Waiting for Cardiac Surgery
Results of a Risk-Stratified Queuing Process

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Background—The Queen Elizabeth II Health Sciences Centre uses a weekly peer-review conference of cardiovascular experts to prioritize each surgical case to 1 of 4 queues with the use of standardized criteria of coronary anatomy, stress test result, and symptoms. We examined the hazard of waiting as well as the impact of waiting on surgical outcomes.

Methods and Results—Analysis was performed for 2102 consecutive patients queued for CABG, aortic valve replacement, or CABG + aortic valve replacement between January 1, 1998, and December 31, 1999. Among 1854 patients undergoing surgery, median waiting times on the respective queues were as follows: in-house urgent group, 8 days; semiurgent A group, 37 days; semiurgent B group, 64 days; and elective group, 113 days. There were 13 deaths (12 cardiac) that occurred during the waiting period (0.7% of the patients). Of the 8.7% patients upgraded to a more urgent queue, 86.1% required hospitalization before surgery. Although female sex was not associated with prolonged waiting time, it was predictive of urgent status (P = 0.001). The incidence of postoperative complications was 25.0%, and operative mortality was 2.86%. Both were more frequent among patients undergoing surgery early (P = 0.01); however, this difference was attributable to the in-house urgent queue. The median length of stay was 7 days for all patients and was not affected by waiting time.

Conclusions—Death and upgrades while the patients were waiting tended to occur early in the queuing process, and prolonged waiting was not associated with worse surgical outcomes. The cost of reducing waiting times could in part be offset by prevention of hospital admissions among upgraded patients. (Circulation. 2001;104[suppl I]:I-92-I-98.)

Key Words: mortality ■ morbidity ■ coronary disease ■ bypass ■ waiting lists

For several years, there has been considerable popular and professional concern regarding waiting lists for cardiac surgery in Canada. A decade ago, a dramatic increase in referrals for cardiac surgical services in Canada caused waiting lists to reach a critical length, necessitating the referral of patients from several provinces to centers in the United States for treatment. In Ontario, the response to this crisis was the development of an urgency rating score, which was subsequently applied to all cardiac surgical cases in the province and provided a guideline for maximum recommended waiting time.1 In Nova Scotia, similar steps were taken to rationalize the queuing process and to ensure that those patients with the greatest need would undergo surgery expeditiously.2,3 All cardiac surgical cases are referred to a single tertiary care center where cases are evaluated by a panel of cardiovascular experts within days of referral. Institutional standards were adopted to ensure a framework for the queuing process and to make waiting safer.

To date, there have been no comprehensive studies tracking the incidence of waiting-list events in risk-stratified patient groups. Furthermore, the effect of prolonged waiting time as an independent predictor of adverse perioperative outcomes has not been investigated. Thus, we undertook the present study to explicitly examine the hazard function of waiting on the queue over time as well as the impact of waiting time on surgical outcomes.

Methods

Triage Process
The Queen Elizabeth II (QEII) Health Sciences Centre is the only tertiary care facility for the provinces of Nova Scotia and Prince Edward Island, serving a population of \(\approx 1.1\) million people. All patients referred for surgery are presented at a weekly peer-review conference of cardiovascular specialists. Patients are impartially evaluated by using the objective criteria of coronary anatomy, stress-test results, and functional status, as previously described.2

Patients accepted for surgery are then triaged to 1 of 4 queues based on consensus opinion in accordance with accepted guidelines and are assigned to the first available surgeon. Because there is currently no mechanism for referral to an outside center, this provides an opportunity to examine the triage process in great detail.

