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Clinical Research

Variables Associated With Cardiac Surgical Waitlist Mortality From a Population-Based Cohort

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ABSTRACT

Background: Cardiac surgery waitlist recommendations, which were developed based on expert opinion, poorly predict preoperative mortality. Studies reporting risk factors for waitlist mortality have not evaluated the risks including nonadherence to waitlist benchmarks.

Methods: In patients who underwent cardiac surgery or died on the waitlist between 2005 and 2015, we used a Fine and Gray competing risk model to identify independent predictors of waitlist mortality in 12,106 patients scheduled for urgent, semiurgent, or nonurgent surgery. The predictive variables were compared with Canadian Cardiovascular Society (CCS) waitlist recommendations using the Akaike information criterion.

Results: A total of 101 (0.8%) patients died awaiting surgery. The median wait times and frequency waitlist deaths among emergent, urgent, semi-urgent, and nonurgent surgery were 0.6, 7.4, 69.0, 55.5 days ($P < 0.001$) and 6.3%, 0.8%, 0.3%, 0.6% ($P < 0.001$),

RÉSUMÉ

Introduction : Les recommandations en matière de listes d'attente en chirurgie cardiaque, qui sont fondées sur l'opinion d'experts, ne permettent pas de bien prédire la mortalité préopératoire. Les études qui rapportent des facteurs de risque de mortalité durant l'attente n'ont pas permis d'évaluer les risques, y compris le non-respect des délais de référence de la liste d'attente.

Méthodes : Chez les patients qui ont subi une intervention chirurgicale au cœur ou qui sont morts durant l'attente entre 2005 et 2015, nous avons utilisé le modèle de risque concurrent Fine et Gray pour déterminer les prédicteurs indépendants de mortalité durant l'attente de 12 106 patients inscrits pour une intervention chirurgicale urgente, semi-urgente ou non urgente. Nous avons comparé les variables de prédiction aux recommandations en matière de listes d'attente de la Société canadienne de cardiologie (SCC) à l'aide du critère d'information d'Akaike.

Coronary artery bypass grafting and cardiac valvular surgery improve quality of life and survival in appropriately selected patients.[1,2] In publicly funded health care systems, access to these procedures is limited by surgical capacity and priority waitlists have been used to triage patients.[3-8] A recognized consequence of delays in access to cardiac surgical care is waitlist mortality, which has a reported incidence rate of 0.58 to 2.90 deaths per 1000 patient-weeks of waiting (0.5% to 2.6% of patients) in contemporary surgical centres and registries.[8-15] Working group recommendations for acceptable cardiac surgical waitlist times are largely based on expert opinion and cardiac anatomic variables.[8-18] These consensus guidelines were developed over 25 years ago and have subsequently been shown to be poor predictors of preoperative cardiac events.[19,20] Previous studies have identified clinical variables associated with waitlist deaths, but unreported measures of model performance have precluded clinical utilization.[4,19-21] We hypothesized that adherence to current

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respectively. Adherence to CCS waitlist recommendations was higher in patients who died on the waitlist (51.6% vs 70.8%, $P = 0.001$) and was not predictive of waitlist mortality (hazard ratio 1.48, 95% confidence interval 0.62-0.56). Independent predictors of waitlist mortality were age, aortic surgery, ejection fraction $< 35\%$, urgent surgery, prior myocardial infarction, haemodynamic instability during cardiac catheterization, hypertension, and dyslipidemia. These variables were superior to current CCS guidelines (Akaike information criterion 1251 vs 1317, likelihood ratio test $P < 0.001$).

Conclusions: CCS waitlist recommendations were poorly predictive of waitlist mortality and the majority of waitlist deaths occur within recommended benchmarks. We identified variables associated with waitlist mortality with improved clinical performance. Our findings suggest a need to re-evaluate cardiac surgical triage criteria using evidence-based data.

