Impact of Cardiothoracic Resident Turnover on Mortality After Cardiac Surgery: A Dynamic Human Factor

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Background. **The study was designed to determine whether cardiac surgical outcomes are affected during times of major turnover of cardiothoracic resident surgical staff and at the beginning versus the end of their training periods.**

Methods. **This observational cohort study analyzed data from cardiac operations between April 1996 and March 2006 at a single institution. In-hospital mortality and other outcomes were compared between operations done during months of major change in resident staff rotation (July, August, January, February, n = 5,517) and the rest of the year (n = 10,773). We also compared outcomes at the beginning and end of surgical rotation for cardiothoracic residents. Adjustment was made for EuroSCORE (European System for Cardiac Operative Risk Evaluation), year of operation, and surgeon resident status. Analyses were done within surgery procedure subgroups of isolated coronary artery bypass graft surgery (CABG) and complex operations (CABG combined with other procedures).**

Results. **Patient populations in the groups were similar. After risk adjustment, there was a significant increase in hospital mortality for the complex cases during months of resident staff change compared with rest of the year (odds ratio 1.3, 95% confidence interval: 1.3, 1.4; $p = 0.02$). There was, however, no significant difference in mortality for the CABG only cases (odds ratio 1.1, 95% confidence interval: 0.8, 1.4; $p = 0.61$). Risk-adjusted mortality after operations done by residents was the same at the start and finish of their surgical rotation. During the change months, the surgery time was 2.2 minutes longer on average in CABG operations (95% confidence interval: 0.3, 4.0; $p = 0.02$), and no different in combined cases.**

Conclusions. **Periods of major change in resident surgical staff are associated with increased risk-adjusted in-hospital mortality after complex cardiac operations but not after CABG alone.**

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The outcome of a surgical procedure depends on a host of variables related to patient, surgeon and hospital. Each of these entities adopts a structure and process for patient care to achieve assurance of quality care and quality assessment [1, 2]. These entities are both dynamic and evolving [2]. At each operating environment, distinctive forces can influence the context both at professional and administrative level with responsible individuals at the core. By direct and indirect individual interaction, a continuous interplay of variables determine how effectively patient outcome is assessed, audited, and predicted. Risk-adjusted severity scores predict the outcomes of surgical interventions [3, 4] and allow comparison of such outcomes by correcting for case mix. These scores include a limited host of known operative, measured physiological, and disease variables. However, outcomes may also be affected by other important variables such as other patient and surgeon factors and the operating systems in which surgery occurs [5, 6] that are not accounted for by current risk severity scores in heart surgery.

In most teaching institutions in the United Kingdom, January, February, July, and August witness the departure of existing cardiothoracic residents and the arrival of new residents for surgical training. A similar experience occurs during the month of July in the United States as medical students take on the role of junior residents. In surgery, first year general surgery residents have been reportedly associated with worse surgical outcomes in some studies [7, 8] but not all [9, 10]. Furthermore, the beginning and end of a rotation are periods of change as departing resident hand over their experience and patient issues to the incomers. During this period, the continuity of care may be briefly interrupted, patients may be vulnerable, and this may adversely influence surgical outcome. If periods of change of surgical rotation are related to changes in patient care that decrease survival, increased attention to patient care during times of resident turnover would be important. In this study, we examined the influence of cardiothroacic resident

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Table 1. Type and Frequency of Complex Cardiac Operations in Patients Between April 1, 1996, and March 31, 2006

Type of Operation	Frequency (%)
CABG plus aortic surgery	61 (1.0)
CABG plus valve	1,717 (28.5)
CABG plus aortic surgery and valve	62 (1.0)
CABG plus other operation	498 (8.3)
Thoracic aortic surgery	218 (3.6)
Valve	3,040 (50.4)
Aortic and valve	267 (4.4)
Other operation	164 (2.7)
Total	6,027

CABG = coronary artery bypass graft surgery.

turnover and residents starting training on cardiac surgical outcomes for coronary artery bypass graft surgery (CABG) and complex cardiac surgery.

Material and Methods

We analyzed routinely collected hospital episode data on all cardiac surgical patients undergoing their first operation at our center between April 1996 and March 2006. This study was approved by the Research and Development Board at Papworth Hospital NHS Trust. We categorized the group of patients into complex cardiac surgery and noncomplex cardiac surgery for purposes of stratification and research. We defined complex cardiac surgery as any open heart surgery other than coronary revascularization with or without another cardiac surgical procedure (valve, aortic surgery, arrhythmia ablation, other). We considered one procedure type coronary revascularization (CABG) as noncomplex.

