Impact of the opening of a specialized cardiac surgery recovery unit on postoperative outcomes in an academic health sciences centre

[Impact de l'ouverture d'une unité spécialisée de rétablissement après chirurgie cardiaque sur les devenirs postopératoires dans un centre de santé universitaire]

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Purpose: It is controversial as to whether cardiac surgery patients are optimally managed in a mixed medical-surgical intensive care unit (ICU) or in a specialized postoperative unit. We conducted a prospective cohort study in an academic health sciences centre to compare outcomes before and following the opening of a specialized cardiac surgery recovery unit (CSRU) in April 2005.

Methods: The study cohort included 2,599 consecutive patients undergoing coronary artery bypass grafting (CABG), valve and combined CABG-valve procedures from April 2004 to March 2006. From April 2004 to March 2005 (year 1) all patients received postoperative care in mixed medical-surgical ICUs at two different sites staffed by critical care consultants, fellows and residents. From April 2005 until March 2006 (year 2) patients were cared for in a newly-established CSRU on one site staffed by cardiac anesthesiology fellows, a nurse practitioner and consultants in critical care, cardiac anesthesiology and cardiac surgery. The effect of this change on in-hospital mortality, the incidence of ten major postoperative complications, postoperative ventilation hours, readmission rates and case cancellations due to a lack of capacity was assessed using Chi-square or Wilcoxon tests, where appropriate.

Results: Coronary artery bypass grafting, valve and combined CABG-valve mortality rates were similar in years 1 and 2. There was a significant reduction in the composite major complication rate (16.3% to 13.0%, $P = 0.02$) and in median postoperative ventilation hours (8.8 *vs* 8.0 hr, $P = 0.005$) from year 1 to 2. On multivariable logistic regression analysis, the pre-merger interval (year 1) was a significant independent predictor of the occurrence of death or major complications.

Conclusion: A specialized CSRU with a multi-disciplinary consultant model was associated with stable or improved outcomes postoperatively, when compared to a mixed medical-surgical ICU model of cardiac surgical care.

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Objectif *: La question de savoir si les patients de chirurgie cardiaque sont traités de façon optimale dans une unité de soins intensifs mixte, c'est-à-dire médico-chirurgicale, ou dans une unité postopératoire spécialisée, demeure controversée. Nous avons mené une étude de cohorte prospective dans un centre de santé universitaire afin de comparer les devenirs avant et après l'ouverture d'une unité spécialisée de rétablissement après chirurgie cardiaque (CSRU) en avril 2005.*

Méthode *: La cohorte de l'étude a été constituée de 2 599 patients consécutifs subissant une chirurgie de revascularisation coronarienne, un remplacement valvulaire, et des chirurgies combinant les deux procédures entre avril 2004 et mars 2006. D'avril 2004 à mars 2005 (1ère année), tous les patients ont été traités dans des unités de soins intensifs mixtes dans deux différents sites employant des consultants en soins intensifs, des fellows et des résidents. D'avril 2005 à mars 2006 (2ème année), les patients ont été pris en charge dans une nouvelle unité CSRU dans un seul site, dont le personnel se composait de fellows en anesthésie cardiaque, d'un infirmier praticien et de consultants en soins intensifs, en anesthésie cardiaque et en chirurgie cardiaque. L'effet de ce changement sur la mortalité à l'hôpital, l'incidence de*

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dix complications postopératoires majeures, le nombre d'heures de ventilation postopératoire, les taux de réadmission et les annulations de cas par manque de capacité, ont été évalués à l'aide des tests du chi-carré et de Wilcoxon, lorsqu'ils étaient adaptés.