In-house urgent (IHU) patients are critically ill and may be hemodynamically unstable. They require in-hospital treatment, such as intravenous heparin, intravenous nitroglycerin, or intra-aortic
Patients listed as semiurgent A (SUA) can perform balloon counterpulsation. Patients that initially present with unstable coronary syndromes who can be weaned from intravenous heparin and nitroglycerin are mobilized and subjected to stress testing for further stratification of risk. It remains a physician's judgment and nitroglycerin are mobilized and subjected to stress testing for whether to wean these agents, so that, for example, an ulcerated 90% left main stenosis in a patient with an unstable coronary syndrome can perform ≤2 metabolic equivalents (METs) according to a standard Bruce protocol. In addition, this group includes patients with critical left main stenosis or critical aortic valve stenosis who are stable enough to allow discharge. Patients listed as semiurgent B (SUB) can perform 2 to 5 METs by a standard Bruce protocol. Elective patients are stable on medical therapy except immediate cardiac surgery. Patients in this category have unrelenting cardiac compromise that is unresponsive to any therapy except immediate cardiac surgery. Patients in this category proceed to surgery without delay.

Institutional standards for waiting time were initially adopted in 1991 by a multidisciplinary task force of primary care physicians and cardiovascular specialists in conjunction with the Nova Scotia Department of Health. This process has been subject to subsequent refinement to make queuing safer. The current standards for waiting time are as follows: IHU group, within 7 days; SUA group, within 21 days; SUB group, within 56 days; and elective group, within 91 days. Patients were considered to be within the standard for waiting time if the surgery was performed within the intervals previously adopted as the institutional standards for waiting time.

### Inclusion Criteria

Data were analyzed retrospectively for 2102 consecutive patients queued for CABG, aortic valve replacement (AVR), or CABG+AVR between January 1, 1998, and December 31, 1999. Waiting time was defined as the interval between cardiac catheterization and surgery. In general, cardiac catheterization preceded the peer-review conference, at which the decision to accept all patients for surgery was made.

### Data Collection

The Division of Cardiac Surgery maintains a waiting-time database that captures all cases referred to the peer-review conference. This database records the date of catheterization and the date of the conference as well as cardiac events on the waiting list, including upgrade and mortality occurring in the interval before surgery. In the present study, the waiting-time database was linked with the Society of Thoracic Surgeons (STS) surgical database maintained by the Division of Cardiac Surgery. The STS database includes a complete description of patient demographics, comorbidities, data from cardiac catheterization and surgery, and a detailed account of postoperative outcomes, including mortality.

### Outcomes

The primary preoperative end points of interest were death of a patient on the waiting list and upgrade to a more urgent queue. Upgrades reflect a worsening of symptoms or adverse events, such as unstable angina occurring while the patient awaits surgery. Such events lead to a repeat presentation at the peer-review conference, at which all available data are evaluated.
The postoperative end points were operative mortality, length of stay (LOS), and a composite end point of mortality, prolonged ventilation (>24 hours), and prolonged hospital stay (LOS >9 days). LOS was defined as time in the hospital from the procedure until discharge. All deaths of patients on the waiting list were reviewed.

Statistical Analysis
Continuous demographic data were analyzed by ANOVA, and categorical variables were examined by using $\chi^2$ analysis or the Fisher exact test. Waiting time was expressed as a median with an interquartile range (IQR) and analyzed by using nonparametric statistical methods. To examine freedom from event for patients on the waiting list, Kaplan-Meier survival analysis was performed by using a standardized waiting time for all queues. Standardized waiting time was expressed as a function of the adopted standard for waiting time for each queue.

Results
Over the course of 2 years, 2102 patients were referred for CABG, AVR, or CABG+AVR at our center. In total, 234 (11.1%) patients initially accepted at the conference did not undergo surgery because of subsequent deferral by a cardiologist or cardiac surgeon or because of subsequent refusal of surgery by the patient. There were 13 (12 cardiac and 1 noncardiac) deaths (0.7%) as well as 1 major adverse event among patients waiting for surgery, leaving 1854 patients that underwent surgery. The median number of cases accepted at conference per week was 18 (IQR 14 to 21, range 6 to 29).

