Safety and efficiency assessment of training Canadian cardiac surgery residents to perform aortic valve surgery

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Background: Research has demonstrated equivalent patient safety outcomes for various cardiac procedures when the primary surgeon was a supervised trainee. However, cardiac surgery cases have become more complex, and the Canadian cardiac surgery education model has undergone some changes. We sought to compare patient safety and efficiency of aortic valve replacement (AVR) between Canadian patients treated by senior cardiac trainees and those treated by certified cardiac surgeons.

Methods: We completed a single-centre, case-matched, prospectively collected and retrospectively analyzed study of AVR. Patients were matched between trainees and consultants for age, sex, New York Heart Association and Canadian Cardiovascular Society status, urgency of operation and diabetes status.

Results: We analyzed 1102 procedures: 624 isolated AVRs and 478 AVRs with coronary artery bypass graft (CABG). For isolated AVR, there was no significant difference in 30-d mortality (p = 0.13) or in major adverse events (p = 0.38) between the groups. In the AVR+CABG group, there was no significant difference in 30-day mortality (p = 0.10) or in the rates of major adverse events (p = 0.37) between the groups. Secondary outcomes (hospital and intensive care unit lengths of stay, valve size and type) did not differ significantly between the groups for isolated AVR or AVR+CABG.

Conclusion: Despite a higher-risk patient population and changes in the cardiac surgery training model, it appears that outcomes are not negatively affected when a senior trainee acts as the primary surgeon in cases of AVR.

Contexte : La recherche a fait état de résultats équivalents au plan de la sécurité des patients lors de diverses interventions cardiaques lorsque le chirurgien principal était un résident supervisé. Toutefois, la chirurgie cardiaque se complexifie et le modèle de formation canadien en chirurgie cardiaque a subi quelques transformations. Nous avons voulu comparer la sécurité de patients canadiens et l'efficience du remplacement de la valvule aortique (RVA) selon que les patients étaient traités par des résidents séniors en chirurgie cardiaque ou par des chirurgiens certifiés.

Méthodes : Nous avons procédé à une collecte prospective de cas assortis, dans 1 seul centre, puis à une analyse rétrospective des cas de RVA. Les patients ont été répartis entre résidents et experts et assortis selon l'âge, le sexe, la classification de la NYHA (New York Heart Association) et de la Société canadienne de cardiologie, le caractère urgent de l'intervention et le statut à l'égard du diabète.

Résultats : Nous avons analysé 1102 interventions : 624 RVA isolés et 478 RVA avec pontage aorto-coronarien (PAC). Dans les cas de RVA isolés, on n'a noté aucune différence significative pour ce qui est de la mortalité à 30 jours (p = 0,13) ou des effets indésirables majeurs (p = 0,38) entre les groupes. Pour ce qui est du groupe RVA+PAC, on n'a noté aucune différence significative quant à la mortalité à 30 jours (p = 0,10) ou quant aux taux d'effets indésirables majeurs (p = 0,37) entre les groupes. Les paramètres secondaires (durée du séjour à l'hôpital et à l'unité des soins intensifs, taille et type de valvule) n'ont pas été significativement différents entre les groupes qu'il s'agisse de RVA isolé ou de RVA+PAC.

Conclusion : Malgré une population de patients à risque plus élevé et les transformations apportées au modèle de formation en chirurgie cardiaque, il semble que les résultats ne soient pas affectés négativement lorsqu'un résident sénior agit à titre de chirurgien principal dans les cas de RVA.