***Résultats** : Les taux de mortalité pour les pontages aortocoronariens, les remplacements valvulaires et les chirurgies combinées étaient similaires la première et la deuxième année. Il y a eu une réduction significative dans le taux composite de complications majeures (de 16,3 % à 13,0 %, P = 0,02) et dans la moyenne du nombre d'heures de ventilation postopératoire (8,8 vs 8,0 hres, P = 0,005) entre la première et la deuxième année. Dans l'analyse multivariée de régression logistique, l'intervalle avant la fusion (1ère année) a constitué un prédicteur indépendant significatif de l'incidence de décès ou de complications majeures.*

***Conclusion** : Un modèle d'unité CSRU spécialisée avec des consultants pluridisciplinaires a été associé à des devenirs postopératoires stables ou meilleurs par rapport à un modèle d'unité de soins intensifs mixte médico-chirurgical pour les soins post-chirurgie cardiaque.*

THE practice of cardiac surgery has become increasingly complex and high risk.[1] This is due to the steadily increasing age and comorbidities of patients referred for surgery and to the increasing use of percutaneous coronary intervention for multivessel coronary revascularization, instead of traditional coronary artery bypass grafting (CABG).[2] The decreased percentage of patients referred for CABG surgery has in turn contributed to the restructuring of tertiary care units performing advanced cardiac procedures, as both community and academic health centres adapt to the new clinical realities of contemporary cardiac care.

A pivotal study ten years ago clearly demonstrated that the institution of a new rapid extubation clinical care pathway for postoperative cardiac surgical care could reduce morbidity,[3] while improving resource use.[4] Nonetheless, the continued ability of cardiac surgery units to streamline postoperative care is under constraint in view of the increasing age and comorbidities of patients referred for surgery. Recent research has also demonstrated that the organizational features of intensive care units (ICUs) have a major impact on postoperative outcomes.[5] Furthermore, ICU care protocols can have an effect on important variables such as the duration of mechanical ventilation.[6] However, no study in the past decade has compared the outcomes of postoperative cardiac surgery patients cared for in a mixed medical-surgical ICU *vs* a specialized cardiac surgery recovery unit (CSRU).

At the London Health Sciences Centre, a tertiary academic cardiac surgery unit performing 1,300 to 1,400 major cases a year, several pivotal challenges to the provision of cardiac surgical care have recently occurred. First, as in other centres, we have experienced fewer patients referred for isolated CABG surgery and more referred for valve, combined valve-CABG and other complex cases during the past few years. Second, a nearby community-based cardiac surgery centre opened in July 2003 and has drawn low and intermediate risk patients from our catchment area. Third, due to hospital restructuring mandated by the Ministry of Health and Long Term Care of the Province of Ontario, the physical consolidation of our city's two separate cardiac surgery units occurred in April 2005. These two units had well-established traditions that had developed over 30 to 35 years, but widely different institutional cultures; nonetheless, their postoperative outcomes have been similar over the years. In response to these challenges, we opened a specialized CSRU coincident with the merger of the two units in April 2005, in an attempt to maintain and improve further our postoperative outcomes. The objective of this study was to determine how this change from a mixed medical-surgical ICU setting to a specialized CSRU for postoperative cardiac surgical care affected morbidity, mortality and other outcomes in cardiac surgery patients in our academic health sciences centre. We hypothesized that the opening of a specialized CSRU would be associated with improved postoperative outcomes, as compared to the previous patient management paradigm in our mixed medical-surgical ICUs.

Patients and methods

Approval for data collection for this study was granted by the Research Ethics Board of the University of Western Ontario, which waived the requirement for informed consent from individual patients. After several years of planning, the CSRU opened several weeks prior to the physical consolidation of the two cardiac surgery units in April 2005. Continuous (24-hr) medical in-house coverage was provided in both units before and after the merger; cardiac surgery residents and consultants were encouraged to write patient care orders, which were reviewed promptly by the ICU and CSRU teams before being enacted. Before the merger cardiac surgery patients were cared for in general medical-surgical ICUs staffed by critical care consultants, critical care fellows and second year anesthesiology, medical and surgical residents. Night call in the two medical-surgical ICUs was provided by second year residents with close backup from critical