Study Population
Patient characteristics are reported in Table 1, according to urgency category. Patients were predominantly male (71.5%), with a mean age of 65.5±11.1 years. Isolated CABG surgery constituted 87.3% of the surgical case mix, followed by AVR (6.74%) and CABG+AVR (5.93%). In accordance with triage criteria, patients awaiting aortic valve surgery for aortic stenosis were predominantly in the SUA queue. As expected, several measures of disease acuity were found to be predictive of higher urgency rating. Lower left ventricular ejection fraction ($P=0.001$), prior history of myocardial infarction ($P=0.001$), previous sternotomy ($P=0.007$), and a history of congestive heart failure ($P=0.001$) were significant predictors of urgency. These findings were consistent with the intent of the triage process to assign higher priority to patients at greater risk.

Waiting Time
In total, 692 (37.3%) patients underwent surgery within the institutional standard for waiting time. As reported in Table 2, median waiting times differed significantly by queue. The median waiting time of IHU patients was 8 days (IQR 4 to 12 days); SUA patients, 37 days (IQR 26 to 49 days); SUB patients, 64 days (IQR 44 to 91 days); and elective patients, 113 days (IQR 76 to 145 days). Median waiting time exceeded the institutional standard for each queue.

Sex
Females, constituting 28.5% of the sample population, were found to be significantly overrepresented in the most urgent queues, suggesting that females presented to the peer-review conference with greater disease acuity than did male patients (Figure 1). The sex of the patient was not found to be associated with prolonged waiting time ($P=0.06$), and females were as likely as males to exceed the institutional standard for waiting time ($P=0.518$).

Events on Waiting List
Of those patients proceeding to surgery, 161 (8.68%) experienced a change in functional status that required an upgrade to a more urgent queue. A further 6 (3.73%) patients experienced a second upgrade to an even more urgent queue.

**TABLE 2. Median Waiting Times, Waiting List Events, and Perioperative Outcomes by Queue**

<table>
<thead>
<tr>
<th>Total</th>
<th>IHU</th>
<th>SUA</th>
<th>SUB</th>
<th>Elective</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>1854</td>
<td>620</td>
<td>437</td>
<td>576</td>
</tr>
<tr>
<td>Median waiting time (IQR), d</td>
<td>8 (4–12)</td>
<td>37 (26–49)</td>
<td>64 (44–91)</td>
<td>113 (76–145)</td>
</tr>
<tr>
<td>Patients treated within standard waiting time, n (%)</td>
<td>692 (37.3)</td>
<td>308 (49.7)</td>
<td>80 (18.3)</td>
<td>218 (37.9)</td>
</tr>
<tr>
<td>Upgrade, n (%)</td>
<td>160 (8.63)</td>
<td>6 (0.97)</td>
<td>57 (13.0)</td>
<td>71 (12.3)</td>
</tr>
<tr>
<td>Mortality on waiting list,* n (%)</td>
<td>13 (0.70)</td>
<td>3 (0.48)</td>
<td>2 (0.46)</td>
<td>6 (1.04)</td>
</tr>
<tr>
<td>Composite perioperative outcome, n (%)</td>
<td>463 (25.0)</td>
<td>227 (36.6)</td>
<td>104 (23.8)</td>
<td>110 (19.1)</td>
</tr>
</tbody>
</table>

*Includes 2 deaths before cardiovascular conference (perioperative mortality and composite perioperative outcome of mortality, prolonged ventilation [>24 h], or prolonged hospital stay [>9 d after surgery]).

Figure 1. Distribution of males and females across queues. E indicates elective group. Bars represent percentage of total cases for given sex allotted to given queue. Distribution of males and females across queues was different.
after the development of unstable symptoms (Figure 2). In total, 143 (86.1%) of all patients experiencing upgrades were reassigned to either IHU or emergency status. These patients required hospitalization before surgery, resulting in 858 unscheduled hospital days. All patients experiencing an upgrade were accommodated by expedited surgery, and there were no waiting-list deaths among this group (Table 3).

