Papers

Improving mortality of coronary surgery over first four years of independent practice: retrospective examination of prospectively collected data from 15 surgeons

Ben Bridgewater, Antony D Grayson, John Au, Ragheb Hasan, Walid C Dihmis, Chris Munsch and Paul Waterworth on behalf of the North West Quality Improvement Programme in Cardiac Interventions

Abstract

Objective To study the "learning curve" associated with independent practice in coronary artery surgery.
Design Retrospective analysis of prospectively collected data.
Setting All NHS centres in north west England that carry out cardiac surgery in adults.
Participants 18 913 patients undergoing coronary artery surgery for the first time between April 1997 and March 2003, 5678 of whom were operated on by 15 surgeons in the first four years after their consultant appointment.
Main outcome measures Observed and predicted mortality (EuroSCORE) for surgeons in their first, second, third, and fourth years after appointment as a consultant compared with figures for established surgeons.
Results Overall mortality decreased over the six years of study (P = 0.01). Of the patients operated on by established surgeons or newly appointed consultants, 265/13 235 (2.0%) and 109/5678 (1.9%), respectively, died (P = 0.71). There was a progressive decrease in observed mortality with time after appointment as a consultant from 2.2% in the first year to 1.2% in the fourth year (P = 0.049). This result remained significant after adjustment for time and case mix (P = 0.019).
Conclusions Mortality in patients operated on by newly appointed consultant surgeons is similar to mortality in patients operated on by established surgeons. There are significant decreases in crude and risk adjusted mortality in the four years after appointment. These findings should influence the nature of practice in newly appointed surgeons.

Introduction

In British medicine consultants are appointed to hospitals after a defined period of training, once they have satisfied national training bodies and been successful in open competition for an advertised post. NHS consultants are independent practitioners who function under clinical governance systems in the institutions in which they are employed. Increasingly, they are also regulated by national initiatives, such as the planned publication of surgeon specific mortality data for coronary artery surgery.[1]

In a recent study of outcomes of coronary artery surgery for individual surgeons in north west England,[2] an incidental finding was a strong association between the volume of operations each surgeon had performed and mortality. This may be due to a "learning curve" effect, with higher mortality in patients operated on by newly appointed surgeons. We studied this in more detail by looking at changes in case mix and mortality after new consultant appointments in cardiac surgery.

Methods

The north west quality improvement programme in cardiac interventions is a regional consortium involving all four NHS centres (Blackpool Victoria Hospital; Cardiothoracic Centre, Liverpool; Manchester Royal Infirmary; and South Manchester University Hospital) in north west England.

We prospectively collected data on 18 913 consecutive adult patients undergoing cardiac surgery between 1 April 1997 and 31 March 2003. We included only those patients undergoing isolated coronary artery surgery (excluding repeat surgery). For each patient we collected data on preoperative and operative variables to calculate predicted mortality. Mortality was defined as any death in hospital. Every patient record contained an identifier for each consultant surgeon.

Design of the project

We addressed four specific questions:

- Are there differences in observed and predicted mortality between patients operated on by newly appointed surgeons and their more experienced colleagues?
- Are there changes in observed and predicted mortality in patients operated on by newly appointed surgeons over the first four years of appointment?
- If there are improvements in risk adjusted mortality over the first few years of appointment, what is the time course of those changes?
- If there are decreases in mortality are they seen in low or high risk patients?

This is the abridged version of an article that was posted on bmj.com on 6 August 2004: http://bmj.com/cgi/doi/10.1136/bmj.38173.577697.55

Editorial by Zamvar

South Manchester University Hospital, Manchester M23 9LT
Ben Bridgewater *consultant cardiac surgeon*
Paul Waterworth *consultant cardiac surgeon*

Cardiothoracic Centre, Liverpool L14 3PE
Antony D Grayson *regional clinical information analyst*
Walid C Dihmis *consultant cardiac surgeon*

Manchester Royal Infirmary, Manchester M13 9WL
Ragheb Hassan *consultant cardiac surgeon*

Blackpool Victoria Hospital, Blackpool FY3 8NR
John Au *consultant cardiothoracic surgeon*

