Heart, Lung and Circulation (2015) **24**, 583–589
1443-9506/04/$36.00
http://dx.doi.org/10.1016/j.hlc.2014.11.014

ORIGINAL ARTICLE

Procedure-specific Cardiac Surgeon Volume associated with Patient outcome following Valve Surgery, but not Isolated CABG Surgery

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Received 23 September 2014; accepted 5 November 2014; online published-ahead-of-print 5 December 2014

Purpose Trends towards surgical sub-specialisation to improve patient-outcomes are well-documented and largely supported by evidence. However few studies have examined whether this benefit exists within adult-cardiac surgery. To answer whether sub-specialisation within adult-cardiac surgery improves patient-outcomes, this study assessed the relationship between procedure-specific and total-cardiac surgeon-volume and mortality and morbidity in cardiac-valve and coronary artery bypass grafting (CABG) surgery.

Methods Data came from the Australian and New Zealand Society of Cardiac and Thoracic Surgeons (ANZSCTS) registry from 2001 to 2010 and included 23 hospitals, 109 surgeons, 20,619 patients with isolated-CABG-surgery and 11,536 patients with a valve-procedure. Hierarchical logistic regression using generalised estimating equations was used to analyse outcomes. Measures included operative-mortality and occurrence of a complication (deep sternal wound infection, new stroke, acute kidney injury).

Results Crude operative mortality (and complication rates) were 1.7% (4.9%) and 4% (11%) in the isolated-CABG and valve-surgical populations respectively. A greater procedure-specific surgeon volume was associated with reduced mortality and complication rates in valve-surgery but not isolated-CABG. There was a 33% decrease in odds of dying for every additional 50 valve procedures performed [OR 0.67, p=0.003]. Conversely, greater total-cardiac surgical volume for individual surgeons did not result in improved outcomes, for both isolated-CABG and valve populations.

Conclusions Our finding of an association between increased valve-specific surgeon volumes with improved valve-surgery outcomes, and absence of an association between these outcomes and annual total-cardiac surgical experience supports the case for sub-specialisation specifically within the field of valve surgery.

Keywords Adult cardiac surgery • Valve surgery • Coronary artery bypass • Specialization • Hospital • High-volume

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Introduction

As the depth of knowledge in complex medical fields increases, there is a corresponding increase in the number of recognised specialties and sub-specialties with over 80 specialties currently recognised by the Australian government. It is widely accepted that specialisation and sub-specialisation significantly enhance the quality of healthcare outcomes by allowing surgeons to develop and maintain expertise and competence within highly sophisticated fields.

Cardiac surgery has been divided into paediatric and adult cardiac surgery. In the field of paediatric cardiac surgery, there are consistent findings of lower mortality rates in patients operated on by surgeons with higher annual paediatric cardiac surgical volumes [1–3]. Cardiac surgeons sub-specialising in paediatric surgery outperformed general cardiac surgeons for both low complexity and high complexity cases. Within adult cardiac surgery however, the evidence is more uncertain and the impact of sub-specialisation in cardiac surgery has yet to be explored in detail. Girotra demonstrated that there is a mortality benefit in patients undergoing surgery in a hospital specialising in coronary artery bypass graft (CABG) surgery, independent of CABG volume and patient characteristics [4].

Procedural volume has been reported to have an increasingly strong association with outcome in procedures of increasing complexity and risk [5]. Valve surgery can be perceived as a more complex and high-risk procedure than CABG surgery, given its higher documented mortality risk for the patient. For example, predicted mortality using the EURO score for a 70 year-old female with no previous cardiac procedures and no significant risk factors undergoing isolated CABG surgery is 2.5%, whilst the same patient undergoing mitral valve surgery would have a predicted mortality of 4.2%.

The nature of both valve surgery and CABG surgery has changed over time, with an increased complexity in both the valve surgery (aortic valve/mitral valve/tricuspid valve) and coronary artery bypass graft (CABG) surgery operations being performed [5–8].

Are the skills and decision-making processes sufficiently similar that a surgeon whose practice consists of equal volumes of isolated CABG surgery and valvular operations would have similar valve surgical results as a surgeon sub-specialising in valve surgery?

The aim of this retrospective study was to examine the impact of total cardiac surgeon-volume compared with procedure-specific surgeon-volume on operative morbidity and mortality within a particular hospital, for isolated CABG or valve (+/- CABG) surgery.

Patients & Methods

Data from the Australian and New Zealand Society of Cardiac and Thoracic Surgeons (ANZSCTS) registry including 43,000 patients from 23 hospitals, 109 surgeons, 145 surgeon-hospital combinations for isolated CABG operations and 122 surgeon-hospital combinations for valve surgery from 2001 to 2010 were reviewed. The registry also includes patient demographics, risk factors, physiological parameters, and intra- and post-operative outcomes. All the patient and surgeon data provided for the project was de-identified but individual surgeons did have unique identifiers enabling their surgical history across the different hospitals to be quantified. The study was approved by the ANZSCTS Steering Committee. Ethical approval for the use of de-identified registry data for secondary research purposes such as this project had previously been provided by each participating institution's ethics review committee.

Inclusion criteria were adult patients (>/=18 y.), undergoing isolated CABG, isolated or multiple valve, or valve and CABG.

The registry does not have complete coverage of all hospitals (both public and private) operating throughout Australia, so we were unable to measure total cardiac surgeon volume across all hospitals. Instead, an evaluation of the hospital-specific surgeon volume (both total cardiac and procedure-specific) was performed and, for patients undergoing isolated CABG operations, use of the left internal thoracic artery was also adjusted for in-statistical analyses, being a surgeon-level factor consistently associated with improved short-term and long-term outcomes [9].

