Monitoring the performance of residents during training in off-pump coronary surgery

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Objective: Control charts (eg, cumulative sum charts) plot changes in performance with time and can alert a surgeon to suboptimal performance. They were used to compare performance of off-pump coronary artery bypass surgery between a consultant and four resident surgeons and to compare performance of off-pump coronary artery bypass surgery and conventional coronary artery bypass grafting within surgeons.

Methods: Data were analyzed for consecutive patients undergoing coronary artery bypass grafting who were operated on by one consultant or one of four residents. Conversions were analyzed by intention to treat. Perioperative death or one or more of 10 adverse events constituted failure. Predicted risks of failure for individual patients were derived from the study population. Variable life-adjusted displays and risk-adjusted sequential probability ratio test charts were plotted.

Results: Data for 1372 patients were analyzed; 769 of the procedures were off-pump coronary artery bypass operations (56.0%). The consultant operated on 382 patients (293 off-pump, 76.7%), and the residents operated on 990 (474 off-pump, 47.9%). Patients operated on by residents tended to be older, more obese, more likely to require an urgent operation, and more likely to need a circumflex artery graft but less likely to have triple-vessel disease. There were 7 conversions (consultant 5, residents 2). The overall failure rate was 8.5% (9.2% for consultant's operations and 8.2% for residents' operations), including 10 deaths (0.7%). Predicted and observed risks of failure were similar for all five surgeons. After 100 off-pump coronary artery bypass operations, performance was the same or better for the residents as for the consultant. For all surgeons, performance was the same or better for off-pump as for conventional coronary artery bypass grafting.

Conclusions: Off-pump coronary artery bypass surgery can be safely taught to cardiothoracic residents. Implementation of continuous performance monitoring for residents is practicable.

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Disseminating a new surgical procedure involves significant scientific, ethical, and logistic issues. In recent years, residents in cardiothoracic surgery have had to gain competence in performing coronary artery bypass grafting (CABG) off-pump (OPCAB)[1-4] as well as conventionally with cardiopulmonary bypass (ONCAB). During recent years, the number of OPCAB operations performed at our institution has increased significantly, and residents have carried out many of these procedures.

We recently reported our early experience in teaching OPCAB surgery by comparing the early and midterm clinical outcomes of ONCAB and OPCAB procedures performed by residents with or without direct consultant supervision.[3] However, conventional frequentist statistical methods are not optimal for analyzing sequential data. Control chart techniques (eg, cumulative sum) have the advantage of taking into account the order in which observations accrue while also avoiding the problem of repeated significance testing.[5-8] By providing a graphic summary of changes in performance with time, control charts can alert a surgeon to suboptimal performance.[8] They are therefore also well suited to monitoring surgical learning curves.[9]

The purpose of this report was to use control charts to describe learning curves for OPCAB for four resident surgeons, to compare performance for consultant and resident surgeons after risk adjustment, and to compare performance for OPCAB and conventional CABG within surgeons after risk adjustment.

Methods

Patient Selection and Data Collection

Standard data are collected prospectively for all patients undergoing CABG at our institution.[10] For this study, data were extracted from the database for consecutive patients who had undergone CABG between April 1996 and September 2002 and who were operated on either by the lead academic consultant (G.D.A., who introduced OPCAB to our institution) or one of four residents who were in years 3 to 6 of the UK National Training Program.[11] Patients undergoing emergency or salvage operations, which are rarely carried out by residents at this stage of their training, were excluded. Anesthetic and surgical techniques were standardized for all patients and have been previously reported elsewhere.[12-14]

The database describes whether cardiopulmonary bypass was used but not whether the original intention of the surgeon was to carry out OPCAB. Therefore, operative notes for all patients were reviewed to identify conversions from OPCAB to ONCAB. Such operations were recoded as OPCAB, and the analyses were carried out according to the principle of intention to treat.

Training

In our institution, residents train to carry out cardiothoracic operations through a period of 6 years. They are exposed to and start to perform ONCAB and OPCAB from the second year of their training program. With respect to OPCAB surgery, the program aims to start residents on simple cases that require only left anterior descending coronary artery or diagonal grafts; residents then progress to grafting posterior descending coronary arteries.[2] Details of the OPCAB training experience of the four residents monitored with control charts have been reported previously.[11]

Data Definitions

Perioperative death is rare after elective or urgent CABG operations (<1.0% in our institution during the study period). It is therefore unsuitable for monitoring performance. We thus sought a more sensitive outcome, and in advance of any analyses we defined surgical failure as the occurrence of one or more of the following events[15,16]: (1) perioperative death,[11] (2) perioperative myocardial infarction,[12] (3) ventricular tachycardia or fibrillation,[17]; (4) stroke (permanent or transient),[18] (5) acute renal failure with need for hemodialysis, (6) septicemia defined as development of postoperative fever with positive blood cultures, (7) use of an intra-aortic balloon pump, (8) reoperation for bleeding, (9) sternal rewiring because of infection, (10) postoperative ventilation longer than 48 hours, and (11) need for reintubation.

