS score of  $\geq 5$ .<sup>3,16</sup> Health-related quality of life (HRQL) was assessed using the EuroQol (EQ-5D-3L)<sup>17</sup> in person, prior to surgery, and by telephone at 6 months and 12 months post-surgery. Surgical details, comorbidities, and adverse events were obtained from health records. The CFS is an instrument widely available, intuitive to use, and easy to apply to patients in any setting; it has been used as a dichotomous and categorized variable in regression models to predict patient-centred outcomes in community, acute care, and critical care settings.<sup>3,16,18</sup>

## Perspective and time horizon

This comparative cost analysis was completed from a public payer perspective to account for costs to Alberta's healthcare system, over a time horizon 1 year prior and extending to 5 years following the index surgery.

## Data sources and costing methods

Data were captured for all encounters with publicly funded health services in Alberta. For this study, costing data were obtained from Alberta Health Services and Alberta Health (AH). Cost components were captured reflecting inpatient services, outpatient visits, emergency department visits, practitioner/physician service claims, and community care services (ie, long-term facility-based care [LTC], designated supportive living [DSL], and home living [HL]). Alberta cost data are rigorously validated in accordance with provincial and



**Figure 1.** Number of patients deceased or lost to follow-up annually following surgery. Mortality in intensive care unit 1% (n = 4); 1 year following surgery 3% (n = 18); 5 years following surgery 12% (n = 66); others lost-to-follow-up due to leaving province.

national guidelines.<sup>19,20</sup> Data linkages were performed using facility medical record numbers and/or provincial unique personal health number. An inflation rate referencing the Canadian consumer price index was used to adjust all costs to the 2018 Canadian dollar equivalent.<sup>21</sup> All costs were summed at the patient level annually.

Cost of individual hospitalization was estimated by adjusting cost per standard hospital stay (CSHS) by resource intensity weight (RIW). The RIW is assigned on discharge, reflecting the amount of resources consumed by an individual patient relative to what is expected for the case mix group, age, discharge status, and comorbidities.<sup>22,23</sup> In Alberta, the inpatient discharge abstract database captures demographic, administrative, and clinical data for inpatient interventions to determine the RIW. CSHS includes costs of inpatient nursing services, surgery, ICU, general ward, medical imaging, clinical laboratory, and pharmacy for the duration of hospital stay, and is estimated using a Canadian Institute for Health Information micro-costing approach to inpatient discharge abstract database elements for each case mix group.<sup>22</sup> CSHS was obtained from the AH Interactive Health Data Application.<sup>24</sup>

We obtained average cost adjusted for inflation from the Interactive Health Data Application for each individual emergency department visit, outpatient clinic visit, and day procedure. Visits were grouped by the Canadian Institute for Health Information Comprehensive Ambulatory Care Classification System grouping methodology.<sup>25</sup>

Practitioner claims were captured for each fee-for-service claim in line with the provincial schedule of medical benefits, and the assessed amount for each alternative relationship

plan claim in the provincial practitioner claims database.<sup>26</sup> Duration of stay in LTC and DSL were captured in the Alberta Continuing Care Information Systems, a transaction processing system supporting delivery of LTC, DSL, and HL. Continuing care costs depend on assessed resource needs and authorized services. The mean daily costs in LTC and DSL sites for the cohort were provided by AH for this study and applied to actual patient days in care.<sup>27</sup> Costs associated with HL services were excluded.

Outpatient prescription drug costs were excluded due to variable patient insurance coverage in the group aged 50-65 years, recognizing that patients in this age group would be eligible for coverage from multiple private insurance payers.

### Measured outcomes

The primary outcome was the cost attributable to frailty, determined by the difference-in-difference (DID) cost between propensity score—matched frail and nonfrail patients prior to and following surgery. Secondary outcomes included: quality-adjusted life-years (QALYs) realized 1 year following the index surgery; QALYs gained attributable to frailty at 1 year following surgery; 5-year health services costs; and 5-year mortality.