Résultats : Un total de 101 (0,8 %) patients sont morts durant l'attente d'une intervention chirurgicale. Les temps d'attente médians et la fréquence des décès durant l'attente pour les interventions chirurgicales émergentes, urgentes, semi-urgentes et non urgentes étaient respectivement de 0,6, de 7,4, de 69,0 et de 55,5 jours ($P < 0,001$), et de 6,3 %, de 0,8 %, de 0,3 % et de 0,6 % ($P < 0,001$). Le respect des recommandations en matière de listes d'attente de la SCC était plus élevé chez les patients qui sont morts durant l'attente (51,6 % *vs* 70,8 %, $P = 0,001$) et n'ont pas permis de prédire la mortalité durant l'attente (rapport de risque 1,48, intervalle de confiance à 95 % 0,62-0,56). Les prédicteurs indépendants de mortalité durant l'attente étaient l'âge, la chirurgie aortique, la fraction d'éjection < 35 %, l'intervention chirurgicale urgente, l'infarctus du myocarde antérieur, l'instabilité hémodynamique durant le cathétérisme cardiaque, l'hypertension et la dyslipidémie. Ces variables étaient supérieures aux lignes directrices actuelles de la SCC (critère d'information d'Akaike 1251 *vs* 1317, test du rapport de vraisemblance $P < 0,001$).

Conclusions : Les recommandations en matière de listes d'attente de la SCC n'ont pas permis de bien prédire la mortalité durant l'attente et la majorité des décès durant l'attente sont survenus dans les délais de référence recommandés. Nous avons déterminé les variables associées à la mortalité durant l'attente avec une meilleure performance clinique. Nos résultats laissent croire qu'il y a lieu de réévaluer les critères de triage en chirurgie cardiaque à l'aide des données probantes.

cardiac surgical triage guidelines would poorly predict waitlist mortality and many deaths would occur within recommended triage timeframes. Using a contemporary population-based cardiac surgical registry, we sought to describe variables associated with cardiac surgical waitlist mortality that could be used to improve current triage practices.

Materials and Methods

Data sources

The Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH) registry prospectively collects detailed information on all patients undergoing cardiac catheterization and cardiac surgery in the Province of Alberta, Canada.[22] Data are collected and reviewed by trained abstracters. The registry records individual patient demographic, medical, angiographic, surgical, and postoperative information.[23] Preoperative demographics and medical information as well as cardiac diagnostic and surgical information are entered into the database by trained cardiac catheterization laboratory and cardiac operating room staff. APPROACH was linked to the cardiac surgery waitlist databases at all provincial cardiac surgical centres (University of Alberta Hospital in Edmonton and Foothills Medical Centre in Calgary). The datasets record surgical acceptance dates, the proposed surgical procedure, the surgical urgency based on Canadian Cardiovascular Society guidelines (Supplemental Table S1), the incidence and reason(s) for surgical postponements, adherence to waitlist benchmarks, and waitlist mortality.[24-26] Waitlist deaths are adjudicated as cardiac, noncardiac (eg, trauma), or unknown (eg, found deceased with no autopsy performed) by local physicians and nurses using available heath records.

Study population

All patients $\geq$ 18 years scheduled for cardiac surgery between January 1, 2009, and December 31, 2015, in the Province of Alberta, Canada, who underwent cardiac surgery or died on the cardiac surgical waitlist were included in the study. Patients scheduled for cardiac or lung transplantation or ventricular assist device implantations were excluded. Information on patients who removed themselves from the waitlist for personal reasons or who had a preference for medical or minimally invasive treatments (eg, percutaneous coronary intervention or transcatheter aortic valve implantation) are not maintained by hospital databases. Similarly, information on patients who develop serious intercurrent noncardiovascular medical illnesses (eg, cancer) while on the waitlist who are subsequently deemed not suitable for surgery are removed from hospital level databases; however, patients with cardiovascular deterioration that results in death are maintained and adjudicated in hospital datasets. All cardiac surgical cases are peer-reviewed in a Heart Team conference consisting of cardiac surgeons and cardiologists specialized in interventional cardiology, echocardiography, and advanced imaging. Based on group consensus and Canadian Cardiovascular Society surgical waitlist guidelines, patients are categorized into 4 waitlist groups.[26] Waitlist times were based on the time from surgical acceptance to the time of surgery or waitlist mortality. Approval for this study was given by the Human Research Ethics Board of the Research Ethics Office of the University of Alberta (Pro00059729).