Upgrades were not found to be associated with perioperative mortality ($P = 0.766$) or the composite outcome of mortality or complication ($P = 0.138$).

Waiting-List Mortality

There were 13 (12 cardiac and 1 noncardiac) deaths during the waiting period, representing $0.70 \pm 0.19\%$ of those queued for surgery (Table 3). Despite differences in disease acuity, deaths were distributed across all queues. There were 3 deaths among the IHU queue, 2 deaths among the SUA queue, 5 deaths among the SUB queue, and 1 death among the elective queue. In addition, 2 patients died before evaluation by the peer-review conference. Subsequent review of available data (including coronary angiography and functional limitations) concluded that both patients would have been placed on the IHU queue. While waiting, 1 patient experienced a nonfatal myocardial infarction and ventricular fibrillatory arrest and was subsequently removed from the surgical queue because of marked neurological injury.

The majority (10 of 13) of waiting-list deaths occurred within the institutional standards for waiting times. Of 3 patients experiencing waiting times greater than the institutional standard, 2 patients requested delays that significantly increased the time to surgery (140 and 275 days, respectively). Both patients were in the SUB category (Table 3).

The mean age of patients who died awaiting surgery was 68.1 $\pm$ 10.1 years. No patient had experienced an upgrade before death. There were 12 cardiac deaths recorded among patients awaiting isolated CABG, and there was 1 noncardiac death in the AVR+CABG group.

The majority of both deaths and upgrades occurred among patients who were within the institutional standard wait time for their queue (10 of 13 deaths and 62.1% of upgrades occurred in patients within the institutional standard). Freedom from event was analyzed to determine the risk of mortality and upgrade to a more urgent queue during the waiting time (Figure 3). These events were plotted against the institutional standards for waiting time. The cumulative risk was determined to be $7.4 \pm 1.3\%$ at the institutional standard for waiting time for a given queue.

Perioperative Outcomes

Hospital mortality was reported as death occurring from the time of surgery to discharge. The cumulative unadjusted operative mortality was 2.86%. There were 46 deaths among isolated bypass patients (2.84%), 3 among isolated AVR patients (2.40%), and 4 among CABG+AVR patients (3.64%). The composite perioperative end point of mortality or complication occurred in 25.0% of all surgical cases.

![Figure 2. Distribution of upgrades to more urgent queues. Upgrades are tracked from queue of origin to new queue. Majority of upgrades were assigned to IHU queue.](image-url)
median LOS was 7 days (IQR 5 to 9 days) for those patients within the institutional standard and for those waiting longer. Both mortality and mortality/complication were more frequent among patients who underwent surgery within the institutional standard for waiting time ($P=0.001$ and $P=0.01$, respectively; data not shown); however, this difference was attributable to expedited surgery among actively managed patients waiting in the hospital. When they were considered separately, IHU patients within the institutional standard experienced significantly greater operative mortality ($P=0.004$) or mortality/complication ($P=0.01$) than did those patients experiencing prolonged waiting times (Table 4). This difference was not noted among those patients waiting at home.

**Discussion**

Cardiac surgery waiting lists are a subject of much professional and public attention. In the present study, we have determined the results of a prospective, multidisciplinary, peer-review process used to stratify patients by risk to 1 of 4 queues of graded urgency. This process allows for individual patient discussion but ultimately depends on consensus opinion in accordance with institutional guidelines for anatomy, stress test, and symptom burden. Despite this meticulous approach, 0.7% of patients died while they waited, and 8.7% experienced an increase in symptom burden that warranted upgrade to a higher queue. Fully 86% of the upgraded patients were sufficiently unstable to require hospitalization before surgery.