### Statistical methods

In alignment with recommendations from the Canadian Agency for Drugs and Technologies in Health,<sup>28</sup> a DID approach presented a simple model to describe the attributable cost of frailty among patients referred for cardiac surgery. Although we are unable to test the common trend assumption

**Table 1. Characteristics of the cohort, comparisons before and after propensity-score matching**

| Characteristic                           | Before matching (n = 529) |                               |         | After matching <sup>§</sup> (n = 482) |                               |         |
|--|---------------------------|-------------------------------|---------|---------------------------------------|-------------------------------|---------|
|  | Frail CFS ≥ 5<br>(n = 51) | Nonfrail CFS ≤ 4<br>(n = 478) | P       | Frail CFS ≥ 5<br>(n = 41)             | Nonfrail CFS ≤ 4<br>(n = 441) | P       |
| CFS prior to surgery (median, IQR)       | 5 (5-6)                   | 3 (5-6)                       | < 0.001 | 5 (5-5)                               | 3 (3-4)                       | < 0.001 |
| Sex, female                              | 26 (51)                   | 111 (23)                      | < 0.001 | 21 (51)                               | 107 (24)                      | < 0.001 |
| Age (median, IQR)                        | 75 (65-80)                | 67 (60-73)                    | < 0.001 | 74 (63-80)                            | 67 (60-73)                    | 0.001   |
| EuroSCORE (mean, SD)                     | 8 (3)                     | 5 (3)                         | < 0.001 | 8 (3)                                 | 5 (3)                         | < 0.001 |
| Charlson comorbidity index (median, IQR) | 2 (0-4)                   | 1 (0-3)                       | 0.04    | 1 (0-3)                               | 1 (0-3)                       | 0.26    |
| Employed or volunteer                    | 9 (18)                    | 233 (49)                      | < 0.001 | 9 (22)                                | 214 (49)                      | 0.001   |
| Education postsecondary                  | 35 (71)                   | 255 (54)                      | 0.02    | 27 (69)                               | 236 (54)                      | 0.07    |
| Married                                  | 38 (75)                   | 380 (80)                      | 0.39    | 33 (80)                               | 349 (79)                      | 0.86    |
| Race non-Caucasian                       | 8 (16)                    | 50 (11)                       | 0.25    | 8 (20)                                | 45 (10)                       | 0.06    |
| Support at home                          | 34 (67)                   | 254 (53)                      | 0.07    | 28 (68)                               | 231 (53)                      | 0.05    |
| Previous 12-month hospitalizations       | 22 (45)                   | 106 (23)                      | 0.001   | 17 (44)                               | 101 (23)                      | 0.005   |
| <b>Presurgical conditions</b>            |                           |                               |         |                                       |                               |         |
| <b>Cardiac</b>                           |                           |                               |         |                                       |                               |         |
| Congestive heart failure                 | 17 (33)                   | 63 (13)                       | < 0.001 | 14 (34)                               | 59 (13)                       | < 0.001 |
| Peripheral vascular disease              | 10 (20)                   | 48 (10)                       | 0.04    | 7 (17)                                | 44 (10)                       | 0.16    |
| Pacemaker or AICD                        | 6 (12)                    | 12 (3)                        | 0.001   | 3 (7)                                 | 11 (2)                        | 0.11    |
| Aortic valve stenosis                    | 31 (61)                   | 196 (41)                      | 0.01    | 23 (56)                               | 181 (41)                      | 0.06    |
| Previous cardiac surgery                 | 3 (6)                     | 29 (6)                        | 0.96    | 2 (5)                                 | 24 (5)                        | 1.00    |
| Pulmonary arterial hypertension          | 11 (22)                   | 36 (8)                        | 0.001   | 10 (24)                               | 29 (7)                        | < 0.001 |
| Hypertension                             | 41 (80)                   | 360 (75)                      | 0.42    | 32 (78)                               | 334 (76)                      | 0.74    |
| Dyslipidemia                             | 37 (73)                   | 335 (70)                      | 0.71    | 30 (73)                               | 313 (71)                      | 0.77    |
| Smoker, current                          | 4 (8)                     | 60 (13)                       | 0.50    | 4 (10)                                | 55 (13)                       | 0.80    |
| Smoker, previous                         | 22 (43)                   | 218 (46)                      | 0.74    | 19(46)                                | 203 (46)                      | 0.97    |
| Ejection fraction < 40%                  | 2 (4)                     | 42 (9)                        | 0.30    | 2 (5)                                 | 36 (8)                        | 0.76    |
| Past MI                                  | 10 (20)                   | 97 (20)                       | 0.91    | 10 (24)                               | 87 (20)                       | 0.48    |
| Recent MI                                | 1 (2)                     | 13 (3)                        | 1.00    | 1 (2)                                 | 13 (3)                        | 1.00    |