Cardiac surgical education in Canada is designed for trainees to develop the operative and clinical skills required for cardiac surgical care safely and efficiently, as outlined by the Royal College of Physicians and Surgeons of Canada.[1] The Canadian education model follows an apprenticeship style of learning, whereby trainees perform clinical and operative tasks under the supervision of a certified physician or surgeon and, for the duration of the training period, gain increasing clinical autonomy.[2] Residents progress from performing junior postgraduate-level tasks, such as opening and closing surgical incision sites, harvesting bypass conduits and assisting surgeries, to completing entire cardiac procedures from skin-to-skin under the direct supervision of the cardiac consultant during their senior postgraduate years.[3] Outcomes using this model of learning have traditionally demonstrated no negative impact on patient care for cardiac procedures, including coronary artery bypass graft (CABG) both on and off cardiopulmonary bypass, mitral valve repair/replacement, aortic valve replacement (AVR) and various congenital surgeries.[3–8]

However, within the past decade, patients presenting for cardiac surgery have become increasingly high-risk; patients are often advanced in age and have declining cardiac function and an increased prevalence of peripheral vascular disease, lung disease and renal dysfunction.[9] This increasingly high-risk population may have significant implications on the educational opportunities of cardiac surgery residents. Patients may have become too challenging for cardiac residents to act as primary operators, and subsequently patient outcomes may be affected.

Changes to the Canadian education model for cardiac surgical training have also occurred, which may impact trainee experience and patient outcomes. Cardiac surgery, which before 1995 was a 2-year fellowship after completion of 5 years of general surgery training, is now a 6-year postgraduate specialty that residents may enter directly from medical school.[1] As a result, the surgical experience of trainees undergoing cardiac surgery education has decreased substantially. Also, while there is currently no Canadian legislation mandating maximum hours per work week, many provincial residency associations have implemented restrictions resulting in maximal consecutive work hours per shift.[10] This has raised concern regarding the effect that decreasing clinical and operative volume for surgical residents would have on the ability of current residents to perform operations in a safe and efficient manner.[11,12]

Given the aforementioned changes in the Canadian cardiac surgical education model and the increasing medical complexity of patients, it is imperative to reassess patient outcomes for procedures performed primarily by cardiac surgery trainees. The purpose of this study was to assess the outcomes of high-risk patients undergoing isolated AVR or AVR with CABG (AVR+CABG) performed by cardiac surgery trainees compared with those of patients whose operations were performed by certified cardiac surgeons. Results will have important clinical implications regarding the safety and effectiveness of cardiac trainees performing AVR surgery on the Canadian population and provide validation to the current cardiac surgical educational model.

Methods

This was a single-centre, case-matched series of prospectively collected and retrospectively analyzed data on isolated AVR and AVR with concomitant CABG surgery. We searched a local database using the keyword "AVR" to identify eligible patients for inclusion. All patient data were collected using a modified Society of Thoracic Surgeons database form by the most responsible surgeon assigned to each case and designated research assistants. The Western University Research Ethics Board approved the study protocol, and the consents from patients were waived.

The primary surgeon was defined as the operator who excised and implanted the aortic valve and performed the majority of the procedure. A trainee case referred to an operation in which the cardiac surgery resident was the primary surgeon. All trainee cases were performed under the direct supervision of a cardiac surgery consultant. A consultant case referred to an operation in which a certified cardiac surgeon excised and implanted the aortic valve, with the resident or professional assistant acting as the primary assistant.

Aortic atherosclerosis was defined as atherosclerosis of the ascending aorta assessed intraoperatively by palpation or by epiaortic ultrasound. Salvage procedures were those performed to correct major coronary artery disease or aortic valve defects that were immediately life-threatening. We considered surgery to be urgent if required within 48 hours and emergent if required within 3 hours. Major adverse cardiac events (MACE) referred to any of the following 10 complications: arrest/arrhythmia, respiratory failure, postoperative intra-aortic balloon pump, renal failure, reintervention, septicemia, postoperative myocardial infarction, neurologic complications, reoperation for bleeding and mediastinitis. All AVR procedures involved central venous line access, Swan-Ganz catheter monitoring and transesophageal echocardiogram assessment and used standard cardiopulmonary bypass and cardioplegia techniques. The type of aortic valve was determined based on preoperative discussions with the patient. Postoperative care was managed by standard protocols with daily monitoring of rhythm; sternal wound; blood work, including complete blood count and electrolytes; and chest radiographs.