care fellows. After the merger patients were transferred directly from the operating rooms to a 16-bed CSRU staffed by a consultant group that included a cardiac surgeon, cardiac anesthesiologists and critical care physicians. The consultant call schedule for the CSRU was organized so that two consultants were on call for the unit each week, one on weekdays (07:00 - 16:00 hours) and weekends, and the other on evenings and nights from Monday to Thursday, inclusive. In the CSRU, night call was provided approximately 80% of the time by cardiac anesthesiology fellows or (less commonly) by mid-level cardiac surgery or anesthesiology residents; backup was provided by the CSRU evening and night-time consultant, who usually remained in-house until 22:00 – 23:00 hours and lived less than 20 min away. An acute care nurse practitioner joined the CSRU team at the time of the merger and 24/7 charge nurse coverage was provided in the CSRU since the time of its opening. Nursing care of CSRU patients was provided by a pool of 165 critical care nurses, who rotated through the CSRU for four weeks at a time; a significant number of new nursing staff were hired in the spring of 2005 to cover the shortfall of nurses who were not relocating. All CSRU nurses also rotated through the adjoining medical-surgical ICU at the same institution. Respiratory therapists caring for CSRU patients were members of a larger pool of practitioners who also staffed the medical-surgical ICU on a rotational basis.

In view of recent research demonstrating the safety of protocol-guided weaning of mechanical ventilation, as performed by nurses and respiratory therapists,[6] we opted to emphasize as a care standard a rapid ventilation-weaning protocol coincident with the opening of the CSRU. The key elements of this rapid-weaning protocol are shown in Table I. This protocol had been formalized initially in the medical-surgical ICU at our institution in 1998, but compliance with the protocol in the cardiac surgical population had diminished during the succeeding seven years.

Statistical analysis

Sample size calculations indicated that an analysis of 1,300 patients per year would permit us to detect a 3% reduction in the composite morbidity outcome described below with 80% power. Key outcome variables in this study included the occurrence of in-hospital mortality or any of ten major postoperative complications. These included respiratory failure, dialysis-dependent renal failure, neurological complications, perioperative myocardial infarction, reoperation for bleeding, septicemia, sternal dehiscence, mediastinitis, life-threatening arrhythmia and insertion of a new intra-aortic balloon pump postoperatively; the operational definitions of these variables have been described in recent publications from our unit and have remained constant for the past eight years.[7,8] Unfortunately, data on catheter-related infections and ventilator-associated pneumonias were not directly measured, although the consequences of these complications were captured by the variables "septicemia" and "respiratory failure", respectively. The rates of major morbidity and mortality were reported for the three different types of surgeries (isolated CABG, isolated valve and combined CABG-valve) as well as for all patients. In addition, the median number of postoperative ventilation hours, readmission rates from the ward to the ICU/CSRU and the frequency of surgical cancellations due to ICU/CSRU bed constraints were calculated. For all of the above variables, the results in the year preceding the opening of the CSRU (April 2004 to March 2005 – year 1) were compared to those of the year following the opening of the CSRU (April 2005 to March 2006 – year 2). Categorical data were compared using a Chi-square or Fisher's exact test, where appropriate, whereas median lengths of stay and median ventilation hours were compared using the Wilcoxon test. A P value < 0.05 was considered significant.

In addition to the univariable analyses noted above, we used multivariable stepwise logistic regression, allowing for entry of variables at the 0.05 level and removal at the 0.10 level, to determine the independent predictors of in-hospital mortality or major complications. Variables considered in the analysis included patient age, gender, preoperative length of stay, type of surgical procedure, cardiac surgery consultant, preoperative ejection fraction, urgency status, primary or redo surgery, body mass index, chronic obstructive pulmonary disease, recent myocardial infarction (within 30 days), peripheral vascular disease, preoperative Canadian Cardiovascular Society/New York Heart Association functional class, diabetes, cerebrovascular disease, coronary anatomy, preoperative creatinine, congestive heart failure, ascending aortic atherosclerosis, planned on *vs* off-pump surgery and the time interval prior to the merger (i.e., year 1) *vs* after the merger (year 2). One of the purposes of this analysis was to determine whether the time interval had an independent predictive effect on postoperative outcome, with all other measured preoperative risk factors held constant.

Results

After extensive planning, the physical consolidation of our two cardiac surgery units occurred in April 2005 after the physical infrastructure was in place. Intensive

TABLE I Elements of postoperative rapid weaning protocol

- Patient hemodynamically stable and receiving no or only low doses of inotropic medication
- Patient oriented, obeys commands, has pain controlled and can maintain a patent airway
- ABG: O_2 saturation ≥ 93% on FIO_2 ≤ 0.50 and PEEP of 5 cm H_20, pH 7.35–7.45
- Minute volume ≤ 150 mL·kg^{-1} ideal body weight
- Place patient on pressure support ventilation of 5 cm H_20 at same FIO_2 and evaluate
  - Spontaneous Vt > 4 mL·kg^{-1} ideal body weight
  - Respiratory rate ≤ 25 per min
  - Minute ventilation maintained at ≥ 80% of previous controlled ventilation
- If all of above criteria are met, proceed to extubate patient without necessarily informing attending physician

ABG = arterial blood gas; FIO_2 = fractional inspired oxygen concentration; PEEP = positive end expiratory pressure; Vt = tidal volume.