Outcomes

The primary clinical outcome of interest was cardiac surgical waitlist mortality that was adjudicated as either a cardiac or an unknown etiology. Unknown deaths, which include patients who were found deceased with no cause identified, were grouped with definitive cardiac deaths given that an indeterminate cause of death among patients with cardiovascular disease awaiting surgery was clinically felt to most likely be cardiac in nature. The primary analysis was performed in the group of patients triaged as urgent (inpatient), semiurgent (outpatient), and nonurgent (outpatient). A secondary analysis was performed with all patients (including emergency patients). Patients were considered adherent to waitlist guidelines if they underwent cardiac surgery within Canadian Cardiovascular Society (CCS) recommended timeframes assigned at the time of surgical acceptance: $\leq$ 48 hours for emergent, $\leq$ 7 days for urgent, $\leq$ 14 days for semiurgent, and $\leq$ 6 weeks for nonurgent surgery.

Statistical methods

Categorical variables were summarized as percentages. Discrete variables were tested with the χ^2 test, and Fisher's exact test was used when cell counts were < 5. Continuous variables were tested with Student's t test and summarized with means and standard deviations for normally distributed data and with medians and 25th and 75th percentiles for skewed data. A P value of ≤ 0.05 was considered significant for all analyses. The primary analysis used a Fine and Gray competing risk model to identify independent predictors of preoperative cardiac surgery waitlist cardiac mortality death (a combination of cardiac and undetermined cause death) with noncardiac waitlist mortality and cardiac surgery considered to be competing risks. Candidate variables (age, sex, surgery type, priority, hypertension, heart failure, dyslipidemia, chronic kidney disease, current smoker, coronary anatomy, prior myocardial infarction, ejection fraction, and adherence to guidelines) were selected based on univariate significance and clinical relevance, and a final model was developed using backward stepwise elimination. Adherence to guidelines was defined as a time-varying covariate such that each patient was "adherent" while within the priority-specific benchmark and "nonadherent" beyond the benchmark and was forced into all models even if not statistically significant. The resulting model was compared with a model containing only "adherence to guideline" using the Akaike information criterion (AIC) as well as the likelihood ratio test. The AIC is a method of comparing goodness of fit for multiple models with a particular dataset with a lower AIC indicating better model fit. The AIC penalizes for every parameter added into the model to reduce the risk of overparameterization. The proportionality assumption was evaluated for all models and determined to be satisfied. In a *post hoc* sensitivity analysis, we restricted the cohort to only patients with wait times of 1 year or less to ensure that these extreme wait times did not significantly alter our results. Data analysis was performed using the SPSS (Statistical Package for the Social Sciences; IBM Corp., Armonk, NY) data management system version 23, SAS version 9.4 (Cary, NC), and R version 3.4.3 (Vienna, Austria).

Results

Between January 1, 2009, and December 31, 2015, 12,565 patients either underwent cardiac surgery or died on the waitlist in the Province of Alberta including 12,106 patients scheduled for urgent, semiurgent, or nonurgent surgery. A total of 101 (0.8%) patients died while awaiting cardiac surgery, and the number of deaths adjudicated as cardiac, unknown, and noncardiac was 86 (85.1%), 8 (7.9%), and 7 (6.9%), respectively. Administrative database follow-up in this cohort was 100%. The baseline characteristics of all patients in the study cohort are presented in Table 1. Patients with a waitlist death had a lower frequency of hypertension, dyslipidemia, family history of coronary artery disease, and chronic obstructive pulmonary disease. A history of congestive heart failure, acute kidney injury, or haemodynamic instability at the time of angiography were more frequent in the waitlist mortality cohort. Triple vessel or left main coronary stenoses were less frequent among patients who died waiting for surgery.

The surgical scheduling characteristics of all accepted patients stratified by waitlist death are provided in Table 2. Cardiac surgical waitlist deaths were most frequent among emergent procedures, planned aortic surgery, or combined coronary artery bypass grafting with aortic valve replacement. Adherence to waitlist guidelines was 52.9% overall and declined from 57.4% in 2010 (n = 2020 surgeries) to 47.5% in 2014 (n = 2231 surgeries). Adherence to CCS waitlist recommendations was higher in patients who died on the waitlist (51.6% vs 70.8%, $P = 0.001$).