The primary outcome was 30-day mortality for isolated AVR compared with AVR+CABG. We calculated propensity scores based on sex, New York Heart Association class (NYHA 4 v. 1/2/3), Canadian Cardiovascular Society class (CCS 3 and 4 v. 0/1/2) and diabetes status (yes v. no). We used a greedy matching process, performed separately for AVR and AVR+CABG, to obtain matches between patients

whose procedures were performed by trainees and those whose procedures were performed by consultants.

Statistical analysis

We used SAS version 9.2 to analyze the data. One-on-one matching was then done on age within 5 years and propensity scores within 0.001. We used the Breslow–Day test for homogeneity of odds ratios to review the effect of time on morbidity and mortality or MACE. Secondary outcomes included MACE, size of aortic valve prosthesis implanted, cardiopulmonary bypass and aortic cross clamp times, and median intensive care unit (ICU) and hospital lengths of stay (LOS). Data analysis for continuous preoperative variables, including age, body mass index (BMI), preoperative LOS, predicted risk of death, predicted risk of complications, pump time and cross clamp time, were assessed using a Wilcoxon 2-sample test. Categorical variables were compared using χ^2 tests. To compare the urgency status of the procedure, we used the Fisher exact test. We considered results to be significant at $p < 0.05$.

RESULTS

From July 1999 to August 2010, 1102 AVR procedures (624 isolated AVR and 478 AVR+CABG) were performed. The trainee group comprised 123 patients who underwent isolated AVR and 84 who underwent AVR+CABG. The consultant group comprised 501 patients who underwent isolated AVR and 394 who underwent AVR+CABG. A total of 10 cardiac surgery trainees and 8 cardiac surgery consultants participated in the study over the 10-year

Table 1. Demographic and clinical characteristics of 624 patients who underwent isolated aortic valve replacement procedures performed by cardiac consultants or residents

	Primary surgeon, no. (%)*		
Characteristic	Consultant, *n* = 501	Resident, *n* = 123	*p* value
Age, mean (SD) yr	66.4 (13.4)	68.7 (11.3)	0.14
Preoperative LOS, mean (SD) d	3.8 (12.2)	2.4 (4.7)	0.19
Female sex	184 (36.7)	46 (37.4)	0.89
Ventricular grade 3/4/not done	73 (14.6)	13 (10.6)	0.25
Urgency			0.17†
Elective	330 (65.9)	88 (71.5)	
Emergent	1 (0.2)	1 (0.8)	
Urgent	161 (32.1)	34 (27.6)	
Salvage	9 (1.8)	0 (0)	
Redo	63 (12.6)	8 (6.5)	0.06
Body mass index > 30	189 (37.7)	47 (38.2)	0.92
Chronic obstructive pulmonary disease	74 (14.8)	16 (13.0)	0.62
Recent myocardial infarction	14 (2.8)	2 (1.6)	0.75†
Peripheral vascular disease	31 (6.2)	7 (5.7)	0.84
NYHA classification			0.035‡
1	48 (9.8)	13 (11.0)	
2	117 (24.0)	23 (19.5)	
3	243 (49.8)	73 (61.9)	
4	80 (16.4)	9 (7.6)	
CCS class			0.002§
1	87 (24.3)	20 (18.2)	
2	64 (17.9)	22 (20.0)	
3	123 (34.4)	57 (51.8)	
4	60 (16.8)	10 (9.1)	
Diabetes	98 (19.6)	24 (19.5)	0.99
Cerebrovascular disease, CVA or TIA	60 (12.0)	25 (20.3)	0.016
Creatinine > 120 μmol/L	65 (13.0)	16 (13.0)	0.99
Congestive heart failure	127 (25.4)	24 (19.5)	0.18
Aortic atherosclerosis	80 (16.0)	19 (15.5)	0.89
Predicted risk of death, %¶	4.3 (7.9)	3.0 (3.2)	0.84
Predicted risk of mortality/major complications, %¶	19.9 (13.8)	17.8 (9.2)	0.56