| Previous ICU                             | 5 (10)                    | 24 (5)                        | 0.17    | 3 (8)                                 | 20 (5)                        | 0.42    |
| <b>Noncardiac</b>                        |                           |                               |         |                                       |                               |         |
| Coagulopathy                             | 6 (12)                    | 12 (3)                        | 0.001   | 5 (12)                                | 12 (3)                        | 0.01    |
| Liver disease                            | 1 (2)                     | 13 (3)                        | 1.00    | 1 (2)                                 | 11 (3)                        | 1.00    |
| Creatinine, presurgery (mean, SD)        | 97 (39)                   | 91 (48)                       | 0.20    | 91 (36)                               | 90 (40)                       | 0.86    |
| Chronic kidney disease*                  | 2 (4)                     | 4 (1)                         | 0.11    | 1 (2)                                 | 3 (1)                         | 0.30    |
| Renal impairment                         | 13 (25)                   | 50 (10)                       | 0.002   | 9 (22)                                | 45 (10)                       | 0.02    |
| COPD                                     | 18 (35)                   | 91 (19)                       | 0.006   | 14 (34)                               | 84 (19)                       | 0.02    |
| Hypothyroid                              | 15 (7)                    | 52 (11)                       | <0.001  | 10 (24)                               | 49 (11)                       | 0.01    |
| Weight loss                              | 10 (20)                   | 64 (14)                       | 0.22    | 9 (22)                                | 60 (14)                       | 0.14    |
| NIDDM                                    | 14 (28)                   | 120 (25)                      | 0.71    | 9 (22)                                | 110 (25)                      | 0.67    |
| IDDM                                     | 2 (4)                     | 33 (7)                        | 0.56    | 1 (2)                                 | 32 (7)                        | 0.34    |
| Peptic ulcer disease                     | 5 (10)                    | 25 (5)                        | 0.20    | 3 (7)                                 | 23 (5)                        | 0.48    |
| Malignancy                               | 13 (26)                   | 55 (12)                       | 0.01    | 9 (22)                                | 51 (12)                       | 0.05    |
| Rheumatoid arthritis                     | 19 (37)                   | 62 (13)                       | < 0.001 | 14 (34)                               | 56 (13)                       | < 0.001 |
| BMI (mean, SD)                           | 31 (6)                    | 30 (6)                        | 0.45    | 31 (7)                                | 30 (6)                        | 0.44    |
| BMI abnormal <sup>†</sup>                | 25 (49)                   | 207 (43)                      | 0.43    | 18 (44)                               | 194 (44)                      | 0.99    |
| History of falls                         | 17 (35)                   | 52 (11)                       | < 0.001 | 12 (29)                               | 50 (11)                       | 0.001   |
| Memory loss                              | 20 (39)                   | 126 (26)                      | 0.05    | 16 (39)                               | 114 (26)                      | 0.07    |
| Cognitive loss                           | 8 (16)                    | 256 (54)                      | 0.01    | 7 (17)                                | 20 (5)                        | 0.001   |
| General mental                           | 7 (14)                    | 26 (5)                        | 0.01    | 5(12)                                 | 16 (4)                        | 0.03    |
| Neurologic dysfunction <sup>‡</sup>      | 16 (31)                   | 21 (4)                        | 0.002   | 13 (32)                               | 64 (15)                       | 0.004   |
| Paralysis                                | 2 (4)                     | 69 (14)                       | 0.29    | 2 (5)                                 | 8 (2)                         | 0.21    |
| Cerebral vascular disease                | 5 (10)                    | 9 (2)                         | 0.85    | 4 (10)                                | 48 (11)                       | 1.00    |
| Prescribed medications (median, IQR)     | 6 (4-10)                  | 5 (3-7)                       | < 0.001 | 6 (4-10)                              | 5 (3-7)                       | 0.005   |
| <b>Surgery type</b>                      |                           |                               |         |                                       |                               |         |
| CABG only                                | 11 (22)                   | 191 (40)                      | 0.01    | 10 (24)                               | 178 (40)                      | 0.05    |
| Valve only                               | 24 (47)                   | 195 (41)                      | 0.39    | 19 (46)                               | 183 (42)                      | 0.55    |
| Combined CABG & valve                    | 15 (29)                   | 76 (16)                       | 0.02    | 11 (27)                               | 66 (15)                       | 0.05    |
| Myomectomy/ASD/ myxoma                   | 0 (0)                     | 9 (2)                         | 0.32    | 0 (0)                                 | 9 (2)                         | -       |
| Aorta only                               | 1 (2)                     | 7 (1)                         | 0.78    | 1 (2)                                 | 7 (1)                         | 0.68    |

Data are presented as n (%), unless otherwise indicated.