Consultant supervision was defined as an operation in which the consultant was scrubbed in and acted as first assistant.[3,11] When supervised, residents were supervised by one of five different consultants or occasionally a locum. The primary factor affecting whether a consultant was scrubbed in as first assistant was the identity of the consultant for whom a resident was working at the time of the operation.

Statistical Analysis

No formal sample size calculation was carried out. However, all residents included in the study were participating in an official training program,[11] and their experience of OPCAB described here included at least 100 OPCAB procedures. Demographic and clinical characteristics of patients were summarized according to surgeon and surgical technique. Some continuously or discretely measured prognostic variables (eg, Parsonnet score; Table 1) were categorized for these summaries and for fitting regression models.

Published risk indices are mainly calibrated for surgical mortality. Risk adjustment models for specific postoperative morbidities and for a different combined end point have recently been published,[19] but none of these was appropriate for the combined end point we defined. Therefore, predictors of failure were investigated empirically in the whole data set by logistic regression modeling. The predicted risk of failure for individual patients was calculated from the final model (see Appendix).

We used multiple regression modeling to investigate whether seniority of surgeon, surgical technique, or accumulating experience (sequence of operation) was associated with the predicted risk of failure. We calculated robust standard errors to take account of clustering of patients within surgeons. These analyses were hypothesis-driven. We also investigated whether for their first 25 operations residents operated on fewer patients (1) considered at high risk from a clinical perspective[11] or (2) receiving circumflex coronary artery (Cx) grafts, than subsequently. The cutoff of 25 cases was chosen after discussing with residents when they believed their experience would begin to reach a plateau.

TABLE 1. Distribution of demographic and preoperative clinical characteristics according to consultant or resident and surgical technique

Patient characteristics	Consultant OPCAB (n = 293)	Consultant ONCAB (n = 89)	Residents 1-4 OPCAB (n = 476)	Residents 1-4 ONCAB (n = 514)
Age at surgery (y, median and interquartile range)	63.9 (56.7-70.9)	62.9 (56.6-70.3)	65.1 (57.7-71.6)	65.2 (58.9-71.0)
Female (No.)	56 (19.1%)	13 (14.6%)	86 (18.1%)	91 (17.7%)
Body mass index (kg/m^2, median and interquartile range)	27.0 (24.5-29.6)	26.7 (23.9-28.6)	27.3 (24.9-30.1)	27.7 (25.3-30.4)
Canadian Cardiovascular Society class (No.)				
≤2	136 (46.4%)	38 (42.7%)	195 (41.0%)	203 (39.5%)
3	93 (31.7%)	30 (33.7%)	162 (34.1%)	176 (34.2%)
4	64 (21.8%)	21 (23.6%)	118 (24.8%)	135 (26.3%)
Unstable angina (No.)	94 (32.1%)	34 (38.2%)	195 (41.1%)	203 (39.6%)
New York Heart Association class (No.)				
1	59 (20.1%)	19 (21.6%)	117 (24.6%)	114 (22.2%)
2	145 (49.5%)	40 (45.5%)	203 (42.7%)	216 (42.1%)
3	78 (26.6%)	25 (28.4%)	143 (30.0%)	171 (33.3%)
4	11 (3.8%)	4 (4.6%)	13 (2.7%)	12 (2.3%)
Parsonnet score (median and interquartile range)	5 (1-10)	5 (2-9)	4 (3-10)	5 (2-10)
Urgent operation (No.)	143 (48.8%)	32 (36.0%)	326 (68.5%)	295 (57.4%)
No. of grafts (No.)				
1	34 (11.6%)	7 (7.9%)	75 (15.8%)	22 (4.3%)
2	124 (42.3%)	30 (33.7%)	170 (35.7%)	117 (22.8%)
3	106 (36.2%)	48 (53.9%)	201 (42.2%)	292 (56.8%)
≥4	29 (9.9%)	4 (4.5%)	30 (6.3%)	83 (16.2%)
Diabetes (No.)	49 (15.7%)	14 (16.7%)	85 (17.9%)	98 (19.1%)
Hypertension (No.)	158 (53.9%)	48 (53.9%)	282 (59.2%)	299 (58.2%)
Current smoker (No.)	35 (12.0%)	13 (14.6%)	55 (11.6%)	67 (13.0%)
Use of inotropes (No.)	106 (36.2%)	39 (43.8%)	171 (35.9%)	188 (36.6%)
Extent of coronary disease (No.)				
Single vessel	36 (12.3%)	7 (7.9%)	69 (14.5%)	24 (4.7%)
Double vessel	86 (29.4%)	22 (24.7%)	154 (32.4%)	123 (23.9%)
Triple vessel	171 (58.4%)	60 (67.4%)	253 (53.2%)	367 (71.4%)
Total "high risk" patients[16] (No.)	127 (43.5%)	34 (38.2%)	216 (45.4%)	218 (42.4%)
Age >75 y (No.)	36 (12.3%)	6 (6.7%)	54 (11.3%)	59 (11.5%)
Ejection fraction <30% (No.)	15 (5.1%)	5 (5.6%)	17 (3.6%)	23 (4.5%)
Myocardial infarction in last month (No.)	5 (1.7%)	4 (4.5%)	23 (4.8%)	17 (3.3%)
Congestive cardiac failure (No.)	10 (3.4%)	2 (2.2%)	9 (1.9%)	8 (1.6%)
Previous stroke (No.)	10 (1.0%)	3 (2.2%)	11 (1.9%)	21 (0.2%)
Creatinine >150 μmol/L (No.)	22 (7.5%)	6 (6.7%)	23 (4.8%)	18 (3.5%)
Chronic obstructive airways disease or asthma (No.)	23 (7.8%)	10 (11.4%)	62 (13.0%)	51 (9.9%)
Peripheral vascular disease (No.)	24 (8.2%)	3 (3.4%)	41 (8.6%)	44 (8.6%)
Previous cardiac surgery (No.)	3 (1.0%)	2 (2.2%)	9 (1.9%)	1 (0.2%)
Left main stem stenosis >50% (No.)	30 (10.2%)	7 (7.9%)	67 (14.5%)	77 (15.0%)
Cx graft (No.)	209 (71.3%)	71 (79.8%)	368 (77.3%)	461 (89.7%)