CCS = Canadian Cardiovascular Society; CVA = cardiovascular accident; LOS = length of stay; NYHA = New York Heart Association; SD = standard deviation; TIA = transient ischemic attack.
*Unless otherwise indicated.
†Fisher exact test.
‡18 missing.
§156 missing.
¶London Health Sciences Centre 2010 Model.

period. Preoperative patient demographics and comorbidities for patients in the trainee and consultant groups are presented in Tables 1 and 2. For patients who underwent isolated AVR, the rates of urgency of "salvage" surgery (1.8% v. 0%), redo surgery (12.6% v. 6.5%), NHYA status IV (16.4% v. 7.6%) and CCS class IV (16.8% v. 9.1%) were higher in the consultant group than the trainee group. For those who underwent AVR+CABG, the rates of redo surgery (5.3% v. 1.2%) and CCS class IV status (34.4% v. 25.3%) were also higher in the consultant group than the trainee group.

There was no difference in the primary outcome of 30-day mortality after isolated AVR with case-matching on a one-to-one basis for age within 5 years, NYHA and CCS functional status, presence of diabetes and urgency of procedure between the trainee and consultant groups (McNemar χ^2, $p = 0.13$). We also found no significant differences in death and MACE after isolated AVR between the trainee and consultant groups (McNemar χ^2, $p = 0.38$). Mortality outcomes of AVR+CABG when matched for the aforementioned factors showed no statistical difference between the trainee and consultant groups (McNemar χ^2, $p = 0.10$). There was no difference in the rates of MACE between the matched trainee and consultant groups of AVR+CABG (McNemar χ^2, $p = 0.37$). Prior to matching, there was a statistically significant 30-day mortality for isolated AVR between the trainee and consultant groups (0 of 123 [0%] in the trainee group v. 20 of 501 [4.0%] in the consultant group, $p = 0.020$). The difference in 30-day mortality for combined AVR+CABG was nonsignificant

Table 2. Demographic and clinical characteristics of 478 patients who underwent concomitant aortic valve replacement and coronary artery bypass graft procedures performed by cardiac consultants or residents

	Primary surgeon, no. (%)*		
Characteristic	Consultant, $n = 394$	Resident, $n = 84$	p value
Age, mean (SD) yr	72.9 (8.4)	73.0 (7.3)	0.80
Preoperative LOS, mean (SD) d	3.2 (5.4)	3.2 (6.9)	0.66
Female sex	93 (23.6)	27 (32.1)	0.10
Ventricular grade 3/4/not done	65 (16.5)	12 (14.3)	0.62
Urgency			0.11†
Elective	234 (59.4)	56 (66.7)	
Emergent	3 (0.8)	1 (1.2)	
Urgent	152 (38.6)	24 (28.6)	
Salvage	5 (1.3)	3 (3.6)	
Redo	21 (5.3)	1 (1.2)	0.15†
Body mass index > 30	135 (34.3)	31 (36.9)	0.64
Chronic obstructive pulmonary disease	75 (19.0)	10 (11.9)	0.12
Recent myocardial infarction	44 (11.2)	4 (4.8)	0.08
Peripheral vascular disease	58 (14.7)	9 (10.7)	0.34
NYHA classification			0.84‡
1	15 (4.3)	3 (3.9)	
2	62 (17.7)	16 (20.5)	
3	196 (56.0)	45 (57.7)	
4	77 (22.0)	14 (18.0)	
CCS class			0.027§
1	22 (6.0)	11 (13.3)	
2	60 (16.3)	8 (9.6)	
3	152 (41.2)	39 (47.0)	
4	127 (34.4)	21 (25.3)	
Diabetes	114 (28.9)	31 (36.9)	0.15
Cerebrovascular disease, CVA or TIA	56 (14.2)	10 (11.9)	0.58
Anatomy, left main and combinations	68 (17.3)	12 (14.3)	0.51
Creatinine > 120 μmol/L	82 (20.8)	16 (19.1)	0.72
Congestive heart failure	96 (24.4)	15 (17.9)	0.20
Aortic atherosclerosis	105 (26.7)	18 (21.4)	0.32
Predicted risk of death, %¶	7.1 (8.7)	7.2 (9.8)	0.53
Predicted risk of mortality/major complications, %¶	30.7 (13.9)	29.7 (14.1)	0.72