All patient data were compiled prospectively as part of a comprehensive, ongoing audit of cardiac procedures. Catheter-based reinterventions and surgical closure of atrial septal defects were excluded. The status of the operating surgeon as resident or attending surgeon (consultant in the United Kingdom) is recorded. A resident case was defined as a case in which the cardiothoracic resident performed the entire surgical procedure with the consultant surgeon assisting. Cardiothoracic residents performed cases that were selected by the consultant surgeon with whom they were working. In the United Kingdom, residents require at least 6 years of training affiliated with a regional deanery governed by its members and the Royal College of Surgeons. This time period may follow prior nonaccredited training in the same institution or elsewhere with time for research or other clinical activities. The cardiothoracic resident (also called registrar in the United Kingdom) usually spends 6 months or multiples thereof on a rotation before changing rotations. The number of those registrars on the training scheme is relatively small All cases were performed by registrars who were either on or not on the training scheme. These surgeons could have been fellows from overseas, locum registrars (training positions that fill the gap in clinical service and on- call rotation), and those on the training scheme approved by the deanery.

Table 2. Characteristics by Cardiothoracic Resident Change and Nonchange Months of Operation in CABG Only Surgical Patients Between April 1, 1996, and March 31, 2006

Characteristic	Change Months n = 3,481	Others n = 6,782	*p* Value
Mean age (SD)	65.7 (9.17)	65.6 (9.38)	0.56
Male (%)	2,808 (80.7)	5,448 (80.3)	0.66
Mean EuroSCORE (SD)	3.7 (2.84)	3.7 (2.82)	0.88
Mean logistic EuroSCORE (SD)	4.3 (6.38)	4.2 (6.22)	0.84
Median days ICU stay (IQR)	0.9 (0.22)	1.0 (0.23)	0.88
Median days ICU stay (IQR) for those alive at discharge from ICU	0.9 (0.22)	0.9 (0.23)	0.65
Median days hospital stay (IQR)	7.3 (3.13)	7.1 (3.12)	0.23
Median days hospital stay (IQR) for those alive on discharge	7.1 (3.10)	7.1 (3.10)	0.17
Unadjusted ICU mortality (%)	24 (0.7)	48 (0.7)	0.90
Unadjusted hospital mortality (%)	86 (2.5)	162 (2.4)	0.82
Mean case duration in minutes (SD)	179.7 (47.49)	177.0 (45.0)	0.007
Comorbidities (%)			
Hypertension	1,985 (57.0)	3,875 (57.1)	0.91
Renal failure	20 (0.6)	53 (0.8)	0.24
Previous myocardial infarction			0.006
6 months or less	525 (15.1)	1,153 (17.0)	
More than 6 months	1,150 (33.0)	2,313 (34.1)	
Chronic pulmonary disease	116 (3.3)	337 (5.0)	< 0.001
Unstable angina	268 (7.7)	409 (6.0)	< 0.001

CABG = coronary artery bypass graft surgery; EuroSCORE = European System for Operative Risk Evaluation; ICU = intensive care unit; IQR = interquartile range.

Table 3. Characteristics by Cardiothoracic Resident and Nonchange Months of Complex Cardiac Operations Between April 1, 1996, and March 31, 2006

Characteristic	Change Months n = 2,036	Others n = 3,991	*p* Value
Mean age (SD)	67.0 (12.20)	66.6 (12.64)	0.23
Male (%)	1,288 (63.3)	2,519 (63.1)	0.92
Mean EuroSCORE (SD)	6.5 (3.24)	6.5 (3.27)	0.87
Mean logistic EuroSCORE (SD)	10.0 (11.57)	10.1 (11.99)	0.65
Median days ICU stay (IQR)	0.9 (0.42)	0.9 (0.38)	0.73
Median days ICU stay (IQR) of those alive at discharge from ICU	0.9 (0.37)	0.9 (0.35)	0.93
Median days hospital stay (IQR)	8.9 (5.98)	9.0 (6.00)	0.46
Median days hospital stay (IQR) in those alive at discharge	8.9 (5.91)	9.0 (5.97)	0.57
Unadjusted ICU mortality (%)	47 (2.3)	60 (1.5)	0.03
Unadjusted hospital mortality (%)	138 (6.8)	217 (5.5)	0.04
Mean minutes, case duration (SD)	200.7 (72.7)	198.6 (69.4)	0.28
Comorbidities (%)			
Hypertension	950 (46.7)	1,765 (44.2)	0.07
Renal failure	22 (1.1)	41 (1.0)	0.85
Previous myocardial infarction			0.91
6 months or less	117 (5.7)	226 (5.7)	
More than 6 months	238 (11.7)	453 (11.4)	
Chronic pulmonary disease	85 (4.2)	269 (6.7)	< 0.001
Unstable angina	80 (3.9)	107 (2.7)	0.008