Numbers do not always sum to the totals for consultant or residents and surgical technique, and denominators for percentages are not always n, because there were missing data for some characteristics (<0.5% for any variable).

Variable life-adjusted displays (VLADs)[20] and risk-adjusted sequential probability ratio tests (SPRTs)[21,22] were plotted. It should be noted that the x-axis in such graphs represents operation number, not calendar time. Boundary lines for SPRT (indications for alert or action) were set to detect an increase in the failure equivalent to an odds ratio of 1.5 (H_1) or to confirm that the observed failure rate was consistent with the rate set as acceptable (H_0). The position of boundary lines was calculated as recently recommended, [22] assuming $\alpha = \beta = .10$ (alert) and .05 (action).

All analyses were carried out with STATA version 7 or 8 (Stata Corporation, College Station, Tex).

Results

The study cohort included a total of 1372 cases, 769 of which were OPCAB operations (56.0%). The consultant operated on 382 patients and the residents operated on 990 (284, 267, 190, and 249, respectively for residents 1-4); 293 operations (76.7%) carried out by the consultant and 474 operations carried out by the residents (47.9%, ranging from 36.0%-64.7%) were OPCAB. More than half of the operations carried out by residents were supervised (663/990, 67.0%). The clinical characteristics of patients by surgeon

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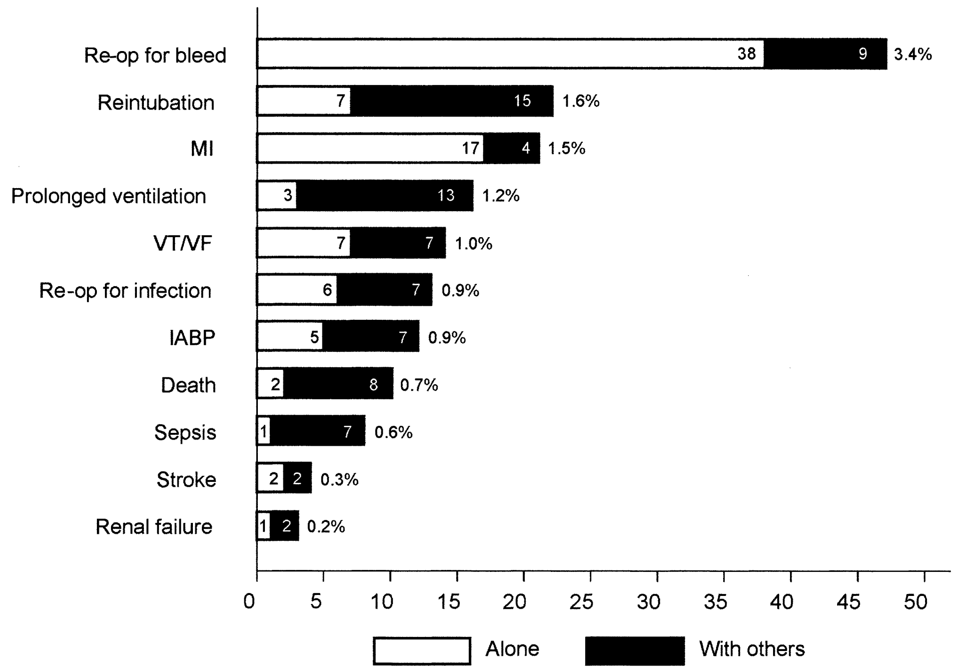