CCS = Canadian Cardiovascular Society; CVA = cardiovascular accident; LOS = length of stay; NYHA = New York Heart Association; SD = standard deviation; TIA = transient ischemic attack.
*Unless otherwise indicated.
†Fisher exact test.
‡50 missing.
§26 missing.
¶London Health Sciences Centre 2010 Model.

(3 of 84 [3.6%] in the trainee group v. 23 of 394 [5.8%] in the consultant group, $p = 0.59$; Table 3).

We reviewed the effect of time on morbidity and mortality or MACE. We grouped years as follows because there would have been too many categories if each year was considered separately: 1999–2004, 2005–2007 and 2008–2010. We conducted a Breslow–Day test for homogeneity of odds ratios, which showed no significant differences between the trainee and consultant groups in death alone ($p = 0.19$) and death or MACE ($p = 0.85$) for the isolated AVR subset. There was no significant difference between the trainee and consultant groups in death alone ($p = 0.39$) and death or MACE ($p = 0.95$) for the AVR+CABG subset.

There were no significant differences between the trainee and consultant groups in secondary outcomes for isolated AVR, including cardiopulmonary bypass times (mean 100.6 [standard deviation (SD) 29.8] v. 104.2 [SD 37.5] min), aortic cross-clamp times (mean 72.4 [SD 32.6] v. 71.9 [SD 23.3] min), median ICU length of stay (1.0 d in both groups), median hospital lengths of stay (7.0 d in both groups) and size of aortic valve (23.5 v. 23.6; Tables 3 and 4. There were no significant differences between the trainee and consultant groups in secondary outcomes for AVR+CABG surgery, including cardiopulmonary bypass times (mean 148.0 [SD 45.0] v. 146.9 [SD 39.5] min), aortic cross clamp times (mean 108.9 [SD 27.7] v. 106.5 [SD 27.5] min), median ICU lengths of stay (2.0 d in both groups), median hospital lengths of stay (8.0 d in both groups) and aortic size (22.9 v. 23.3; Tables 3 and 4). The pump times and clamp times were not distributed normally and failed normality tests. In the isolated AVR subset, the total mean pump time was 122.4 (SD 43.8) min, and the median was 115.5 (interquartile range [IQR] 51.0) min; the mean cross-clamp time was 87.1 (SD 31.5) min, and the median was 82.0 (IQR 39.0) min. In the AVR+CABG subset, the mean total pump time was 147.1 (SD 40.5) min, and the median was 140.0 (IQR 48.0) min; the mean cross-clamp time was 106.9 (SD 27.5) min, and the median was 102.0 (IQR 40.0) min.

Discussion

Our results suggest that when patients were matched for preoperative risk factors, the mortality and morbidity associated with AVR did not appear to be negatively affected when a senior cardiac surgical trainee, as opposed to a consultant cardiac surgeon, acted as the primary surgeon.