TABLE II Observed mortality rates in years 1 and 2

Procedure	*Year 1*	*Year 2*	*P value*
Isolated CABG	17/967 (1.8%)	16/979 (1.6%)	0.86
Isolated valve	8/188 (4.3%)	8/224 (3.6%)	0.44
Combined CABG-valve	12/116 (10.3%)	9/125 (7.2%)	0.44
All cases	37/1271 (2.9%)	33/1328 (2.5%)	0.58

CABG = coronary artery bypass grafting.

TABLE III Observed composite morbidity rates in years 1 and 2

Procedure	*Year 1*	*Year 2*	*P value*
Isolated CABG	127/967 (13.1%)	96/979 (9.8%)	0.003
Isolated valve	37/188 (19.7%)	44/224 (19.6%)	0.91
Combined CABG-valve	43/116 (37.1%)	33/125 (26.4%)	0.10
All cases	207/1271 (16.3%)	173/1328 (13.0%)	0.02

CABG = coronary artery bypass grafting.

care unit nursing and respiratory therapist turnover rates were low at the receiving institution, whereas most of the ICU nurses and respiratory therapists at the institution in which the cardiac surgery unit closed did not relocate. Although one surgeon moved to another centre in August 2004 and a new surgeon joined our team in January 2005, the other surgeons in both units continued full-time practice throughout the two-year duration of the study.

During the study interval a total of 2,730 patients underwent cardiac surgical procedures at our institution. Since our multivariable outcome model to predict the risk of major complications included predominantly patients undergoing CABG, valve and combined valve-CABG procedures, 131 patients undergoing other types of procedures (e.g., heart transplantation, adult congenital heart procedures, aortic procedures, removal of infected permanent pacemaker leads via a sternotomy) were excluded from further analysis. The year 1 and year 2 cohorts included 967 and 979 patients undergoing isolated CABG procedures, 188 and 224 patients undergoing isolated valve repair or replacement procedures and 116 *vs* 125 patients undergoing combined valve-CABG operations, respectively.

The observed rates of mortality and major morbidity after surgery are shown in Tables II and III, respectively. Although mortality rates trended downwards in year 2 for all types of procedures, there was no statistically significant difference in in-hospital mortality rates between the two years. The rates of individual complications were not statistically different in years 1 and 2 (data not shown), except for the occurrence of a life-threatening arrhythmia, which decreased from 4.3% in year 1 to 2.6% in year 2 ($P = 0.04$). There was, however, a significant decrease in the composite major morbidity rate in CABG patients and in the overall cohort in year 2 *vs* year 1, as noted in Table III. The magnitude of this decrease in the entire cohort was 3.3% in absolute and 20.2% in relative terms.

As shown in Table IV, multivariable stepwise logistic regression analysis revealed ten independent predictors of the composite outcome of in-hospital mortality or major complications. The following variables were not significant predictors of adverse outcome in our study: preoperative length of stay, gender, body mass index, chronic obstructive pulmonary disease, recent myocardiac infarction, cardiac surgery consultant, preoperative cerebrovascular disease, coronary anatomy, aortic atherosclerosis, congestive heart failure and planned on *vs* off-pump CABG procedure. Importantly, the pre-merger time interval (i.e., year 1) was an independent predictor of adverse outcome in this study (Table IV). The odds ratio and statistical significance of this variable was similar to that of a preoperative creatinine greater than 120 umol·L^{-1} or a preoperative diagnosis of diabetes mellitus.