Leeds General Infirmary, Leeds LS1 3EX
Chris Munsch *consultant cardiac surgeon*

Correspondence to: B Bridgewater ben.bridgewater@smuht.nwest.nhs.uk

BMJ 2004;329:421–4

Table 1 Observed mortality, predicted mortality, observed to expected mortality ratios, and adjusted mortality in patients operated on by newly appointed surgeons according to year after appointment

Year	Observed mortality (%) (95% CI)	Mean EuroSCORE (median; 25th, 75th centiles)	O:E ratio*	Adjusted mortality (%)†
1	2.2 (1.6 to 3.0)	3 (3; 1, 4)	0.73	2.3
2	2.1 (1.5 to 3.0)	3.1 (3; 1, 4)	0.68	2.2
3	1.6 (0.9 to 2.3)	3.1 (3; 1, 5)	0.52	1.7
4	1.2 (0.5 to 2.1)	3.3 (3; 1, 5)	0.36	1.0
P value‡	0.049	0.03	<0.001	0.019

*Ratio between observed and expected (predicted) mortality is indicator of overall quality of care adjusted for risk.
†Adusted for time and case mix.
‡Significance for trend over time.

Since 1997 there have been 13 new appointments, and two surgeons practising in 1997 were in the first four years of their consultant appointment. For the analysis we pooled these 15 surgeons into four groups according to year of independent practice (first, second, third, and fourth years).

Statistical analysis

Crude mortality was determined for each patient and a predicted mortality calculated by using additive EuroSCORE.[3] The mean EuroSCORE is often given as an indication of operative risk of a group. The score is not normally distributed, so we have given results as means and medians with 25th and 75th centiles. We constructed a logistic regression model and calculated risk adjusted mortality percentages for the first four years of independent practice, in line with the system developed in the state of New York.[4] The results reflect performance adjusted for time and case mix (see bmj.com for full details).

Results

A total of 18 913 patients underwent surgery in the region during the study period, 5678 of whom were included in the learning curve analysis. See bmj.com for details of the consultant appointments and number of patients operated on. The average number of patients per surgeon was 379. The learning curve dataset included 30% of the total number of patients undergoing surgery.

Overall, 374 patients (2.0%) undergoing isolated coronary artery surgery died. Mortality in patients operated on by surgeons in their first four years after appointment and that of established consultants was similar (109/5678 (1.9%, 95% confidence interval 1.6% to 2.3%) and 265/13 235 (2.0%, 1.8% to 2.2%), respectively, P = 0.71). The mean predicted mortality for patients operated on by consultants in the first four years after appointment (EuroSCORE mean 3.1, median 3, 25th and 75th centiles 1 and 4) was similar to that of those operated on by more established surgeons (mean 3, median 3, 25th and 75th centiles 1 and 4) (P = 0.79).

Table 2 Changes in observed mortality in low and high risk patients for newly appointed surgeons by year after appointment. Figures are percentage mortality

	Low risk group (deaths/patients)	High risk group (deaths/patients)
Year 1	1.7 (29/1700)	5.6 (15/267)
Year 2	1.6 (20/1280)	5.1 (13/254)
Year 3	0.8 (9/1099)	6.5 (12/184)
Year 4	0.3 (2/722)	5.2 (9/172)
P value*	0.011	0.93

*Significance for trend over time.

The ratio of observed to expected mortality is the best risk adjusted summary of performance. The ratios for the patients operated on by surgeons in the first four years of practice and more established surgeons were 0.61 and 0.66, respectively.

There was a progressive decrease in observed mortality during the first four years after appointment, the predicted mortality progressively increased over the four years, the ratio reduced by a factor of 50% and the adjusted mortality decreased (table 1).

There was a significant reduction in mortality in the low risk group with increasing length of time since appointment that was not seen in high risk patients (table 2). For established consultants there was a significant reduction in mortality over the time of the study from 2.3% in 1997-8 to 1.5% in 2002-3 (P = 0.01).