Figure 1. Frequencies of events contributing to failures, with occurrence alone or in combination with other events and overall incidence (%). Incidences and frequencies sum to more than overall incidence of failure because some patients had more than one event occur. *Re-op,* Reoperation; *MI,* myocardial infarction; *VT/VF,* ventricular tachycardia or fibrillation; *IABP,* intra-aortic balloon pump.

grade and type of operation are summarized in Table 1. Patients operated on by residents and consultants had broadly similar characteristics, although the former tended to be older, more obese, more likely to require an urgent operation, and less likely to have triple-vessel disease. Residents also tended to carry out more Cx grafts but fewer grafts overall. There were 7 acute conversions of OPCAB to ONCAB operations for electrical or hemodynamic instability, 5 carried out by the consultant and 2 carried out by the residents.

Failures

The failure rates were 9.2% (35/382) among patients operated on by the consultant and 8.2% (81/990) among patients operated on by residents, for an overall failure rate of 8.5% (95% confidence interval 7.1%-10.1%). The distributions and incidences of events defining failures are shown in Figure 1. There were 10 deaths (0.7%; 95% confidence interval 0.4%-1.3%), 8 of which occurred after one or more other events. Conversion from OPCAB to ONCAB was not itself considered to constitute failure; failures occurred in 2 of 7 (29%; 95% confidence interval 4%-71%) conversions.

Predicted risks of failure for individual patients ranged from 0.02 to 0.38, with a similar range across surgeons (Figure 2, *A*). The mean predicted risk was similar to the observed failure rate for all five surgeons. There was no evidence that the predicted risk differed between ONCAB and OPCAB operations carried out by residents. The median predicted risks were 0.067 (interquartile range 0.037-0.113) and 0.064 (interquartile range 0.039-0.113), respectively.

We hypothesized that patients with the highest risk of failure would not have been operated on by residents, at least not when they were starting to learn OPCAB. Figure 2, *B,* shows the moving average of predicted risk for OPCAB operations for each resident with accruing experience (sequence of operations). The graphs show no general tendency for residents initially to operate on patients at low risk of failure or for the predicted risk to increase with experience. For two of the residents (1 and 4), there appears to be quite a sharp increase in the predicted risk during the first 10 to 15 OPCAB operations. However, the moving average smoothes the predicted risk for individual patients. In fact, resident 1 operated on a patient with a predicted risk of 0.21 as early as his fifth OPCAB operation, and resident 4 operated on a patient with a predicted risk of 0.16 as early as his 11th OPCAB operation.

Figure 3 shows the percentages of patients operated on by residents who were classified as at high risk on clinical grounds[11] and who had a Cx graft grouped according to "early" (first 25 operations) versus subsequent operations.