With respect to additional outcomes, the median postoperative ventilation hours decreased from 8.8 to 8.0 from year 1 to year 2, which was statistically significant ($P = 0.005$). The readmission rate from the postoperative ward to the ICU or CSRU was 32/1,271 (2.5%) in year 1 *vs* 40/1,328 (3.0%) in year 2 ($P = 0.52$). In addition, in year 1, 31 cases were cancelled due to a lack of ICU beds out of a total of 1,431 available day-time operating room slots (2.2%); in year 2, 46 of 1,451 (3.2%) available day-time operating room slots were cancelled due to a lack of CSRU beds ($P = 0.12$ *vs* year 1).

TABLE IV Independent predictors of death or major complications on multivariable logistic regression analysis

Variable	*Odds ratio (95% confidence interval)*	*P value*
Increasing age	1.30 (1.14, 1.47) per decade	< 0.001
Procedure type		< 0.001
- CABG only	1.0 (reference value)	
- Valve only	2.21(1.50, 3.28)	
- CABG & valve	2.93 (1.99, 4.32)	
Urgency		< 0.001
- Elective	1.0 (reference value)	
- Urgent	0.80 (0.58, 1.11)	
- Emergent	1.12 (0.55, 2.29)	
- Salvage	5.56 (2.64, 11.69)	
Redo surgery	2.59 (1.56, 4.29)	< 0.001
Disease severity via increasing CCS/NYHA class	1.50 (1.19, 1.91)	< 0.001
Peripheral vascular disease	1.81 (1.25, 2.62)	0.002
LVEF < 35%	1.52 (1.10, 2.11)	0.012
Period: pre-merger (year 1)	1.37 (1.05, 1.77)	0.019
Creatinine >120 umol·L^{-1}	1.46 (1.05, 2.04)	0.025
Diabetes	1.35 (1.02, 1.79)	0.039

CABG = coronary artery bypass grafting; CCS = Canadian Cardiovascular Society; NYHA = New York Heart Association; LVEF = left ventricular ejection fraction; C statistic = 0.74; Hosmer-Lemeshow goodness of fit *P* value = 0.12.

Discussion

This study showed that despite the anticipated stresses associated with the mandated physical consolidation of two cardiac surgery units into one, postoperative outcomes were either stable or improved after the opening of a specialized CSRU staffed by consultants from different disciplines. Specifically, whereas the in-hospital mortality rates after CABG, valve and CABG-valve procedures decreased only slightly in the year after the opening of the CSRU as compared to the year before, there was a relative 20% reduction in major morbidity in the entire cohort, which was clinically and statistically significant. On the other hand, there was only a 10% reduction in median postoperative ventilator hours, which although statistically significant was of limited clinical importance. Furthermore, ICU/CSRU readmission rates did not significantly change and there were 15 more case cancellations in year 2 due to a lack of in-patient beds and ICU/CSRU capacity.

No other recent studies have examined the effect of service consolidations on clinical outcomes and on the quality of care in surgical or anesthetic practice. Indeed, the vast majority of published papers in this field have focused on the financial implications of mergers and market consolidations in health care. The limited clinical literature in this area has suggested that staff morale and even clinical outcomes are at risk in the acute phase after a merger occurs. A previous study analyzed the quality of care before and after hospital mergers and acquisitions in California during the 1990's, with a focus on heart attack and stroke patients as well as normal newborn babies.[9] This study showed that consolidation had no impact on inpatient mortality after heart attack or stroke. However, consolidation resulted in an increase in the 90-day readmission rate for heart attack patients and increased the likelihood that normal newborns would be discharged before 48 hr. Another study examining the impact of a merger on staff, patient and financial outcomes in an acute inpatient system showed that unit level costs and hours per patient day increased during and immediately after merger.[10] The authors found no significant variation in medication errors nor in the incidence of patient falls. Nursing staff member surveys revealed a significant negative effect of the merger on staff morale and job satisfaction. This study showed that the early period after a health care merger can be associated with worsening staff morale and increased costs, even if measured quality of care variables do not change.

There are several limitations to our study that should be highlighted. The opportunity to redesign the postoperative care of cardiac surgery patients at our institution arose as a result of a merger of two units in our city that was mandated under hospital restructuring guidelines promulgated by the Ministry of Health and Long Term Care of the Province of Ontario. Thus, this study was not a randomized controlled trial of two different treatment settings that exhibited "a priori equipoise", but a prospective cohort study of a "natural experiment". Fortunately, postoperative outcomes were similar at both sites prior to the merger and all but two of the consultant cardiac surgeons continued full-time practice for the two years of the study; one member relocated at the three-month mark in year 1 and another started on faculty at the eight-month mark in year 2. Furthermore, the same template for nursing and respiratory therapist coverage was carried forward from the ICU to the CSRU, and members of both of these professional groups rotated through the CSRU and the medical-surgical ICU after the merger.