AICD, automated implanted cardioverter/defibrillator; ASD, atrial septal defect; BMI, body mass index; CABG, coronary artery bypass graft; CFS, Clinical Frailty Scale; COPD, chronic obstructive pulmonary disorder; ICU, intensive care unit; IDDM, insulin-dependent diabetes mellitus; IQR, interquartile range; MI, myocardial infarction; NIDDM, non-insulin dependent diabetes mellitus; SD, standard deviation.

\* Creatinine > 200 presurgery.

† BMI abnormal if < 19 or > 29.

‡ Neurologic dysfunction: Disease severely affecting ambulation or day-to-day functioning.

§ Kernel common matching using logit of propensity score from age group, sex, employment status, cognitive loss, congestive heart failure, aortic valve stenosis, pulmonary arterial hypertension, chronic obstructive pulmonary disease, hypothyroidism, malignancy, rheumatoid arthritis, neurologic dysfunction, and falls.

**Table 2. Health services costs for cardiac surgery cohort**

| Health services cost   | Overall cohort (n = 529)        | Frail CFS $\geq 5$ (n = 51)     | Nonfrail CFS $\leq 4$ (n = 478) | P       |
|--|---------------------------------|---------------------------------|---------------------------------|---------|
| 1-year presurgery (median, IQR)  | \$7753 (\$5914-\$12,393)        | \$12,708 (\$7775-\$18,852)      | \$7642 (\$5802-\$11,513)        | < 0.001 |
| 1-year postsurgery (median, IQR)   | \$149,532 (\$103,124-\$193,470) | \$200,709 (\$146,177-\$486,852) | \$147,730 (\$100,674-\$177,025) | < 0.001 |
| Cumulative costs, 1 year presurgery to 5 years postsurgery (median, IQR) | \$178,106 (\$135,967-\$268,327) | \$347,128 (\$187,253-\$606,743) | \$173,738 (\$132,307-\$252,597) | < 0.001 |

Health services cost = hospital, ambulatory care, claims, supportive living, and long-term care costs.  
CFS, Clinical Frailty Scale; IQR, interquartile range.

in the 2-period DID, the increasing trend of health expenditure per capita in Canada is supportive.<sup>29,30</sup> A propensity score-matched analysis was performed to account for differences in sociodemographic, comorbidity, and clinical factors among the cohort, and the likelihood of confounding variables predicting frailty at the time of surgery. Propensity scores were calculated by logistic regression with preoperative frailty as the dependent variable. All preoperative variables were included in the initial logistical model, with subsequent step-wise removal of covariates that predicted treatment perfectly, were nonsignificant ( $P > 0.25$ ) or where observations were missing<sup>31</sup> (Supplemental Table S1).

Subsequent DID analyses of cost differences between frail and nonfrail patients during the presurgery year compared to each year post surgery were performed. Patients were excluded from each annual comparison if a full year of costs were unavailable (ie, death or loss-to-follow-up; Fig. 1). Baseline characteristics between groups were compared before and after propensity-score adjustment to assess balance and bias reduction (Supplemental Table S2). We conducted the DID using kernel-based matching on estimated propensity scores, matching each frail patient with one or more nonfrail patients. Results were compared using local linear matching, followed by bootstrapping to estimate standard error.<sup>32</sup>

HRQL was estimated using EQ-5D-3L, a validated measure in cardiac surgery patients, focused on 5 dimensions: mobility; self-care; usual activities; pain/discomfort and anxiety/depression. Each dimension has 3 levels: no problems, some