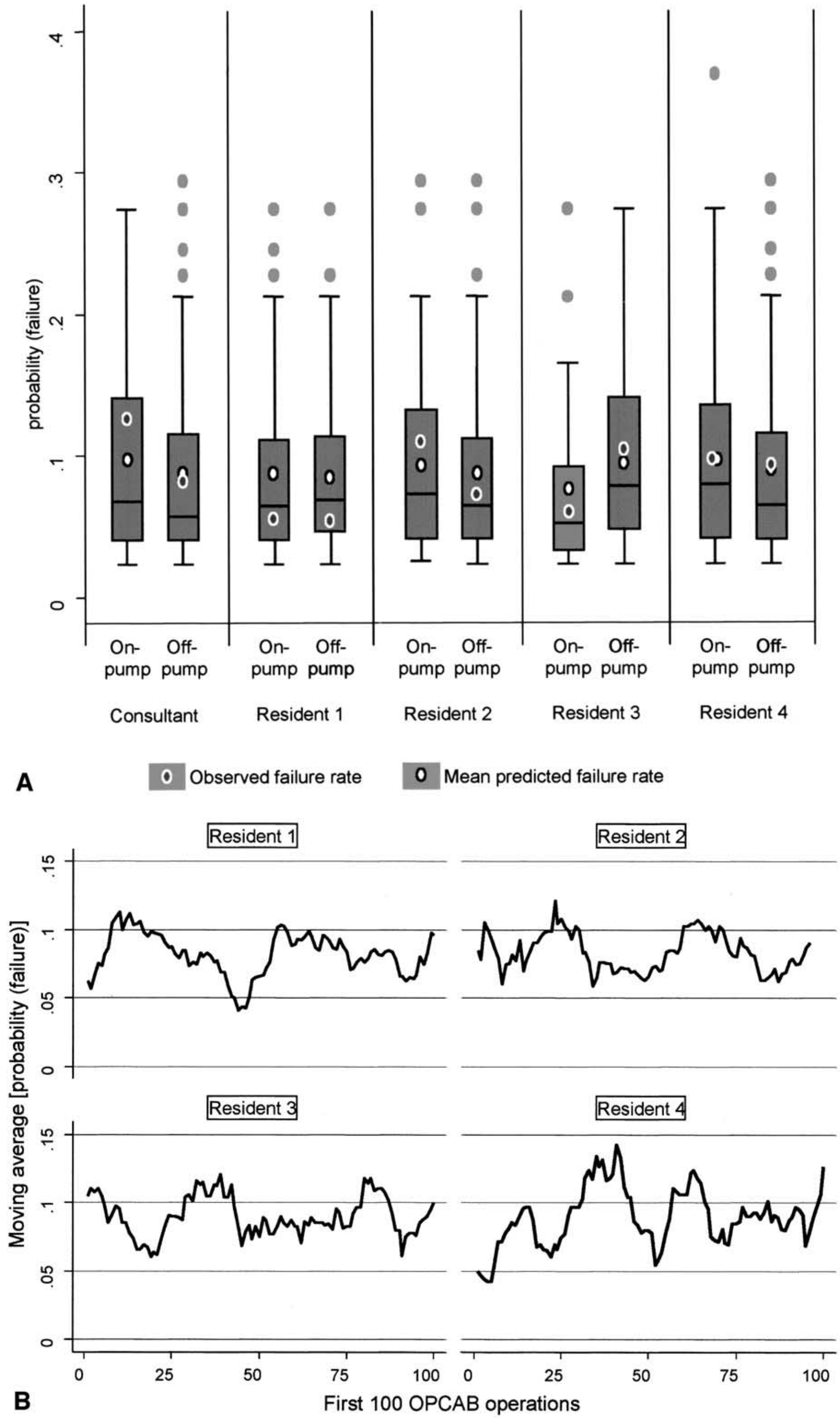

Figure 2. A, Box and whisker plots showing distributions of predicted risk by consultant versus resident and ONCAB versus OPCAB; mean predicted risk and observed failure rate are also shown for each box and whisker plot. Box and whisker plots show median *(middle horizontal line in the box),* 25th and 75th percentiles (*lower and upper bounds of box;* interquartile range), and most extreme observations within 1.5 interquartile ranges of quartiles (*lower and upper whiskers*); more extreme points are plotted separately as *filled gray circles. On-pump,* ONCAB procedures; *Off-pump,* OPCAB procedures. B, Moving average of predicted risk of failure for OPCAB operations for each resident. Moving average was average of predicted risk for previous 5 patients, current patient, and next 5 patients.

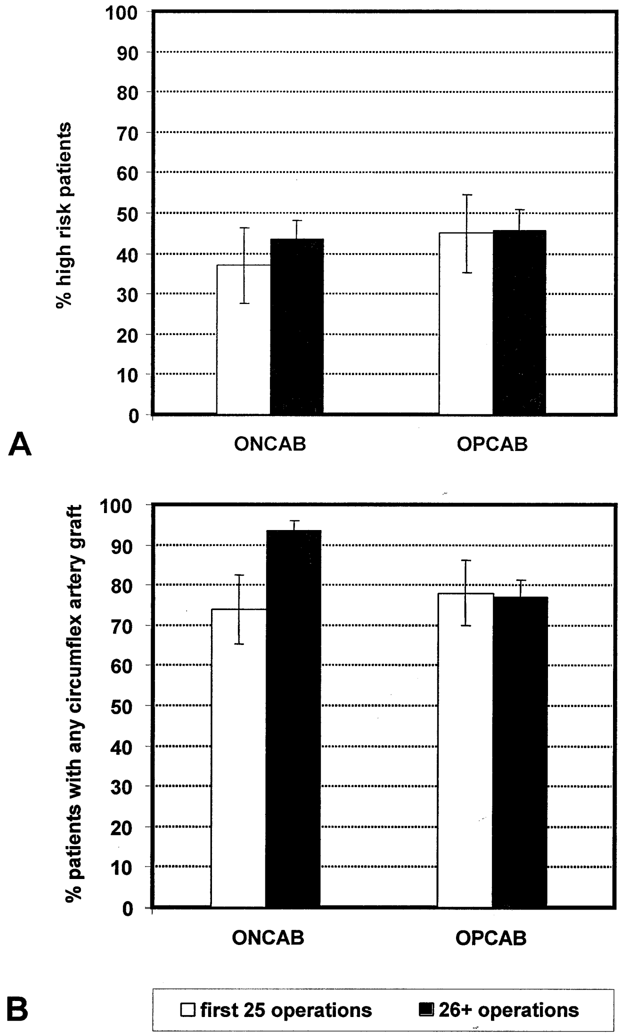

Figure 3. Proportion of patients operated on by residents who were considered clinically to be at high risk[16] (A) and who received Cx grafts (B) according to ONCAB versus OPCAB operation and according to sequence of operation (1-25 vs ≥26).