EuroSCORE = European System for Operative Risk Evaluation; ICU = intensive care unit; IQR = interquartile range.

Nonetheless, all these cases were done in the direct presence of the consultant surgeon (attending surgeon).

The consultant in charge would have adequately assessed the relative difference in experience of resident in training versus fellow for him or her either before allowing the cardiothoracic resident to assist or perform the cardiac case.

Virtually all rotation changes take place at the end of January and July for cardiothoracic trainees and at the end of February and August for junior noncardiothoracic trainees. The junior trainees are not registrars and do not perform cardiothoracic surgery cases. This subset of doctors was not analyzed in our study. They are considered senior house officers in the English system. The role of these noncardiothroacic trainees is one of second assisting in surgery, harvesting vein, and taking care of patients on the ward. The residents are gradually exposed to increasing levels of responsibility commensurate with their experience. In our study, we only reviewed the cardiothoracic trainees (equivalent to thoracic residents in the United States) and excluded the noncardiothoracic trainees. These cardiothoracic trainees either first assist in surgery or directly operate as surgeon under the direct supervision of the consultant. They take on-call duty as well as help take care of intensive care unit patients under the consultant intensivist direction. The intensive care unit is closed unit under the care of the anesthetic department with patient care provided by the attending cardiothoracic anesthetist, cardiothoracic anesthetist resident, as well cardiothoracic surgery resident. Noncardiothroacic trainees do not participate in the intensive care unit.

The primary outcome of interest was risk-adjusted hospital mortality, which was analyzed separately for two groups: CABG only surgery versus complex cardiac surgery (CABG plus another cardiac procedure or valve, aortic, adult congenital, or arrhythmia surgery). Two

Table 4. Multiple Variable Logistic Regression Analysis of Relationship Between Cardiothoracic Resident Change Month Group and Hospital Mortality

Variables	CABG Only Odds Ratio	*p* Value	Complex Surgery Odds Ratio	*p* Value
Change months	1.08 (0.81, 1.42)	0.61	1.34 (1.29, 1.37)	0.02
EuroSCORE	1.38 (1.34, 1.44)	< 0.001	1.33 (1.29, 1.37)	< 0.001
Surgery year	—[a]	< 0.001	—[a]	< 0.001
Resident	0.86 (0.63, 1.17)	0.33	0.59 (0.40, 0.87)	0.007

[a] Odds ratios for each year not shown.

CABG = coronary artery bypass graft surgery; EuroSCORE = European System for Operative Risk Evaluation.