The significantly lower mortality before case-matching that we detected in the trainee group compared with the consultant group can be explained by a number of factors. First, important patient demographic differences existed between patients in the cardiac consultant and trainee groups. Cardiac consultants operated on a higher portion of cases classified as "salvage" surgery, meaning that their patients were at greater risk for postoperative mortality or morbidity based on preoperative clinical status. Cardiac consultants also performed procedures on a greater percentage of patients requiring repeat sternotomy. Second, there may have been technical factors, such as small aortic root, friable tissue, heavily calcified root and/or annulus and poor exposure, not identified among the patients' clinical characteristics. Third, when acting as the primary surgeon, the trainee has the important additional benefit of the experience, expert assisting and advice of the cardiac consultant. Another contributing factor to the statistical difference may have been a type 1 statistical error owing to the small sample size in the trainee group ($n = 123$) compared with the consultant group ($n = 501$). To balance the preoperative risks between the 2 groups of patients, we performed subset analysis between propensity score–matched patients. The subsequent analyses with propensity scores and one-on-one

Table 4. Primary outcome of isolated aortic valve replacement (AVR) and AVR with coronary artery bypass graft (CABG) between consultant and trainee groups

	Primary surgeon; no (%)		
30-day mortality	Consultant	Trainee	*p* value
AVR+CABG	23/394 (5.8)	3/84 (3.6)	0.07
Isolated AVR	20/501 (4.0)	0/123 (0)	0.08

Table 3. Comparison of outcomes of isolated aortic valve replacement (AVR) and AVR with coronary artery bypass graft (CABG)

	Isolated AVR			AVR+CABG		
	Primary surgeon			Primary surgeon		
Characteristic	Consultant, $n = 501$	Trainee, $n = 123$	*p* value	Consultant, $n = 394$	Trainee, $n = 84$	*p* value
Valve size, mean (SD) mm	23.6 (2.2)	23.5 (1.8)	0.80	23.3 (1.9)	22.9 (1.6)	0.039
Total pump time, mean min	104.2	100.6	0.53	146.9	148.0	0.92
Cross clamp time, mean min	71.9	72.4	0.68	106.5	108.9	0.42
Death, no. (%)	20 (4.0)	0 (0)	0.020	23 (5.8)	3 (3.6)	0.60
Death or any of 10 major complications, no. (%)*	92 (18.4)	15 (12.2)	0.10	111 (28.2)	27 (32.1)	0.47
ICU length of stay, median d	1.0	1.0	0.10	2.0	2.0	0.91
Total hospital length of stay, median d	7.0	7.0	0.77	8.0	8.0	0.94

ICU = intensive care unit; SD = standard deviation.
*Defined as major adverse cardiac events.

matching revealed no significant difference in outcomes.

Our results have important clinical relevance to the current cardiac surgical training/residency programs. University and teaching hospitals in Canada are most often high-volume centres receiving complex and high-risk patients. Consultant cardiac surgeons have an academic responsibility to balance the education needs for cardiac surgical trainees while maintaining patient safety and outcomes. The safety and efficiency outcomes achieved in our study by current cardiac residents performing AVR suggest that Canadian consultant cardiac surgeons should continue to offer residents educational opportunities while being assured that they are maintaining equivalent mortality and morbidity outcomes. Secondary outcomes of this study suggest similar morbidity and efficiency outcomes between cardiac trainees and consultants in performing AVR surgery. There were no significant differences between the trainee and consultant groups in MACE, cardiopulmonary bypass time, aortic cross clamp time, hospital length of stay, intensive care length of stay and prosthetic valve size for isolated AVR or AVR+CABG. This suggests that patient safety, use of operative resources and postoperative hospitalization are not significantly affected in the process of cardiac surgery education.

Equivalent patient safety outcomes for AVR performed by trainees have been demonstrated previously by Gulbins and colleagues,[7] and our results agree with their findings. Differences between our studies appear to be in the patient population and the study period. The patient population for the study by Gulbins and colleagues appeared to be at lower risk, with a preoperative EuroScore-predicted risk of postoperative mortality for isolated AVR of 6.5%. We used an institutional multivariable model (London Health Sciences Centre [LHSC] model) for predicting risk of death and/or any of the 10 major complications that had a C statistic of 0.74 and a Hosmer–Lemeshow goodness of fit result of $p = 0.12$. Variables included patient age, sex, BMI, preoperative ejection fraction, urgency of surgery, primary or redo surgery, chronic obstructive pulmonary disease, recent myocardial infarction (within 30 d), peripheral vascular disease, preoperative CCS-NYHA functional class, diabetes, cerebrovascular disease and preoperative kidney function. While the EuroScore and LHSC models are different for predicting postoperative outcomes, we feel that a 19% LHSC predicted mortality and morbidity in the consultant group for isolated AVR describes a moderate- to high-risk patient population, which would be different than that in the study by Gulbins and colleagues.