This figure shows that as the residents gained experience the percentages of patients considered at high risk and patients receiving a Cx graft increased for ONCAB but not OPCAB operations. It also shows that once experience had been acquired a smaller proportion of patients undergoing OPCAB than ONCAB received a Cx graft. This latter finding was also true for the consultant's recent OPCAB operations.

Performance Monitoring

VLAD and SPRT graphs for each resident superimposed on VLAD and SPRT graphs for the consultant are shown in Figure 4. The OPCAB graphs for the consultant represent his last 200 operations. The consultant's early operations were not included for two reasons: first, because this period included the consultant's learning curve and, second, to make the period of the consultant's operations more contemporaneous with the OPCAB operations carried out by the residents. ONCAB operations tended to have been done longer ago, especially for the consultant. This may explain the increase in the proportion of patients at high risk and patients receiving a Cx graft as residents gained experience for ONCAB but not for OPCAB.

After 100 OPCAB operations, cumulative performance was the same or better for the residents than for the consultant. For the consultant and all residents, the control chart for OPCAB was at the same level or below (better cumulative performance) the chart for ONCAB. With time, VLAD plots tended to oscillate about zero (except for resident 1), and SPRT plots tended to decline steadily with increasing number of operations. The SPRT plots for OPCAB and ONCAB operations carried out by resident 1 reached the "accept" boundary after about 100 and 175 operations, respectively. For continuous monitoring, the plots could have been reset to zero at these times.[9]

Discussion

There are four main findings from this study. First, it is safe to teach OPCAB to residents in a setting where consultants regularly practice OPCAB surgery, because we found no indication at all that the failure rate was higher among residents, not even within their first few operations. Second, teaching OPCAB in a residency program is effective, because the average failure rate for OPCAB after adjustment for case mix was similar to or better than that for ONCAB surgery for both consultant and residents. Third, in our training program residents learning OPCAB are not obviously "protected" from high-risk cases, because the predicted risk of failure and the proportion of patients at high risk or patients who required a Cx graft did not increase as residents gained more experience. Fourth, implementing continuous performance monitoring for residents is practicable, because the methods used in this study could be easily programmed in standard office software.

The study was necessarily observational for both logistic and ethical reasons, and it is important to consider this issue and other limitations when interpreting the main findings. The way in which cases are selected by consultants for residents is unlikely to be adequately characterized by our data despite the large number of clinical variables available. The estimates of predicted risk for each case are therefore likely to be affected by residual confounding, not only because the preoperative risk of a poor outcome was inadequately characterized but also because adjusted risk estimates never perfectly take into account all the prognostic factors that were measured. These limitations almost certainly favored residents' operations, because the true risk of the consultant's operations is probably not properly reflected in the predicted risk scores. Residents may therefore