This study has an additional potential theoretical limitation, specifically the possibility of biases that are inherent in all before/after study designs.[11] These include threats to internal validity such as temporal trends, selection bias, instrumentation or information

bias, and differential patient drop out.[11] Since patients being referred for cardiac surgery have been older and have had more comorbidities in recent years, temporal trends would have favoured improved results in year 1 *vs* year 2, which was not the case. Moreover, selection bias did not occur in our study since all CABG, valve and combined CABG-valve patients undergoing surgery in both years were included in the study cohort. In addition, instrumentation or information bias was not an issue, since all of our mortality and morbidity data were collected prospectively and an identical operational definition of study variables was used in both years. Finally, differential patient drop out was not a threat to internal validity in our study, since only the 131 patients undergoing non-CABG and non-valve procedures were excluded from the final study cohort, including approximately the same number and type of cases in both years.

We believe that our experience with systems redesign of perioperative cardiac care has generalizability to that of other academic health science centres, many of which have embarked on a similar process in response to the rapidly changing realities of contemporary cardiac surgery practice. Nonetheless, it is difficult to ascertain which factors could have had the most beneficial impact on postoperative outcomes in the CSRU. The appointment of practicing cardiac anesthesiologists, as well as a cardiac surgeon, as CSRU consultants could have been important; none of these individuals had worked as consultants in the medical-surgical ICU prior to the merger. The increasing familiarity and certification of CSRU consultants in transesophageal echocardiography could have been helpful in promoting earlier surgical reintervention in hemodynamically unstable patients, given recent evidence of discordance between clinical and echocardiographic diagnoses in patients with unexplained hemodynamic instability after cardiac surgery.[12] Moreover, the change in the consultant call system to a day-night rotation involving two consultants instead of the previous single consultant per week may have had an independent beneficial effect. In addition, an acute care nurse practitioner joined the CSRU team at the beginning of year 2 of the study, whereas no nurse practitioner had worked in the medical-surgical ICU at the receiving institution prior to merger. Preliminary studies have shown that the involvement of advanced practice nurse practitioners was associated with enhanced compliance to clinical practice guidelines,[13] as well as the promotion of better continuity of care and collaboration amongst health care providers.[14] Furthermore, the medical directive empowering CSRU nurses and respiratory therapists to wean patients from the ventilator when hemodynamic status and respiratory function were stable, may have had other benefits in addition to a modest reduction in postoperative ventilator hours.[15] The fact that the post-merger time interval was an independent predictor of the avoidance of in-hospital mortality or major morbidity in this study suggests that these human resource factors were as important as changes in patient-specific risk factors in year 2 *vs* year 1 of our study.

Although the initial clinical results following the opening of our specialized CSRU have been positive, a long-term, longitudinal follow-up study is warranted to determine if the improvements in postoperative outcomes are sustainable. It is likely that the median number of postoperative ventilation hours will continue to decrease in the near-term, as the postoperative care model in the CSRU further "matures" and use of the rapid ventilator weaning protocol is continually reinforced; to that end, the median postoperative ventilation hours of our patients has been 7.1 during the past nine months. We are also performing a longitudinal study of the changes in patient safety culture before and after the merger of our two cardiac surgery units. We have employed a previously-validated questionnaire to assess organizational patient safety climate[16,17] and plan to extend this study to at least three years post-merger, given the high likelihood that changes in organizational safety culture will take some time.

In summary, opening a specialized CSRU with a multi-disciplinary medical consultant model (cardiac anesthesiology, cardiac surgery and critical care medicine) was associated with stable or improved outcomes after cardiac surgery at our institution, despite the anticipated stresses that may occur following the merger of a tertiary care, advanced cardiac program. Carefully planned changes and refinements to perioperative care paradigms can be associated with improved outcomes, even in cardiac surgery programs with a long tradition of excellence.

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