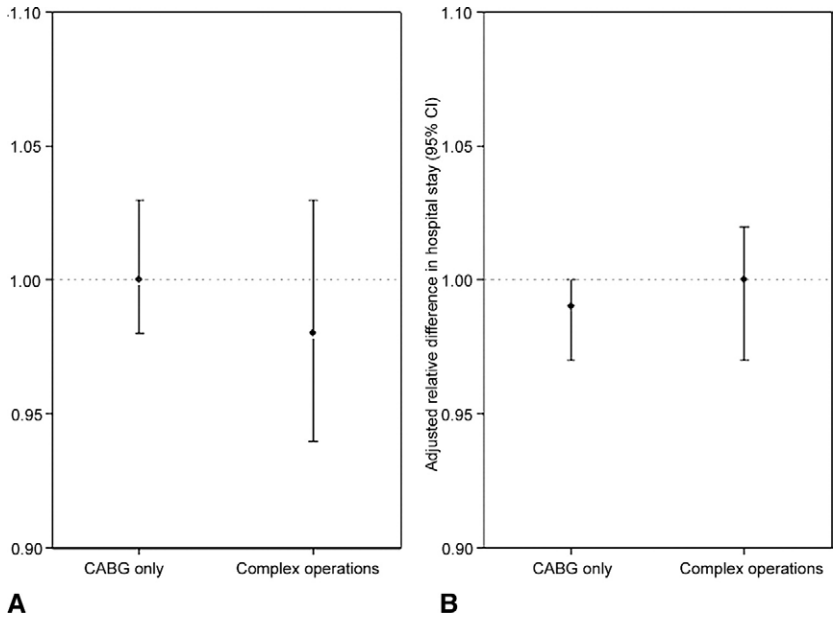

Fig 1. Adjusted relative difference in length of stay in the intensive care unit (ICU) (A) and hospital (B) between doctor change months and nonchange months (adjusted for EuroSCORE, year of surgery, and resident status): ICU stay, CABG, p = 0.90; complex operations, p = 0.51; hospital stay, CABG, p = 0.13; complex operations, p = 0.77. (CABG = coronary artery bypass graft surgery; CI = confidence interval.)

analyses were performed. The first analyzed the effect of the biannual change of doctors by designating operations occurring within months during which cardiothoracic residents were changing (January, February, July and August) into one group and operations occurring in other months as the comparison group. The second analysis was for resident-only cases studied in a similar fashion. Within this subset of operations, months when residents commenced training (July and February) were compared with months when residents completed training (June and January). These periods of change are well defined at our institution. Secondary endpoints of interest were intensive care unit length of stay (ICU-LOS), hospital length of stay (LOS), and time in surgery.

Analysis

Continuous variables were reported as mean and standard deviation or median and interquartile range (IQR),

Table 5. Characteristics by Cardiothoracic Resident Rotation Start and Finish Months of Operation in CABG Only Surgical Patients Between April 1, 1996, and March 31, 2006

Characteristic	Cardiothoracic Resident Rotation Start, n = 586	Cardiothoracic Resident Rotation Finish, n = 591	*p* Value
Mean age (SD)	65.5 (9.33)	65.8 (9.30)	0.56
Male (%)	486 (82.9)	484 (81.9)	0.64
Mean EuroSCORE (SD)	3.4 (2.57)	3.5 (2.59)	0.27
Mean logistic EuroSCORE (SD)	3.7 (5.50)	3.5 (2.59)	0.81
Median days ICU stay (IQR)	0.9 (0.21)	0.9 (0.21)	0.54
Median days ICU stay (IQR) of those alive at discharge from ICU	0.9 (0.21)	0.9 (0.21)	0.51
Median days hospital stay (IQR)	7.1 (2.94)	7.0 (3.11)	0.84
Median days hospital stay (IQR) of those alive at discharge	7.1 (2.92)	7.0 (3.10)	0.99
Unadjusted ICU mortality (%)	4 (0.7)	6 (1.0)	0.75
Unadjusted hospital mortality (%)	11 (1.9)	13 (2.2)	0.70
Mean minutes, case duration (SD)	188.7 (49.9)	184.7 (43.5)	0.15
Comorbidities (%)			
Hypertension	341 (58.2)	350 (59.2)	0.72
Renal failure	2 (0.3)	3 (0.5)	> 0.99
Previous mycardial infarction			0.37
6 months or less	84 (14.3)	91 (15.4)	
More than 6 months	201 (34.3)	180 (30.5)	
Chronic pulmonary disease	22 (3.8)	28 (4.7)	0.40
Unstable angina	25 (4.3)	41 (6.9)	0.05

CABG = coronary artery bypass graft surgery; EuroSCORE = European System for Operative Risk Evaluation; ICU = intensive care unit; IQR = interquartile range.

Table 6. Characteristics by Cardiothoracic Resident Rotation Start and Finish Months of Complex Cardiac Operations Between April 1, 1996, and March 31, 2006