One half of the adverse events occurred among patients within the institutional standard for waiting time, demonstrating that events occur early in the queuing process. This observation was consistent with similar findings by Naylor et al. Additionally, adverse events were distributed among all queues, indicating our inability to adequately risk-stratify patients before surgery. One possibility is that risk stratification could be improved by taking into account factors important in predicting surgical outcomes, such as ejection fraction, prior CABG, history of myocardial infarction, and history of congestive heart failure. However, our analysis indicates that patients with these risk factors were assigned to more urgent queues, even though these factors were not overtly considered in the triage process. Thus, further refinements in the risk stratification process are unlikely to yield a better prediction of patients at risk for waiting-list death or upgrade. Taken together, these data suggest that the unacceptably high rates of death and upgrade that we have demonstrated would require marked shortening of standard waiting times. The median number of cases referred per week for the procedures of interest was 18 (range 6 to 29). To reduce waiting-list deaths would require an excess surgical capacity sufficient to respond to these marked variations in referrals. Costs could be defrayed in part by preventing hospital admissions among upgraded patients. Based on 858 extra hospital days incurred by the upgraded patients in the present study and a QEII charge of $1066 Canadian per day, a potential savings of almost $915 000 could be realized.

**TABLE 4. Effect of Prolonged Waiting Time on Outcome**

<table>
<thead>
<tr>
<th></th>
<th>Within Standard</th>
<th>Over Standard</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Patients</td>
<td>692</td>
<td>1162</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>65.5±11.0</td>
<td>65.4±11.2</td>
<td>0.481</td>
</tr>
<tr>
<td>Female, %</td>
<td>36.2</td>
<td>63.8</td>
<td></td>
</tr>
<tr>
<td>Male, %</td>
<td>37.8</td>
<td>62.2</td>
<td>0.518</td>
</tr>
<tr>
<td>Median wait (IQR), d</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IHU</td>
<td>4 (2–6)</td>
<td>12 (10–15.5)</td>
<td>0.0001</td>
</tr>
<tr>
<td>SUA</td>
<td>17.5 (13–20)</td>
<td>41 (33–51)</td>
<td>0.0001</td>
</tr>
<tr>
<td>SUB</td>
<td>36.5 (25–49)</td>
<td>80 (66–103)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Elective</td>
<td>56 (35–79)</td>
<td>139 (120–161)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Upgrade on queue, %</td>
<td>62.1</td>
<td>37.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Operative mortality, %</td>
<td>4.62</td>
<td>1.81</td>
<td>0.001</td>
</tr>
<tr>
<td>Composite perioperative outcome, %</td>
<td>28.3</td>
<td>23.0</td>
<td>0.01</td>
</tr>
<tr>
<td>Median LOS (IQR), d</td>
<td>7 (5–9)</td>
<td>7 (5–9)</td>
<td>0.720</td>
</tr>
</tbody>
</table>

Values are mean±SD for age and as indicated for others. Clinical characteristics and outcomes are shown for patients proceeding to surgery within standard for waiting time and for patients whose waiting time exceeded institutional standard. Composite perioperative outcome includes mortality, prolonged ventilation (>24 h), and prolonged hospital stay (LOS >9 d).
Further efficiencies may be achieved through flexible staffing and cross training of the operating room and ICU staff. Nevertheless, given the dramatic variation in cardiac surgical referrals, these savings would likely not allow the marked increase in surgical capacity required to consistently avoid the waiting list.

Restricted hospital resources through global budgeting in the Canadian healthcare system have resulted in lower rates of utilization of cardiac surgery as well as waiting lists for cardiac surgery. A strict peer-review process, such as that used by us, could be the mechanism to restrict utilization of cardiac surgery to cases for which there is solid evidence to support intervention. A recent analysis of our isolated CABG data over a 5-year period demonstrated that 86% of patients accepted for revascularization had either 3-vessel disease, left main stenosis, or diabetes and 2-vessel disease; ie, they were patients for whom randomized trial evidence supported intervention for survival benefit. With a strict peer-review process in place, surgical capacity could be increased, where economically feasible, to allow reduction in waiting time without fear of rampant overuse of cardiac surgical procedures.