Cardiac surgery volume and quality metrics stratified by surgical priority are presented in Supplemental Table S2. The median wait times and the percentage of surgeries that adhered to clinical practice guidelines among emergent, urgent, semiurgent, nonurgent were 0.6, 7.4, 69.0, 55.5 days and 86.9%, 81.7%, 9.2%, 39.6% ($P < 0.001$), respectively. For those patients who did not adhere to waitlist guidelines, the median excess times were 0.6, 7.8, 67.8, and 49.5 days, respectively. The frequency of waitlist death was 6.3% in emergent, 0.8% in urgent, 0.3% in semiurgent, and 0.6% in nonurgent patients. Table 3 shows the number and percentage of cardiac deaths that occurred before the current CCS waitlist recommendations. In emergency, urgent, and nonurgent cases, the vast majority of cardiac deaths occurred before the current waitlist guideline cutoffs. In the cohort of 457 patients scheduled for emergency surgery, only 1 death occurred within 6 hours of surgical referral whereas the remaining 28 deaths occurred in patients with surgical delays exceeding 6 hours. Supplemental Table S3 provides cardiac surgery volume and quality metrics stratified by procedure type. Notably, aortic surgeries constituted 12.1% of the total procedures, but 35.6% of the waitlist deaths. Median wait times ranged from 10.4 days (coronary artery bypass) to 78.4 days (tricuspid or pulmonic valve surgery), whereas adherence to guidelines ranged from 33.6% (mitral valve surgery) to 65.8% (coronary artery bypass). The lowest frequency of waitlist mortality was 0.0% (tricuspid or pulmonic valve surgery), whereas the highest was 2.3% (aortic surgery). In a univariable analysis, adherence to CCS guidelines was not associated with waitlist mortality (hazard ratio 1.48, 95% confidence interval 0.62-3.56).

Table 1. Baseline characteristics of all patients accepted for cardiac surgery stratified by preoperative cardiac surgical waitlist cardiac mortality

Baseline characteristics	Underwent surgery (n = 12,464)	Waitlist death (n = 101)	*P* value
Demographics			
Age, mean (SMD), y	64.7 (0.007)	65.7 (14.0)	0.462
Male, n (%)	9389 (75.3%)	68 (67.3%)	0.063
Body mass index, mean (SMD), kg/m^2	28.9 (0.071)	29.1 (5.7)	0.812
Medical history, n (%)			
Hypertension	9222 (74.0%)	46 (45.5%)	< 0.001
Dyslipidemia	9761 (78.3%)	45 (52.3%)	< 0.001
Diabetes mellitus	3768 (30.2%)	24 (23.8%)	0.158
Prior myocardial infarction	960 (7.7%)	8 (7.9%)	0.935
Congestive heart failure	1918 (15.4%)	28 (27.7%)	0.001
Current smoker	2648 (21.2%)	15 (14.9%)	0.117
Family history of coronary artery disease	4337 (34.8%)	6 (5.9%)	< 0.001
Acute kidney injury	100 (0.8%)	9 (8.9%)	< 0.001
Chronic kidney disease	408 (3.3%)	4 (4.0%)	0.699
Cerebrovascular disease	1137 (9.1%)	7 (6.9%)	0.446
Chronic obstructive pulmonary disease	3529 (28.3%)	17 (16.8%)	0.011
Peripheral vascular disease	768 (6.2%)	8 (7.9%)	0.465
Preoperative dialysis	179 (1.4%)	3 (3.0%)	0.199
Left ventricular ejection fraction, %			
> 50%	32.4%	11.9%	< 0.001
> 35% to 50%	10.6%	6.9%	
> 20% to 34%	3.5%	6.9%	
< 20%	3.9%	2.0%	
Not done—haemodynamic instability	15.2%	22.8%	
Not available	34.4%	49.5%	
Number of > 70% coronary stenoses, %			
0	21.4%	15.8%	0.003
1 or 2	9.0%	13.9%	
3	23.4%	13.9%	
Left main	16.8%	12.9%	
Canadian Cardiovascular Society class, %			
Class 0 or Unknown	43.3%	55.4%	< 0.001
Class I	4.0%	1.0%	
Class II	15.8%	8.9%	
Class III	8.8%	2.0%	
Class IV	27.6%	32.7%	
Atypical	0.5%	0%	

SMD, standardized mean difference.