Characteristic	Cardiothoracic Resident Rotation Start, n = 149	Cardiothoracic Resident Rotation Finish, n = 164	*p* Value
Mean age (SD)	67.1 (12.15)	67.7 (10.00)	0.66
Male (%)	98 (65.8)	106 (64.6)	0.91
Mean EuroSCORE (SD)	5.9 (2.88)	6.2 (3.03)	0.37
Mean logistic EuroSCORE (SD)	7.9 (8.2)	9.2 (8.2)	0.25
Median days ICU stay (IQR)	0.9 (0.25)	0.9 (0.30)	0.96
Median days ICU stay (IQR) of those alive at discharge from ICU	0.9 (0.25)	0.9 (0.30)	0.93
Median days hospital stay (IQR)	8.3 (5.07)	8.9 (4.18)	0.45
Median days hospital stay (IQR) of those alive on discharge	8.2 (5.03)	9.0 (4.50)	0.89
Unadjusted ICU mortality (%)	2 (1.3)	3 (1.8)	> 0.99
Unadjusted hospital mortality (%)	7 (4.7)	10 (6.1)	0.59
Mean mins case duration (SD)	193.8 (60.9)	195.8 (56.6)	0.77
Comorbidities (%)			
Hypertension	86 (57.7)	81 (49.4)	0.14
Renal failure	0	3 (1.8)	0.25
Previous myocardial infarction			0.91
6 months or less	5 (3.4)	7 (4.3)	
More than 6 months	18 (12.1)	19 (11.6)	
Chronic pulmonary disease	5 (3.4)	11 (6.7)	0.18
Unstable angina	6 (4.0)	9 (5.5)	0.55

EuroSCORE = European System for Operative Risk Evaluation; ICU = intensive care unit; IQR = interquartile range.

while categorical variables were reported as frequencies and proportions. The relationship between change months and variables of interest was examined in a univariate analysis using Student's *t*, Mann-Whitney *U*, Pearson χ^2 tests, or Fisher's exact tests as appropriate.

The relationship between change months and hospital mortality was studied further using multiple logistic regression models. The EuroSCORE (European System for Cardiac Operative Risk Evaluation), year of surgery, and whether or not the operation was performed by a resident were included in models to adjust for presurgery risk, changes over time, and the difference in type of operations performed by cardiothoracic residents. In the case of resident start and finish months, adjustment was made for EuroSCORE and year of surgery. For this analysis among residents only, there was an insufficient number of events to study the CABG and complex surgery groups separately, so mortality was studied for all operations combined.

Table 7. Multiple Variable Logistic Regression Analysis of Relationship Between Cardiothoracic Resident Rotation Start Versus Finish Months and Hospital Mortality, n = 1,485

Variables in Model	Odds Ratio	*p* Value
Resident start versus finish	0.89 (0.45, 1.78)	0.75
EuroSCORE	1.56 (1.40, 1.74)	< 0.001
Surgery year	—[a]	0.123

[a] Odds ratios for each year not shown.

EuroSCORE = European System for Operative Risk Evaluation.

The relationship between change months and ICU-LOS were examined using general linear models. The natural logarithm of ICU stay and hospital stay in days were used because of the skewed nature of these distributions. Patients who died in ICU were removed from the analysis of ICU-LOS; similarly, patients dying before discharge from hospital were excluded from analysis of LOS. As in the case of hospital mortality, EuroSCORE, year of surgery, and resident status were included in change month models, while EuroSCORE and year of surgery were included in the resident start and finish month models, and separate models were run for the two surgery groups. General linear models with the same adjusting variables were also used to study the relationship between change and training months and surgery time; however, in this case, no transformation was made.

Results

Resident Change Month

There were 16,290 patients who had a first record of cardiac surgery between April 1, 1996, and March 31, 2006, with 10,263 patients having CABG only and 6,027 patients having another procedure instead of or as well as CABG. Other procedures are shown in Table 1. During the months of cardiothoracic resident turnover, all surgeons performed 5,517 operations. Seventy-three resident surgeons performed 4,599 operations over this 10-year period. There were 2,778 operations performed during the resident starting months of February and July and 2,760 during the end of training months, January and