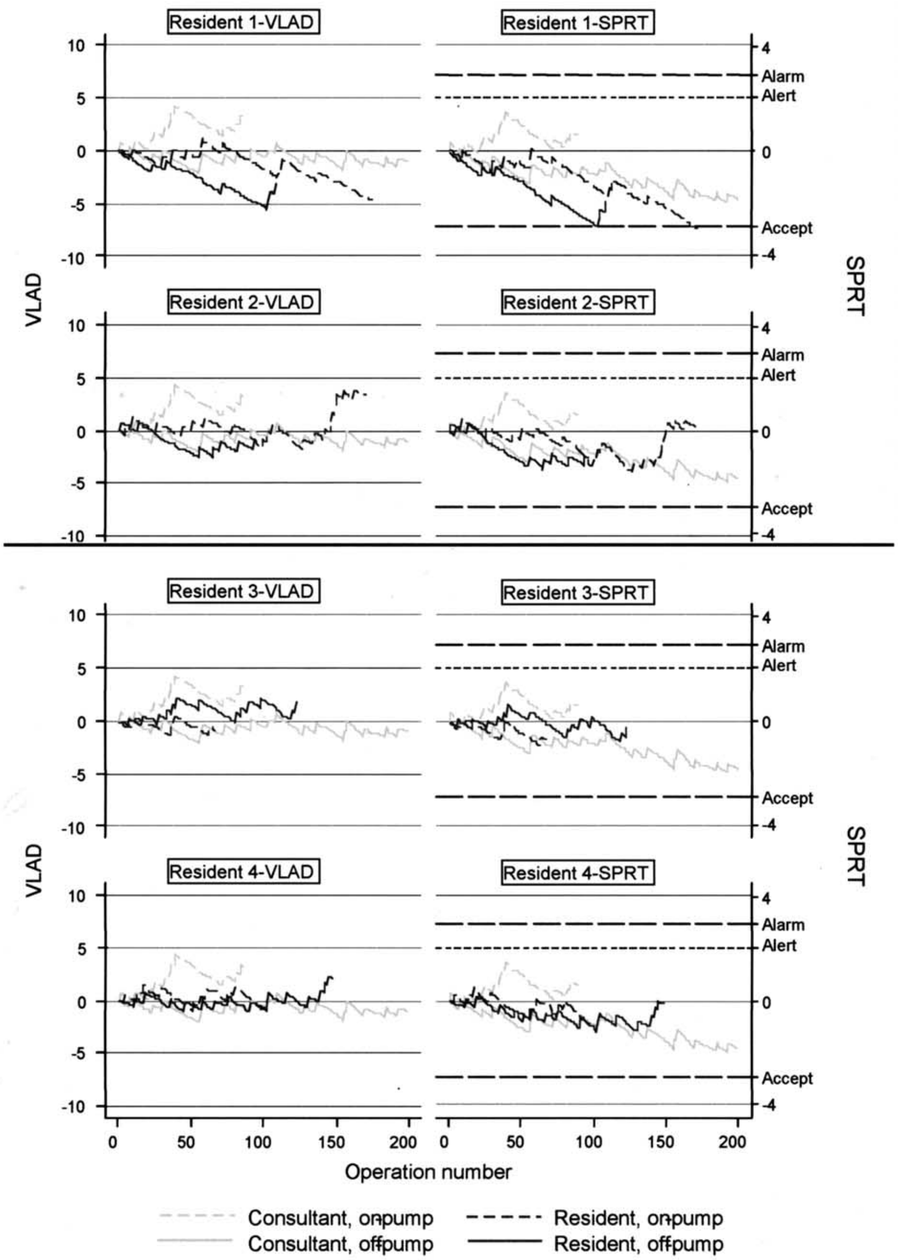

Figure 4. VLAD *(left column)* and SPRT *(right column)* charts for residents compared with consultant (data for consultant's 200 most recent operations within study period are shown for comparison on each chart). The x-axis represents operation number, not calendar time (see text). Note that y-axes are different for VLAD plots (cumulative observed minus predicted risk of failure) and SPRT plots (cumulative log likelihood ratio), and charts have been scaled accordingly. Acceptable performance in VLAD plot should oscillate around 0, whereas acceptable performance in SPRT plot will tend toward "accept" boundary line.[9]

not compare as favorably with the consultant as indicated in the graphs, but residual confounding would be unlikely to overturn the basic conclusion that teaching OPCAB is safe and effective.

A change in the designation of main operator from resident to consultant, for example when complications leading to classification as failures occurred, would have led to the performance of residents being overestimated. We do not believe that this occurred to a significant extent. Neither consultants nor residents could recall specific instances of this kind. Consequently, we conclude that changes in designation in the main operator were extremely uncommon.

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However, residents volunteered that during the early stages of their OPCAB training the consultant may have intervened in one of two ways. The consultant may have taken over in a planned manner to carry out one or more anastomoses, for example a Cx graft. When asked directly about the frequency of such events, residents thought that they might have occurred up to a maximum of 5 times per resident. Alternatively, the consultant may have intervened to show the resident how to position the heart to gain access to carry out the required distal anastomosis; in these instances, the operating resident carried out the anastomosis.

The predicted risks of failure for individual patients were calculated from the entire study cohort. Because we compared resident against consultant and OPCAB against ONCAB, it might be argued that we should have modeled predicted risk with, for example, only the consultant's data. However, there was no evidence that the model differed for consultant and residents (or for OPCAB and ONCAB), and the model would then have been based on a relatively small sample and few events. We observed that the model did not predict failure particularly well, which was possibly a consequence of trying to predict a combined end point; different predictors may be prognostic of different specific events. The total number of failures may also have limited the power to detect important risk factors.

The study also gave equal weight to the varied events that separately or in combination defined failure. Ideally, it would be preferable to have a method for attributing more importance to events that culminated in death, permanent disability, or long-term sequelae than to events from which patients recovered completely. However, the control chart methods described here and previously[9] are usually applied to binary outcomes, although the SPRT principle can be applied to counts.[22] The appropriateness of and best methods for combining "near miss" events need to be researched in more detail; Steiner and colleagues[23] have described a method for combining near misses and deaths but not with adjustment for case mix.