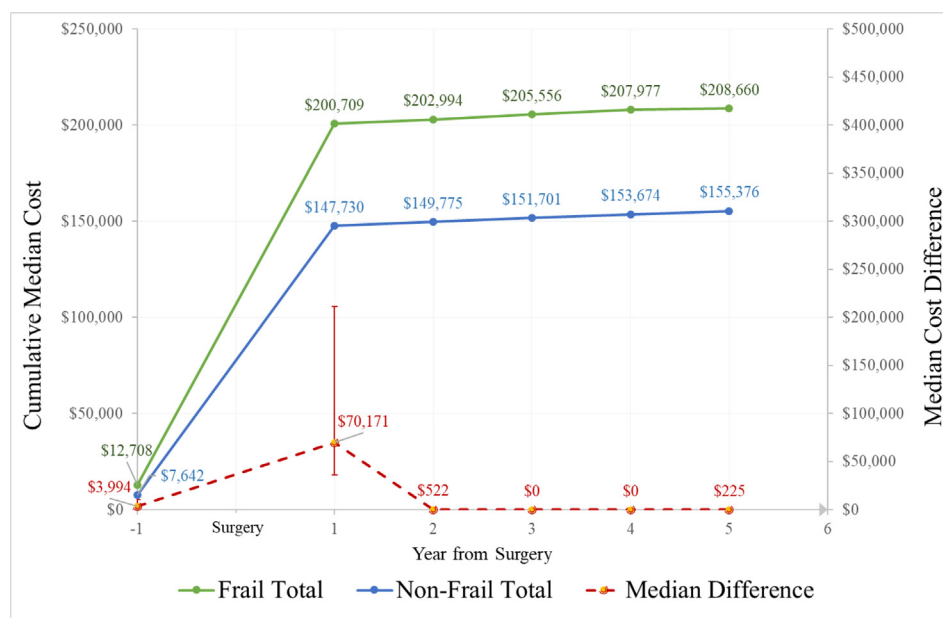
problems, and extreme problems.<sup>33</sup> Scores were combined with the Canadian valuation of health states to determine equivalent health utilities.<sup>34</sup> The sum of each individual average of presurgery baseline and 6-month utilities, and 6-month and 12-month health utilities, provided individual QALYs. Further, DID was used to compare frail to nonfrail QALYs gained at 1 year following surgery, to demonstrate the differential effect of frailty on QALYs gained.<sup>32,35</sup>

Descriptive statistics were used to summarize the cohort by CFS  $\geq 5$  (frail) compared to CFS  $\leq 4$  (nonfrail). Statistical analyses were performed using Stata 14 (College Station, TX).

## Results

### Demographic and clinical characteristics

Of 529 patients enrolled in the study, 10% (n = 51; 95% CI, 7%-13%) were considered frail preoperatively. The median (interquartile range [IQR]) age was 67 (60-74) years; 26% were female, mean (standard deviation) EuroSCORE was 5 (3); 41% (n = 219) underwent isolated valve surgery; 38% (n = 202) underwent isolated coronary artery bypass grafting surgery; and 17% (n = 91) received combined coronary artery bypass grafting/valve surgery. ICU stay was 1 (1-3) day, and postoperative hospital stay was 7 (6-11) days. Mortality was 1% (n = 4, 95% CI, 0.3%-2%) in ICU, 3% (n = 18, 95% CI, 2%-5%) at 1 year, and 12% (n = 66, 95% CI, 10%-16%) at 5 years (Table 1; Supplemental Tables S3 and S4; Supplemental Fig. S1)



**Figure 2.** Cumulative median cost of frail vs nonfrail patients 1 year presurgery to 5 years following surgery.

**Table 3. Difference-in-difference, frail vs nonfrail by year following cardiac surgery compared to year prior to surgery, for patients with a full year of costs available**

| Year postsurgery to year presurgery | Cohort                   | Frail mean cost     | Nonfrail mean cost   | Difference-in-difference | 95% confidence interval | P       |
|-------------------------------------|--------------------------|---------------------|----------------------|--------------------------|-------------------------|---------|
| 1st year                            | Unmatched                | \$251,921           | \$159,553            | \$92,369                 | \$45,970-\$138,768      | < 0.001 |
|                                     | Matched (ATT)<br>n = 482 | \$261,692<br>n = 37 | \$203,856<br>n = 441 | <b>\$57,836</b>          | \$-28,608-\$144,280     | 0.19    |
| 2nd year                            | Unmatched                | \$-3496             | \$-5774              | \$2278                   | \$-9890-\$14,446        | 0.71    |
|                                     | Matched (ATT)<br>n = 462 | \$2079<br>n = 37    | \$-8019<br>n = 425   | <b>\$10,098</b>          | \$-9330-\$29,526        | 0.31    |
| 3rd year                            | Unmatched                | \$-8996             | \$-688               | \$-8308                  | \$-24,807-\$8191        | 0.32    |
|                                     | Matched (ATT)<br>n = 443 | \$-8115<br>n = 35   | \$2998<br>n = 408    | <b>\$-11,113</b>         | \$-33,759-\$11,533      | 0.34    |

Matched (ATT): Cost ‘attributed to treatment’, where frailty is the ‘treatment’ variable, matched on propensity score. Kernel common matching method. Unmatched: Comparison of annual cost prior to matching. Difference in difference: Cost attributable to frailty (bold).