Overall, 37.7% of all patients received surgery within the institutional standard for waiting time. Thus, it is important to determine whether those patients experiencing prolonged waiting times are at an increased risk for adverse perioperative outcomes. One previous investigation failed to demonstrate a correlation between waiting time and outcome; however, that study compared elective and urgent surgical cases but did not account for differences in outcome in patients of similar disease acuity. In the present study, we report that patients proceeding to surgery very rapidly experienced an increased incidence of adverse perioperative outcomes. This seemingly contradictory finding was attributable to IHU patients. One possible explanation for this finding is that sicker patients within the queue undergo expedited surgery without triggering an upgrade. An alternate explanation could be that small delays in surgical intervention may be required to effectively deal with these events. Given our utilization of a peer-review conference to validate indication for surgical intervention, surgical capacity could be increased where economically feasible, allowing reduction in waiting time without fear of rampant overuse of cardiac surgical procedures. Prolonged waiting time was not associated with adverse surgical outcomes among patients undergoing coronary bypass.

Data from Ontario have reported waiting-list mortality of <0.5%. Our rate of 0.7% could be a reflection of the longer waiting times experienced by our patients. We defined waiting time as the interval between cardiac catheterization and surgery rather than the time from acceptance until surgery, as in the study of Naylor et al; however, this difference was not sufficient to offset the shorter wait times experienced in Ontario. In addition, we defined upgraded patients by queue of origin, whereas Naylor et al defined such patients by final queue, a methodological difference that would shorten waiting times in the more urgent queues in our patient population. For example, the median wait of the most urgent patients in Ontario was 1 day, including patients upgraded from less urgent status, whereas waiting times for the IHU patients in our data were 8 days. Alternately, the higher waiting-list mortality may be a reflection of a higher cardiovascular disease burden in Nova Scotia, as predicted by the lower socioeconomic status of our population relative to that of Ontario. We also observed a higher rate of upgrade than was reported in Ontario (8.7% for Nova Scotia versus <5% for Ontario). Longer waiting times and higher disease burden may similarly account for this difference. Finally, it should be noted that with the relatively low event rates, the differences between centers may be due entirely to chance.

In Canada, waiting times for elective cardiac surgical procedures compare favorably with those of other socialized medical systems. For example, in Sweden and the United Kingdom, waiting times for elective procedures may exceed 1 year. In New Zealand and Iceland, waiting times in of >6 months are common. A 2-tier system may not provide a reduction in surgical waiting times. In the United Kingdom, where private treatment is used by 13% of the population, waiting times are significantly greater than those in other countries practicing socialized medicine. Nevertheless, recent data demonstrate that compared with Canada, the United States has higher rates of revascularization and faster access to both catheterization and revascularization in a cohort of patients with unstable angina.

One area that remains to be explored in our patients is the effect of waiting time on quality of life. It has been shown that prolonged waiting is associated with increased anxiety burden. The available evidence suggests that psychological distress adversely affects even hard end points, such as death and return to work.

In summary, a peer-reviewed standardized approach to risk-stratified queue assignment of cardiac surgery patients resulted in a 0.7% waiting-list mortality and an 8.7% rate of upgrades, the majority of which required hospitalization for unstable symptoms. The majority of these adverse events occurred early. A marked increase in surgical capacity would be required to effectively deal with these events. Given our utilization of a peer-review conference to validate indication for surgical intervention, surgical capacity could be increased where economically feasible, allowing reduction in waiting time without fear of rampant overuse of cardiac surgical procedures. Prolonged waiting time was not associated with adverse surgical outcomes among patients undergoing cardiac surgery, and in the urgent queue, earlier intervention was associated with worse outcomes.

References


16. Richmond C. NHS waiting list have been a boon for private medicine in the UK. *CMAJ*. 1996;154:378–381.


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