Variables associated with cardiac waitlist death in nonemergent surgery

In our primary analysis cohort of 12,106 patients, 72 (0.6%) patients died before surgery and the median time to death was 6.0, 47.5, and 20.5 days for urgent, semiurgent, and nonurgent surgeries, respectively. The variables determined to be significantly associated with waitlist cardiac death from the Fine and Gray competing risk analysis were age, aortic surgery, ejection fraction < 35%, urgent surgery, prior myocardial infarction, haemodynamic instability during cardiac catheterization, hypertension, and dyslipidemia (Table 4). This model showed improved goodness of fit compared with the model consisting of only adherence to the CCS waitlist recommendations (AIC 1251 vs 1317, likelihood ratio test $P < 0.001$). Adherence to guidelines was not independently associated with waitlist mortality (hazard ratio 1.77, 95% confidence ratio 0.62-5.05). Figure 1 shows the cumulative incidences of cardiac and noncardiac deaths in our cohort of nonemergent patients. In sensitivity analysis restricted to patients with wait times of 1 year or less, results were similar. Supplemental Table S4 contains all variables in the model including nonsignificant variables for reference.

Notably, preoperative secondary prevention medical therapy use was high among patients with dyslipidemia (83.8% on a statin) and hypertension (89.6% on aspirin, 80.5% on a beta-blocker, 65.7% on an angiotensin converting enzyme inhibitor).

Secondary analysis

A secondary analysis was performed with the full cohort including emergency surgeries. The variables that were found to have a significant association with risk of cardiac surgical waitlist mortality as a result of our Fine and Gray competing risks analysis were age, aortic surgery, emergency surgery, urgent surgery, adherence to guidelines, hypertension, dyslipidemia, and heart failure (Supplemental Table S5).

Table 2. Surgical scheduling characteristics of all patients accepted scheduled for cardiac surgery

Operative characteristic	Underwent surgery n = 12,464	Waitlist death n = 101	*P* value
Surgical priority, n (%)			
Emergent (≤ 48 h)	428 (3.4%)	29 (28.7%)	< 0.001
Urgent (≤ 7 d)	5009 (40.2%)	38 (37.6%)	
Semiurgent (≤ 14 d)	2178 (17.5%)	6 (5.9%)	
Nonurgent (≤ 6 wk)	4847 (38.9%)	28 (27.7%)	
Unknown	2 (0.0%)	0 (0.0%)	
Proposed surgery, n (%)			
Coronary artery bypass grafting	6322 (50.7%)	30 (29.7%)	< 0.001
Aortic valve repair/replacement	1505 (12.1%)	9 (8.9%)	
Mitral valve repair/replacement	753 (6.0%)	4 (4.0%)	
Coronary artery bypass grafting with aortic valve repair/replacement	849 (6.8%)	12 (11.9%)	
Coronary artery bypass grafting with mitral valve repair/replacement	360 (2.9%)	3 (3.0%)	
Tricuspid or pulmonary valve repair/replacement	236 (1.9%)	0 (0.0%)	
Aortic surgery	1509 (12.1%)	36 (35.6%)	
Type A aortic dissection	Not adjudicated	8 (22.2%)	
≥ 1 valve repair or replacement	474 (3.8%)	2 (2.0%)	
Coronary artery bypass grafting and aortic and mitral valve repair/replacement	72 (0.6%)	1 (1.0%)	
Other	384 (3.1%)	4 (4.0%)	
Delayed procedures, n (%)*	1131 (15.1%)	1 (1.9%)	0.005
Procedures that adhere to waitlist guidelines, n (%)	6584 (52.8%)	69 (68.3%)	0.002

*Defined as postponement due to triage of more urgent surgical patients or lack of capacity—data available for University of Alberta Hospital only.

Hypertension and dyslipidemia had a protective association. This model again showed improved goodness of fit compared with the model consisting of only adherence to the CCS waitlist recommendations (AIC 1640 vs 1774, likelihood ratio test $P < 0.001$).