ATT, attributed to treatment.

### Healthcare costs and resource utilization

Overall costs from 1 year prior to surgery to 5 years following surgery were \$142 million. Patients with frailty had higher median (IQR) overall costs compared to nonfrail patients (\$347,128 [\$187,253-\$606,743] vs \$173,738 [\$132,307-\$252,597], *P* < 0.001), a median cost difference of \$142,424 (95% CI, \$66,976-\$263,835). In the year prior to surgery, costs were higher for patients with frailty compared to those for nonfrail patients (\$12,708 [\$7775-\$18,852] vs \$7642 [\$5802-\$11,513], *P* < 0.001), median difference \$3994 (95% CI, \$1906-\$6611). In the year following surgery, costs for patients with frailty were \$200,709 (\$146,177-\$486,852) compared to \$147,730 (\$100,674-\$177,025) in nonfrail patients (*P* < 0.001), median difference \$70,171 (95% CI, \$34,137-\$140,797; Table 2; Fig. 2).

In propensity-matched DID analysis, the mean cost attributable to frailty in the first year following surgery was \$57,836 (95% CI, \$-28,608-\$144,280), falling to \$10,098 (95% CI, \$-9,330-\$29,526) in the second year. Subsequent years’ results indicated, conditional on patient survival to 3 years postsurgery, that costs for patients with frailty approached those of nonfrail patients. Although for a small cohort of patients with frailty, the direction of effect favors diminishing costs for frail patients over time. Similar results were found using local linear matching with standard error calculation by bootstrapping (Table 3).

### HRQL

HRQL was more impaired for patients with frailty compared to nonfrail patients at baseline, at 6 months, and at 12 months following surgery. Complete EQ-5D results were obtained for 88% (n = 464) of patients at all 3 measurement points (frail n = 47, 92%; nonfrail n = 417, 87%). Median (IQR) estimated QALYs in the year following surgery was 0.81 (0.74-0.86). Between preoperative and 12-month measures, patients with frailty had fewer QALYs realized compared to nonfrail patients (0.71 [0.57-0.77] vs 0.82

[0.75-0.86], *P* < 0.001). QALYs gained were similar for frail and nonfrail patients (median [IQR] 0.016 [-0.02-0.05] vs 0.018 [0.00-0.04], *P* = 0.58), median difference 0.003 [95% CI, -0.01-0.02]; Table 4). Results from the DID model were similar, demonstrating a mean QALY gain in the year following surgery of 0.006 attributable to frailty (*P* = 0.61).

### Discussion

#### Key findings

In this prospective cohort study of patients aged ≥50 years referred for cardiac surgery, we found 10% of patients were identified as frail prior to surgery. As expected, patients with frailty were older, had lower baseline HRQL, higher EuroSCOREs, and underwent more complex surgical interventions. We found that patients with frailty had longer durations of stay in the ICU and in hospital, had similar QALYs gained at 1 year after surgery, and had greater healthcare costs 1 year prior to and following surgery.

#### Explanation of findings

Although these findings are consistent with those from studies performed in noncardiac surgery populations,<sup>36</sup> the cost implications of frailty have not been rigorously explored in cardiac surgical settings. Prior work has focused on proximate acute care costs associated with older patients undergoing cardiac surgery.<sup>9</sup> Only one study has previously described hospitalization-related costs among patients with frailty after cardiac surgery.<sup>7</sup> In this study of 235 older patients referred for cardiac surgery, those found to be frail incurred not only greater risk of complications following surgery, but also greater median (IQR) costs during hospitalization compared to nonfrail patients (\$32,742 [\$23,221-\$49,627] vs \$23,370 [\$19,977-\$29,705]).<sup>7</sup> Our findings are largely consistent with these observations; however, our study adds new knowledge by exploring costs prior to surgery, perioperatively, and following hospital discharge. We also

**Table 4. Quality-adjusted life years (QALYs) presurgery to 1 year following cardiac surgery**

| QALY-related measure             | Overall completed EQ-5D (n = 464) | Frail (n = 47) | Nonfrail (n = 417) | P       |
|----------------------------------|-----------------------------------|----------------|--------------------|---------|
| 1-year QALYs realized (mean, SD) | 0.77 (0.14)                       | 0.63 (0.21)    | 0.79 (0.12)        | < 0.001 |
| 1-year QALYs gained (mean, SD)   | 0.02 (0.05)                       | 0.01 (0.07)    | 0.02 (0.05)        | 0.17    |

QALYs calculated by multiplying the health utility score by the time midpoint between surveys.