Discussion

Principal findings

Significant improvements in crude and risk adjusted mortality are associated with coronary artery surgery over the four years after surgeons are appointed to independent practice. The observed mortality for surgeons in their first and second years after appointment was slightly higher than for established consultants, but lower in the third and fourth years. These improvements were due to better outcomes in patients undergoing low risk surgery.

Strengths and weaknesses of the study

The data have been subjected to local validation, but have not been subjected to external validation. The number of surgeons, the large population of patients, and the fact that these appointments were across four different hospitals add strength to our study. We were concerned that some of the learning curve effect detected may have been due to overall changes in mortality because of progressive improvements in outcome with time, an effect that has been seen in previous work.[5] We looked only at mortality; morbidity may be a more sensitive indicator of subtle improvements in the quality of care.

We observed a significant decrease in crude mortality as surgeons became more experienced. Predicted mortality increased in the four years after appointment, suggesting that surgeons are operating on patients with increasing comorbidity, which confirms local clinical perceptions. Use of the ratio of observed to expected mortality highlights this effect of decreasing mortality despite increasing complexity of case mix. It is conceivable that more experienced surgeons may become "smarter" at exploiting limitations within the risk prediction model, which would not affect our observations on crude mortality but may potentially confound the risk adjusted analysis.

The observation that mortality in patients of surgeons in their third and fourth years of appointment is below that seen in patients of more established surgeons, suggests that either the performance of these consultants is better than their peers, or that there are complex issues associated with case mix and higher risk surgery that were not detected with our methods.

Comparison with other studies

There have been few reports of learning curve effects in cardiac[6 7] and non-cardiac surgery.[8–13] There are thought to be three separate components to the learning curve for new procedures: the specialist community, the institution, and the individual surgeon.[7] We observed an "individual surgeon" effect.

A recent study on learning curve effects in complex laparoscopic colorectal surgery[10] suggests a steady state of technical competence is achieved after 70-80 procedures. If we use this model, since all new appointees would have performed well over 100 operations, improvements are probably related to issues other than technical ability.

Implications

The implications are that surgeons improved non-technical aspects of surgery, including decisions on case selection and aspects of preoperative, intraoperative, and postoperative care and decision making.

It has been suggested that learning curve effects in medicine are similar to those in manufacturing. Theories accepted in manufacturing are that outcomes improve with higher volume, improvement increases in decreasing units with progressive experience, and increases in improvement follow a predictable pattern. Previous studies of learning curves in cardiac and non-cardiac surgery have all been detected on a relatively small number of cases. We have observed a learning curve effect in surgeons who are performing high volumes of surgery. While we saw continuous improvements in each of the first four years of appointment, the most marked improvements were between the third and fourth years, which is at odds with data from manufacturing.

Volume of experience, incentives, and managerial factors are potential modifying influences on the learning curve.[14] It seems inappropriate to increase the volume of surgery to higher than current levels. Incentives include planned publication of surgeon specific mortality and use of performance data in clinical excellence awards (but these may also encourage newly appointed surgeons to turn down higher risk cases, unless risk adjusted measures are used for performance management). Managerial input—including the use of clinical pathways, robust clinical risk management strategies, supervision, and targeted continuing professional development—seem to be the most effective way to accelerate learning curve effects.

Unanswered questions and future research

We do not know whether causes of death change as surgeons become more experienced. While the learning curve for cardiac surgery seems to be marked, we do not know whether it is seen in other surgical specialties or is widespread throughout medicine. There are several initiatives that are leading to a reduction in hours during the working week and limiting the number of years of training for surgeons, and we do not know if this will make the effects we have seen more marked. Finally, we do not know whether initiatives such as a structured supervision and targeted continuous professional development would accelerate the learning curve effect.

This study has been conducted on behalf of the north west quality improvement programme in cardiac interventions, and the consultant surgeons involved were John Au, Ben Bridgewater, Colin Campbell, John Carey, John Chalmers, Walid Dhimis, Abdul Deiraniya, Andrew Duncan, Brian Fabri, Elaine Griffiths, Geir Grotte, Ragheb Hasan, Tim Hooper, Mark Jones, Daniel Keenan, Neeraj Mediratta, Russell Millner, Nick Odom, Brian Prendergast, Mark Pullan, Abbas Rashid, Franco Sogliani, Paul Waterworth, and Nizar Yonan. Narinda Bhatnagar, Albert Fagan, Bob Lawson, and Udin Nkere. Peter O'Keefe, Richard Page, Ian Weir, and David Sharpe left the collaboration during the study period. We thank the audit officers working in each centre for their hard work in collecting and validating the data and Mark Jackson for his analytical advice.