Discussion

In a contemporary provincial cardiac surgical dataset with detailed triage information and waitlist times, we have identified several novel and important findings. First, the adherence to the existing cardiac surgical triaging guidelines was poor, and the incidence of cardiac surgical waitlist mortality was 0.6% in patients undergoing nonemergent cardiac surgery. Second, adherence to the CCS wait time benchmarks poorly predicted cardiac surgical waitlist mortality and most deaths occurred within the existing CCS recommended benchmarks, and thus this study suggests that the existing benchmark timeframes merit re-evaluation. Third, we described novel clinical variables that were associated with cardiac surgical waitlist mortality with better predictive performance than the current guidelines.

Previous studies have reported cardiac surgical waitlist mortality rates of 0.5% to 2.6%.[8-18] The highest rates were seen in less developed countries with long wait times due to limited surgical capacity, whereas the lowest reported rate was in a Canadian single payer health system that uses the CCS cardiac surgery wait time triage systems. Our finding of a 0.6% waitlist mortality is in line with these previous findings.[13] Nonadherence to waitlist guidelines has been reported to vary between 25.3% and 64.9% and has previously been univariately associated with higher waitlist mortality.[8,13,19] We postulate that the high nonadherence rates may be a

Table 3. Number and percentage of cardiac waitlist deaths that occurred before the current CCS waitlist guidelines

Surgical priority	n	Cardiac death, n (%)	Number of cardiac deaths before CCS target, n (%)
Emergent	457	24 (5.3)	16 (66.7)
Urgent	5,047	37 (0.7)	28 (75.7)
Semiurgent	2,184	5 (0.2)	0 (0.0)
Nonurgent	4,875	28 (0.6)	22 (78.6)
Unknown	2	0 (0.0)	0 (0.0)
Overall	12,565	94 (0.7)	66 (70.2)

CCS, Canadian Cardiovascular Society.

Table 4. Fine and Gray competing risk model of variables independently predictive of cardiac surgical waitlist mortality in patients scheduled for urgent, semi-urgent, and nonurgent surgery only

Variable	Adjusted hazard ratio (95% confidence interval)
Adherence to guidelines	1.77 (0.62-5.05)
Urgent surgery (referent: scheduled surgery)	2.03 (1.11-3.72)
Aortic surgery (referent: CABG)	3.18 (1.50-6.74)
Prior myocardial infarction	2.45 (1.14-5.29)
Haemodynamic instability at the time of angiography	2.59 (1.20-5.57)
EF < 35% (referent: EF ≥ 35%)	2.61 (1.04-6.55)
Age, per 1-y increase	1.04 (1.02-1.06)
Hypertension	0.43 (0.26-0.72)
Dyslipidemia	0.32 (0.19-0.55)

AIC of model = 1251; AIC of adherence to Canadian Cardiovascular Society guidelines = 1317.

AIC, Akaike information criterion; CABG, coronary artery bypass grafting; EF, ejection fraction.

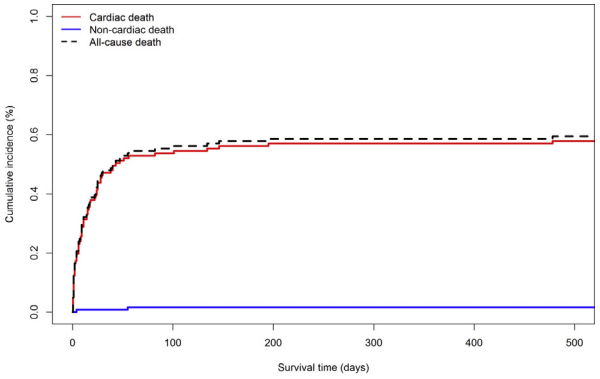

Figure 1. Cumulative incidence function of the Alberta cardiac surgical waitlist model by cause of death in patients undergoing urgent, semiurgent, and nonurgent surgery.

result of increasing demand for cardiac surgical procedures in patients with diabetes, adult congenital heart disease, and advanced heart failure along with an aging and growing population for which cardiac surgical capacity has not increased in parallel.[7,27]