EQ, EuroQol; SD, standard deviation.

provide new findings on the mortality-adjusted cost attributable to frailty and long-term survival for patients with frailty undergoing cardiac surgery. Importantly, we also showed that by 3 years, costs attributable to frailty among survivors were similar among patients who were frail compared to those who were nonfrail, a finding potentially related to survival bias.

Not surprisingly, our results also showed HRQL in frail patients was more impaired at baseline and at 1 year after surgery, compared to that of nonfrail patients. Furthermore, we showed that patients with and without frailty have similar incremental gains in QALYs through 1 year. Functional and HRQL recovery improved over time for frail patients and may take longer than 1 year to be substantially realized, depending on baseline status. These results were similar to findings from a study of 534 cardiac surgery patients aged  $\geq 75$  years over 5 years postsurgery.<sup>37</sup> Although the cohort was older than that in our study, overall HRQL improved from baseline to 6 months postoperatively, and remained stable for up to 5 years after surgery.

### Implications for policy, clinicians, and future research

Patients with frailty undergoing cardiac surgery are at greater risk of complications, prolonged hospitalization, death and higher proximate healthcare costs, along with greater burden of downstream impairment in HRQL, health services use, and long-term healthcare costs, as confirmed in our study.<sup>7,38</sup> Accordingly, a standardized assessment for frailty may offer opportunities for improving patient outcomes and optimizing health resource use.

Frailty case-finding prior to surgery can provide clinicians, patients, and their caregivers better information about the risk of adverse events and expectations about recovery associated with frailty and cardiac surgery. Knowledge of preoperative frailty status may afford opportunity to delay surgery and improve relative fitness (ie, prehabilitation)<sup>39</sup> or target innovative care pathways designed to rapidly restore cognitive and functional status following surgery (ie, enhanced recovery after surgery [ERAS] pathways).<sup>40</sup> The impact of these strategies in cardiac surgery should be evaluated in clinical trials.

### Strengths and limitations

Our study has a number of strengths, including use of validated instruments to determine frailty and capture HRQL, comprehensive provincial costing, and outcome data capture. Our study also has limitations. First, although the CFS was developed in an older ambulatory population and has been validated in ICU settings; it has not been explicitly described in cardiac surgery. We recognize that there are additional validated instruments to screen for frailty. We submit that our data advocate for frailty screening in general which would not solely be dependent on use of the CFS score. Second, the CFS score was not obtained by geriatric medicine clinicians; rather, it was obtained by experienced research personnel trained to reliably capture the CFS score, as previously described.<sup>16,41</sup> Third, we obtained HRQL data to only 1 year following surgery, limiting our ability to project cost per QALY gained for a longer duration. Fourth, we had no comparison group without surgical intervention to determine the net benefit of surgery in frail patients. Fifth, our study excluded patients who were referred for planned transcatheter aortic valve implementation, who are often

considered “too frail” for open aortic valve replacement. We recognize that use of this innovation has increased during the period of our study and acknowledge that clinical outcomes, resource use, and costs are uncertain for this procedure relative to conventional aortic valve replacement.<sup>42</sup> In addition, we submit that many of the frail patients in our cohort received combined procedures that would preclude transcatheter aortic valve implementation. Finally, our study was performed in a single-payer health system in a single Canadian province with 2 cardiac surgery referral centers. As such, our study may have limited generalizability to other health-care jurisdictions.

### Conclusions

Frailty identified a population with greater impairment in quality-of-life and greater healthcare costs. Costs attributable to frailty in the year following surgery were \$57,836, representing opportunity costs that should be considered in future cardiac surgical services planning in the context of our aging population and the growing prevalence of frailty.

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### Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at <https://www.cjopen.ca/> and at <https://doi.org/10.1016/j.cjco.2020.09.009>.