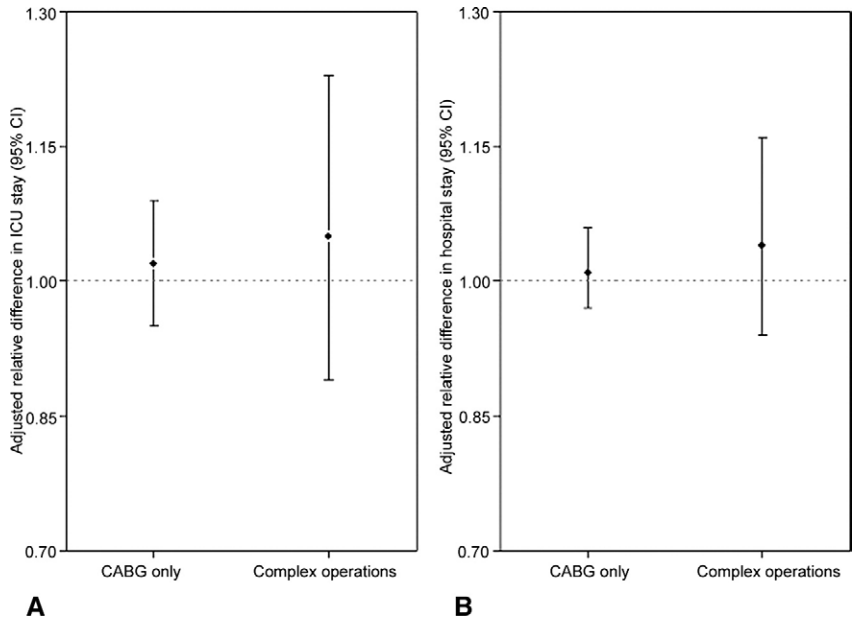

Fig 2. Adjusted relative difference in length of stay in the intensive care unit (ICU) (A) and hospital (B) between training start and finish months in operations done by residents (adjusted for EuroSCORE [European System for Cardiac Operative Risk Evaluation] and year of surgery): ICU stay, CABG, p = 0.54; complex operations, p = 0.57; hospital stay, CABG, p = 0.54; complex operations, p = 0.40. (CABG = coronary artery bypass graft surgery; CI = confidence interval.)

June, 735 and 755 of which, respectively, were performed by residents.

In the CABG only surgery group, there were more operations in nonchange months in patients who had a previous myocardial infarction or chronic pulmonary disease ($p < 0.01$; Table 2). There were more operations in patients with angina during the change months ($p < 0.001$). There was no difference between the change month groups in unadjusted mortality in the ICU, in-hospital mortality, ICU-LOS, or LOS. In the complex surgery group, there were more deaths in ICU and hospital during the change months ($p < 0.05$; Table 3). There were also fewer patients during the change months with chronic pulmonary disease and more with unstable angina ($p < 0.01$). More patients had hypertension in the change months, although this did not reach significance.

The effect on hospital mortality of having an operation during a resident change month is shown in Table 4. There was no effect of resident change month on adjusted hospital mortality in CABG patients, but patients having other types of surgery during change months had 1.3 times the odds of dying in the hospital as compared with patients having operations in nonchange months, when adjusting for EuroSCORE, year of surgery, and whether the operation was done by a resident. When adjusting for the same factors there were no differences in ICU-LOS or LOS (Fig 1, values above 1 indicate longer stay in change months). The CABG performed by resident patients had a 2.2 minutes (95% confidence interval [CI]: 0.3, 4.0; $p = 0.02$) longer surgery time on average during change months than in other months. Patients who had complex operations did not have a difference in surgery time (mean difference 0.9, 95% CI: −2.7, 4.5; $p = 0.63$).

Start and Finish of Cardiothoracic Resident Rotation

More patients having CABG had unstable angina during operations performed by residents in their last month of rotation ($p = 0.05$; Table 5). There were no differences in baseline characteristics in patients having complex operations (Table 6). There were no differences in unadjusted ICU or hospital mortality or ICU-LOS or LOS in either surgery group between resident's rotation start and finish months.

Hospital mortality was not studied separately for CABG only and complex operations because there were an insufficient number of events to do so. In the entire study group, there was no difference in hospital mortality between the beginning and end of resident rotation (Table 7). When adjusting for EuroSCORE and year of surgery, there were no differences in ICU-LOS or LOS in either the CABG only or complex surgery groups (Fig 2, values above 1 indicate longer stay in training start months). Resident operations were 4.6 minutes longer in training start versus finish months, although this was not statistically significant. There were no differences in complex surgery times (mean difference −1.5; 95% CI: −13.9, 10.9; $p = 0.82$) between start and end months of training for cardiothoracic residents.

Comment

Several regulatory bodies, especially in Europe and North America, have taken firm action on the structure and process of cardiac surgery training. As the residents progress through training, they receive direct instruction as well as progressive surgical independence depending on their aptitude, skill and judgement level. Residents need to demonstrate competence in several cardiac procedures over a series of training appointments. The end of a rotation marks an end to an experience with that service and daily operative contact with that particular mentor. Studies have shown that outcomes of a resident performing cardiac surgery are equivalent if not better than their seniors [11,12]. However, these studies did not

adjust for the working pattern of residents on surgical outcomes.