Contributors: See bmj.com

Funding: Funding for the programme was received from all primary care trusts in north west England. All authors were independent of the funding.

Competing interests: None declared.

Ethical approval: Ethical approval for the north west quality improvement programme was obtained from the regional ethical committee.

What is already known on this topic

Learning curves are associated with the introduction of new procedures in medicine

Although mortality for coronary artery surgery has decreased over time, it is not known whether mortality among patients of new consultants changes as the doctors become more experienced and whether such changes are independent of overall improvements of their peers

What this study adds

In the first four years after the appointment of UK consultant surgeons to independent practitioner status outcomes significantly improve

While initial mortality associated with newly appointed consultant surgeons is not significantly higher than that for more established consultants, there is a 50% reduction in risk adjusted mortality over the subsequent four years

1 Dyer O. Heart surgeons are to be rated according to bypass surgery success. *BMJ* 2003;326:1053.
2 Bridgewater B, Grayson AD, Jackson M, Brooks N, Grotte GJ, Keenan DJ, et al. Surgeon specific mortality in adult cardiac surgery: comparison between crude and risk stratified data. *BMJ* 2003;327:13-7.
3 Roques F, Nashef SA, Michel P, Guaducheau E, de Vincentiis C, Baudet E, et al. Risk factors and outcome in European cardiac surgery; analysis of the EuroSCORE multinational database of 19 030 patients. *Eur J Cardiothorac Surg* 1999;15:816-23.
4 Hannan EL, O'Donnell JF, Kilburn H Jr, Bernard HR, Yazici A. Investigation of the relationship between volume and mortality for surgical procedures performed in New York state hospitals. *JAMA* 1989;262:503-10.
5 Keogh B, Kinsman R. *National adult cardiac surgical database report 2000-2001*. London: Society of Cardiothoracic Surgeons of Great Britain and Ireland, 2002.
6 Hassan A, Pozzi M, Hamilton L. New surgical procedures: can we minimise the learning curve? *BMJ* 2000;320:171-3.
7 Bull C, Yates R, Sarkar D, Deanfield J, de Leval M. Scientific, ethical, and logistical considerations in introducing a new operation: a retrospective cohort study from paediatric cardiac surgery. *BMJ* 2000;320:1168-73.
8 Orr RK, Hoehn JL, Col NF. The learning curve for sentinel node biopsy in breast cancer: practical considerations. *Arch Surg* 1999;134:764-9.
9 Gates EA. New surgical procedures: can our patients benefit while we learn? *Am J Obstet Gynecol* 1997;176:1293-9.
10 Dincler S, Koller MT, Steurer J, Bachmann LM, Christen D, Buchmann P. Multidimensional analysis of learning curves in laparoscopic sigmoid resection: eight-year results. *Dis Colon Rectum* 2003;46:1371.
11 Soot SJ, Eshraghi N, Farahmand M, Sheppard BC, Deveney CW. Transition from open to laparoscopic fundoplication: the learning curve. *Arch Surg* 1999;134:278-81.
12 Ford WD, Crameri JA, Holland AJ. The learning curve for laparoscopic pyloromyotomy. *J Paediatr Surg* 1997;32:552-4.
13 Ikhena SE, Oni M, Naftalin NJ, Konje JC. The effect of the learning curve on the duration and peri-operative complications of laparoscopically assisted vaginal hysterectomy. *Acta Obstet Gynecol Scand* 1999;78:632-5.
14 Waldman DJ, Steven A, Ypurstine SA, Smith HL. Learning curves in health care. *Health Care Manage Rev* 2003;28:41-54.

(Accepted 14 June 2004)

doi 10.1136/bmj.38173.577697.55