A final point relates to the residents' whose data were included. During the study period, nine other visiting residents and research fellows carried out a total of 71 OPCAB operations (only one of which was unsupervised), although not as part of an official training program. The numbers of operations carried out by these visiting residents were too small to allow meaningful analysis with control charts. However, other analyses pooling the experiences of all informal residents have suggested that they may have had worse outcomes.[11] Other intrinsic limitations of control charts, such as interpretation of boundaries and the equal weights given to historic and recent data, have been discussed elsewhere.[9]

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Implications for Training of Residents

Residents in cardiothoracic surgery need to gain experience in OPCAB surgery. Consultants face a dilemma between the duty to deliver the highest possible standard of care to their patients and the responsibility to learn new techniques of coronary surgery themselves and to teach the same techniques to residents. A recent survey from cardiothoracic training centers in the United States[24] showed that only 22% of residents had performed 20 or more OPCAB procedures during their training, and only 12% had performed 20 or more complete OPCAB myocardial revascularizations. Of these, only 4% had performed OPCAB Cx revascularization. The survey clearly demonstrated that most residents had not reached proficiency in OPCAB surgery at the end of the residency.

Our study therefore has important implications for training residents in OPCAB surgery. We have previously demonstrated that OPCAB surgery is associated with less renal dysfunction, a less intense systemic inflammatory reaction, less myocardial reperfusion injury, fewer arrhythmias, and overall better early clinical outcomes than ONCAB surgery.[25] The findings we report here confirm that multivessel OPCAB surgery is a safe and reproducible surgical technique that can be taught successfully to residents.

This study also shows that it is relatively simple to implement control charts for continuous performance monitoring. This is particularly relevant when learning OPCAB surgery, because the technique is perceived to be technically difficult yet surgeons are under pressure to take up the technique because of its widespread popularization as an alternative to conventional ONCAB.[24] Nevertheless, the precise way in which control charts are set up needs to be considered carefully. Risk-adjustment is desirable but requires an accepted method for generating the predicted risk for each patient. VLAD and SPRT control charts, plotting performance against different expectations, are complementary.[9] For cardiac surgery residents, use of alarm or alert lines (and hence interpretation of the significance of crossing of these boundaries) may not be critical, because competition for training places is so acute. Indeed, it is possible that residents may be oversensitive to changes in gradient on VLAD plots and seek explanations for any tendency for performance to drift upward. (This may not be true in less competitive specialties or for established consultant surgeons). Paradoxically, the use of a "reassurance" boundary in a SPRT plot (confirming H_0) may be more useful for residents than alarm or alert boundaries, because confirmation of an acceptable failure rate could be interpreted as an evidence-based criterion of competency. It is a relatively simple matter to manipulate H_0, H_1, α and β to set the average number of operations that a resident would have to perform to attain this criterion, assuming that the resident's performance conforms to H_0.

Conclusion

Our data show that OPCAB surgery can be safely taught to cardiothoracic residents. We believe that a modern surgical program should expose residents to both ONCAB and OPCAB techniques, because the latter has become an integral part of coronary surgery. We also strongly recommend the development of specific OPCAB training programs in those centers with senior surgeons proficient in the technique. This will positively affect the future expectations of many cardiothoracic residents who are likely to practice OPCAB coronary surgery after their training is completed.

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Appendix

Determination of Logistic Regression Model for Assigning a Predicted Risk of Failure

Multivariable logistic regression modeling was applied to the data for the whole study population to investigate predictors of failure. All variables listed in Table 1 were considered as possible predictors of failure, but interactions between these variables were not. Multiple regression models were fitted interactively, first by identifying significant predictors separately, second by including significant predictors in a multivariable model, and finally by removing variables that did not reach statistical significance at $P < .2$.

Increasing age, previous myocardial infarction, and preoperative inotropic support were found to be significant risk factors for failure (P %; .05). Current smoker and operative priority (elective vs urgent) were also included in the final model (Appendix Table 1) because there was a suggestion that they increased the risk of failure ($P < .05$).

Appendix TABLE 1. Logistic regression model used for risk adjustment

Predictor variable	Odds ratio	95% Confidence interval	*P* value
Age group			.02
< 55 y	1.00	—	
≥ 55 and < 65 y	1.04	0.53-2.07	
≥ 65 and < 75 y	1.68	0.87-3.24	
≥ 75 y	2.45	1.15-5.25	
Previous myocardial infarction	1.71	1.15-2.53	.008
Preoperative need for inotropic support	3.04	2.04-4.53	<.0001
Urgent operation (vs elective operation)	1.32	0.87-2.00	.19
Current smoker (vs nonsmoker or past smoker)	1.6	0.91-2.83	.1

All odds ratios are adjusted for all the variables included in the model. Model statistics: area under receiver operating characteristic curve = 0.70; Hosmer-Lemeshow goodness-of-fit test, $\chi^2 = 3.30$ (*df* 3), $P = .35$.

ACD