In this study, we found that risk-adjusted outcomes of more complex cardiac surgery (such as valve surgery plus CABG) resulted in a 34% increase in the odds of hospital death during periods of change for surgical residents. This suggests that working patterns of cardiac surgical residents has an influence on the mortality of complex cardiac surgical procedures. When working pattern and periods of change were analyzed for the CABG procedure, the outcomes of surgical procedures during periods of change were as good as any other time periods. One potential explanation is that some patients undergoing more complex procedures have more than one surgical or medical problem requiring careful postoperative follow-up and monitoring. This may not always capture the attention of the caring team. The medical vigilance of incoming residents may be still evolving as they adjust to their new rotation, working environment, patient case mix, and style of their instructor. Flux in nurse staffing and other allied health professionals could contribute to these findings as well, although this was not studied here [13, 14]. Seasonal variation in all-cause mortality has been documented to increase during the cold winter seasons, which in part could explain increased mortality during the change months as these included January and February [15, 16]. Acute coronary syndromes peak during the winter season. This may be related to seasonal variation in blood pressure, lipid levels, and changes in the activity of the coagulation cascade or prevalence of infectious pneumonia [17, 18].

The second major outcome of interest was to determine if risk-adjusted hospital mortality differed at the beginning and end of the academic year for residents. Our denominator encompassed all cardiac procedures that were performed by the resident surgeons. We found no differences in hospital mortality, ICU-LOS, or LOS in either surgery group between resident doctor start and finish months.

Our findings are in agreement with previous studies suggesting that resident experience (beginning versus end of rotation) does not make a significant impact on patient outcomes during critical care and trauma surgery training [10, 19]. However, in a recent observational multi-institutional study from the United States on 20,254 patients by Englesbe and colleagues [7] from the University of Michigan Health System, surgical resident experience was a predictor for mortality. Using the National Surgical Quality Improvement Program (NSQIP)–Patient Safety to compare 30-day mortality rates of surgical patients between two periods of care—early group (July 1 to August 30) and late group (April 15 to June 15)—they witnessed a 41% higher risk for mortality in the early group (odds ratio 1.41, CI: 1.11 to 1.80; $p = 0.005$; c-index 0.938). However, they did not fully control for the urgency of the operation, and the study group encompassed a heterogeneous case mix with all major general surgical as well vascular procedures recruited from 14 academic and 4 community medical centers, which could explain why their results differed from ours.

We further examined the process of individual measures such as surgery time. Time from skin incision to closure of wound was slightly longer in the change months and at the beginning versus the end of training, possibly as a result of relative inexperience or other nonsignificant factors.

This study of more 16,000 patients having cardiac operations at our center, adjusting for the validated EuroSCORE and looking within operation type, revealed no difference in ICU-LOS either during resident period of change nor during start and finish months of the academic year for residents. Our finding was not surprising given that postoperative ICU management is run by fast-track protocols under the direct instruction of the attending intensivist in liaison with attending surgeon. Few prior studies have examined differences in LOS outcomes during different months of the year. In the study by Buchwald and colleagues [20], there was no significant difference in LOS. In contrast, a study by Rich and coworkers [21] showed that LOS decreased as house staff experience increased, and that LOS after surgery actually increased over the academic year. These studies included patients with a number of different diagnoses and factors such as functional status, mental health, social support, and health insurance may have confounded the interpretation of their data with respect to the outcomes observed.

It is possible that the lack of resident experience or optimal instruction could have contributed to our findings, but other system-related processes, attending coverage, nursing staff shifts, as well as team debriefing and in-service introduction need to be examined. The current study does not take into the consideration other measurable or immeasurable factors [22–24] because such variables are not collected prospectively and recorded in our hospital registry. We did not adjust for the number of years in training, as this variable was not readily available. It is possible that some residents had more years than their peers who performed the same risk-adjusted procedure. This may be more important for complex cases as opposed to the CABG.

In recent years, there has been increasing interest in recruiting nonmedically qualified practitioners in surgical care, partly to ensure year-round consistency in knowledge and care [25, 26]. Such staff may help maintain similar process by improving consistency of care during periods of change of residents, in the context of a busy rotation. The role of such surgical assistants at our center is being extended to involve direct patient contact and service with feedback to consultants as well as advice and feedback to junior doctors. Further study will be needed to understand the impact of adding this new group of allied health professionals on surgical outcomes.