Current cardiac surgical waitlist guidelines primarily risk stratify patients based on coronary and valvular anatomic variables, but the prognostic accuracy for cardiac surgical waitlist death has remained unclear. Our findings that combine baseline medical variables, haemodynamics, and proposed surgical information have several novel conclusions. First, aortic surgeries, which include type A dissections, have a significantly increased risk of waitlist mortality. Guidelines presently do not prioritize aortic surgeries beyond type A dissections, and our findings suggest that aortic root, ascending, arch, or descending aneurysm repairs merit a special surgical triage classification. Although acute aortic dissections have always been known to have a high risk of preoperative mortality, only 8 of our 36 aortic surgery deaths were due to acute aortic dissections, suggesting that other aortopathies may merit a special triage classification. Second, severely reduced left ventricular ejection fraction is independently associated with waitlist mortality. This finding is consistent with multiple other studies that have also shown severe left ventricular dysfunction to be predictive of waitlist mortality.[10,13,15] Taken together, our findings suggest that ejection fraction should be considered as a waitlist triage metric. Third, traditional risk factors including hypertension and dyslipidemia attenuated risk and coronary anatomic factors (such as triple vessel disease and left main disease) were not associated with excess waitlist mortality.[28,29] We hypothesize that the high observed adherence to evidence-based secondary prevention therapies including aspirin, beta-blockers, and statins among patients with hypertension and dyslipidemia may explain the protective association. Finally, adherence to surgical guidelines was not found to be predictive of cardiac waitlist death, suggesting a need to re-evaluate the waitlist timeframes.

The current Canadian cardiac surgical wait time benchmarks, which were developed based on the expert opinion of a working group in 2005, poorly discriminate waitlist mortality. Given that many deaths occur within the existing triage guidelines, our findings suggest that the underlying problem is not poor access; rather the existing guidelines are too long. Thus, prospective implementation of an evidence-based clinical prediction tool that incorporates clinical and cardiac anatomical variables has the potential to better align wait times with individual patient risks and reduce waitlist mortality. Future studies should be directed at externally validating these findings, evaluating additional clinical parameters of interest, and performing time-to-event analysis in subsets of cardiac surgical referrals to determine safe wait times for common cardiovascular procedures.

Limitations

The results of this study should be considered in the context of its limitations. First, the waitlist times were derived from the time of acceptance for cardiac surgery and do not include the antecedent symptom or medical treatment times. Waitlist deaths could occur during the surgical referral or diagnostic testing period; however, our methods mirror current cardiac surgical triage practices wherein wait times begin at the time of surgical acceptance. Second, echocardiographic metrics on the severity of valve disease or primary etiology (stenosis or regurgitation) were not available in this dataset. The presence and distribution of coronary artery disease severity was limited to $\geq$ 70% angiographic lumen stenosis (or $\geq$ 50% left main disease). All nonemergent provincial cardiac surgical referrals undergo multidisciplinary peer review, and it is likely that all patients accepted for cardiac surgery met criteria for surgery and were triaged according to practice guidelines. Third, we do not have data on patients who were removed from the waitlist (due to intercurrent noncardiovascular illness or patient preference), change in priority, symptom class changes, or data on socioeconomic or geographic location. Fourth, the current dataset does not help define the optimal timing for surgery to reduce risk. Fifth, we did not include ventricular assist device or transplant referrals in this analysis given this population is not triaged using the existing waitlist guidelines and unique factors such as eligibility and a limited organ and/or device supply are also likely to influence wait times in this population. Finally, only 9.2% of semiurgent surgeries were adherent to guidelines and there were no deaths among those patients who were adherent, so the data may be too sparse to assess the appropriateness of waitlist guidelines for this subset of patients.

Conclusions

In a population-based cohort of cardiac surgery patients, we observed that adherence to cardiac surgical waitlist standards was low. Many cardiac surgical waitlist deaths occurred within the existing triage benchmarks and current guidelines are poorly predictive of cardiac surgical waitlist mortality. These data suggest that the existing triage guidelines are too long and waitlist mortality is not principally associated with poor access. We described novel variables that identify patients at high risk of preoperative mortality that includes preoperative medical and cardiac anatomical variables. Our findings present an opportunity to prospectively employ a more comprehensive and evidence-based approach to cardiac surgical triage practices with the goal of reducing cardiac surgical waitlist mortality.

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Disclosures

The authors declare that they have no relevant conflicts of interest to disclose.

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Supplementary Material

To access the supplementary material accompanying this article, visit the online version of the *Canadian Journal of Cardiology* at www.onlinecjc.ca and at https://doi.org/10.1016/j.cjca.2018.10.007.