Another difference between our study and the previous research is the time period in which the studies were conducted. The study by Gulbins and colleagues was performed between 1994 and 2006, whereas our study occurred between 1999 and 2010. The patient population presenting for cardiac surgery has changed in recent years, becoming more medically complex and higher risk. Our results are also similar to secondary outcomes observed by Baskett and colleagues,[4] who demonstrated equivalent patient safety outcomes in various procedures performed by trainees as the primary surgeon. Isolated AVR mortality (3.6% and 2.8%, respectively; $p = 0.69$) and MACE rates (16.7% v. 19.8%) were similar between resident and consultant surgeons, respectively. However, these results were achieved by cardiac residents who were trained before the entrance changes in Canadian cardiac surgical training, and the sample size was smaller than ours.

Despite a decrease in the surgical experience of trainees entering cardiac surgery since 1995, it appears that current cardiac surgical trainees are capable of achieving the training that allows them to safely and efficiently perform AVR as senior residents. The change from 2-year fellowship in 1995 to direct entry from medical school was viewed as a major shift in cardiac surgery education. Residents are now entering the field of cardiac surgery with less surgical experience. However, the focus of training early in cardiac surgery in this new system appears to be adequate for training technically capable senior trainees. While no direct comparison is made between cohorts of trainees at different time periods, all 8 of the surgical residents who participated in this study were trained after entering cardiac surgery directly from medical school, suggesting no significant impact in patient safety with this associated change at our institution.

The current surgical training "apprenticeship" model is further evolving as changes, such as greater resident work-hour restrictions and an increased emphasis on simulation programs, are being proposed.[13] In July 2000, the Professional Association of Interns and Residents of Ontario and the Ontario Council of Teaching Hospitals limited the work hours of residents and fellows; in July 2003, the Accreditation Council for Graduate Medical Education in the United States imposed similar work-hour restrictions on residency programs.[14] While the potential benefits of surgical simulator training, such as portability, standardization and reusability, are well known, the validation for improving clinical outcome has not been established.[2,15–17] "Face validity," or how closely the assessment resembles the "real" task, of simulation models remains a limitation for simulation cardiac surgery. The high-pressure environment of a cardiac surgery operating room, which requires coordination of technical expertise, communication among various health care professionals and situational awareness of the patients' changing hemodynamic status, is difficult to recreate in a simulation setting. Cardiac surgical educational programs should continue to incorporate simulation teaching while maintaining adequate actual surgical exposure. Further changes to cardiac surgical education training should include monitoring of patient safety outcomes, and our study provides a comparison group of current outcomes of safety and efficiency for AVR performed by recent cardiac trainees.

Limitations

Limitations of our study include those that are intrinsic to retrospective and nonrandomized studies. Also, long-term mortality and morbidity outcomes were not assessed between groups; such an assessment would have provided important clinical information.

Conclusion

The results of our case-matched, retrospective analysis show that clinical outcomes of patients undergoing AVR do not appear to be negatively affected when a senior cardiac surgical trainee acts as the primary surgeon. The current Canadian education model for cardiac surgery continues to train residents in a manner that does not appear to compromise patient care, even with an increasingly medically complex patient population.

Competing interests: None declared.

Contributors: K.J. Chen, C. Adams and L.R. Guo designed the study. D. Adams acquired the data. K.J. Chen and C. Adams wrote the article. All authors analyzed the data, reviewed the article and approved its publication.

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