Despite our significant findings, our study has limitations. Although the database is comprehensive and data are entered and maintained prospectively, these are not data specifically collected for research and may therefore be subject to entry errors. We do not collect data on variables such as the number of postgraduate years of

training for each cardiothoracic residents. However, these residents would have been already assessed by the attending in charge to agree who is able and who is not able to carry out the procedure. It is possible that in relative terms some consultants are willing to teach and train more than others. This means that there may be residual confounding of among the consultants themselves. Furthermore, other potential bias could be incorporated by the differential care of nurse–patient ratios as well as the influence of noncardiothoracic junior trainees. Their impact of the latter group in terms postoperative care on the ward could have an influence bearing a potential confounding risk factor for the final outcome. Other factors such as seasonal variation of staffing protocols, nonmedical allied health care individuals, and level of supervision are also potential confounders.

In conclusion, periods of major change in resident surgical staff are associated with increased risk-adjusted in-hospital mortality after complex cardiac operations but not after CABG alone. This emphasizes the importance of careful patient handover and meticulous monitoring of patients during these periods.

Further research should be conducted in other surgical specialties such as pediatric cardiac surgery and thoracic surgery. This is greatly needed especially as we try to meet the demand of improving surgical outcomes in a challenging educational environment for our future surgeons with reduced working hours and variable apprenticeship.

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DISCUSSION

DR THORALF M. SUNDT (Rochester, MN): That was a fascinating study, and I really liked the way that you risk-adjusted for the outcomes. But I am concerned about the notion that the problem is the handover. How do you know that that's the problem? You don't really have the causes of mortality. In other words, you don't know whether these were technical failures or judgment failures or errors due to information lost in a handoff and so forth. Do you? Can you really

say that trouble with the handoff is the phenomenon that you're really studying here?

DR SHUHAIBER: I agree with you. I think the period of handover is not the main culprit for this. But it is a culprit. And the reason we say that, first of all, we adjusted for all the EuroSCORE variables. And not only that, we also adjusted for the person who is doing the case. We also adjusted for the year of surgery. But other things, for example, like nursing staff patient ratio, working pattern, protocols specific to a particular ICU, could also influence the final outcome. All the patients went to an ICU that was fast-tracked by an intensivist. So we can say that there are quite a few factors that are quite stable at this stage. And when we risk adjust them, even then we found that during the periods of change, residents coming and going, there was a statistically and clinically significant increase in hospital death.

And I can't say that handover is the only mechanism, but it is one that has to come in mind given that we, as surgeons, are always careful and apprehensive when we have new residents coming onto our services. And that's something more like bringing up to the level of awareness and exploration of thought rather than saying, well, this is the only mechanism, at this stage. By such studies we can understand why other non-EuroSCORE or STS-like variable predictors have an external impact even though we cannot measure them precisely at this stage. The area of human factors is difficult to understand but one that we should be aware of constantly. I hope I answered your question.

DR SUNDT: It's certainly important, but I'm still concerned that there may be other kinds of errors. Error is very complex. There may be knowledge-based errors or skill-based errors by the individual that actually have nothing to do with the information transfer. But it's a valid point. Information transfer is a critical element.

DR SHUHAIBER: I agree with you entirely.

DR DARRYL M. HOFFMAN (New York, NY): You could conclude that your study has shown that a well-supervised registrar or resident is an effective effector arm of the consultant supervising him. And I think that's an important point. It perhaps also suggests that you're looking at the wrong metric. Should we be looking at the near misses, which is a lesson we learned from the aviation industry and from other commercial activities, and retrospectively, it's almost impossible to determine those. And perhaps the division of the internal mammary artery by registrar was saved by timely intervention from his consultant.

DR SHUHAIBER: Thank you for your question. I can't really say a lot about near misses. I mean, our endpoints were very defined and discrete. We looked at hospital mortality. I think, to dwell on an area at the beginning, one would like to find out what you're treading onto. And so by finding the statistics and observation that were consistent over a period of 10 years, it was dumbfounding to us and we were very surprised. I think the next step, yes, we would like to look into that. I think one area that Dr Sundt mentioned was very valuable. We could look at cause of death in future research.