Outcomes

Two primary outcome variables were evaluated separately for this study: 30-day operative mortality and major peri-operative complications. To measure complications, three clinical endpoints were identified (new stroke, acute kidney injury, deep sternal wound infection) and a patient with one or more of these events was defined as have a complication.

Statistical analysis

Data analysis was performed using Stata 12.0. Logistic regression analysis (with odds ratios estimated using generalised estimating equations incorporating clustering of patient surgeries by hospital) was used to analyse the effect of both procedure-specific and total cardiac surgical surgeon volumes on operative mortality and complication rates. Missing values were managed by performing the primary analysis using complete case analysis (listwise deletion) assuming data were missing at random. And sensitivity analysis was undertaken to assess for possible bias.

The following variables were adjusted for by inclusion in the regression model's linear predictor: patient demographics (age, gender), comorbid state (BMI, chronic lung disease, pre-operative renal impairment, peripheral vascular disease, diabetes mellitus, hypertension, hypercholesterolaemia, left main coronary artery disease, previous cardiac surgery) and patho-physiological factors (congestive cardiac failure, ejection fraction, pre-operative myocardial infarction within six hours of operation, use of inotropic medication just prior to surgery, emergency/salvage procedure).

Results were deemed significant only if $p<0.01$, because of the important practical and policy implications which may result from significant findings.

Results

Most cardiac surgical patients were between the ages of 60 and 80 years, with the mean age of patients undergoing surgery remaining fairly constant over the past 10 years in the range 65-66 years. 72.2% of patients were classified as overweight, with a BMI >25kg/m^2, this is higher than the reported 67.4% of overweight adults in the general population, as reported in 2007 by the World Health Organization (WHO) [10]

Although 26,652 patients in the ANZSCTS registry underwent an isolated CABG procedure between the years 2001-2010, 6,033 (22%) patients were excluded from the analysis due to incomplete data. This included exclusion of patients from two hospitals, one of which provided no left ventricular Ejection Fraction (EF) or New York Heart Association classification of heart failure symptoms (NYHA) data, which were also the variables with the most amount of missing data, and the other which contributed to the registry for less than a complete calendar year.

A total of 14,201 patients underwent a valve procedure, however due to missing data, 2,665 (19%) patients were excluded from the analysis. As with the missing data in the CABG surgical population, EF and NYHA numbers were the main culprits.

Isolated CABG operations accounted for nearly three-quarters of all operations performed. Over the years however, the registry had an increasing proportion of valve operations – from 25% of cardiac surgeries in 2001 to 36% in 2010.

Across the spectrum of surgeon-specific procedure-specific volumes, there were surgeons who performed isolated CABG operations almost exclusively, and some surgeons whose practice was highly focussed on valvular operations.

Table 1 **Pre-operative risk according to CABG specific surgeon volume.**

Patient Variables	Low Volume[a]	High Volume[b]
Age (mean)	66.7	68.0
Male Gender (%)	76.4	75.2
Body mass index (kg/m^2)		
>30	32.4	32.7
Chronic lung disease	11.8	17.0
Pre-operative renal failure/ impairment	3.1	2.7
Diabetes Mellitus	33.5	29.0
Peripheral Vascular Disease	21.4	25.0
Previous cardiac surgery	4.7	7.8
The New York Heart Association Class		
I & II	72.6	64.5
III	22.7	27.5
IV	4.7	8.0
Ejection fraction estimate		
Normal/Mild (>46)	78.1	73.9
Moderate impairment (30-45)	17.7	18.1
Severe impairment (<30)	4.2	8.0
Urgency of procedure		
Emergency/salvage	4.9	7.1
Inotropic medication (pre-operatively)	1.9	2.7

a: LV Low volume surgeons (within the lowest quartile); b. HV high volume surgeons (within the highest quartile).

Isolated CABG

From within the 23 hospitals and 109 surgeons, 79 surgeons were linked to only one hospital, 24 surgeons operated at two hospitals and a further six surgeons operated at three hospitals. There were consequently a total of 145 surgeon-hospital combinations included in the analysis. The mean number of annual hospital-specific isolated-CABG operations performed by a surgeon was 52, with the majority of surgeons performing between 21 and 100 isolated CABG operations at a single institution in a year, with a small proportion of high volume surgeons performing over 120 operations.

In assessing the population of patients undergoing isolated CABG, surgeons with higher hospital-specific volumes, i.e. with volumes in the highest quartile, tended to operate on patients with more comorbid disease, in poorer physiological condition and in more emergent circumstances, as compared with surgeons within the lowest quartile of hospital-specific volumes [Table 1].

Valve Operations

With regards to hospital-specific surgeon volumes in valve surgery, a total of 90 surgeons were included in the analysis, 23 of whom operated over two hospitals and five who operated over three hospitals. The mean number of valve operations performed annually at a single institution by a cardiac surgeon was 29, with most surgeons performing between 11 and 40 valve operations per year at any one institution.

The patients undergoing valve surgery were older and more likely to be female as compared with the isolated CABG population and although there was a decreased incidence of cardiovascular risk factors such as diabetes, hypercholesterolaemia, hypertension and peripheral vascular disease, there was a higher proportion of redo-sternotomy [14.2% v. 6.5%].

Functionally, valve surgical patients tended to be worse with 44.8% of patients having NYHA class III/IV symptoms compared with only 26.6% of the isolated CABG population. However physiologically, using left ventricular ejection fraction as a guide to quantify heart failure, the two groups are fairly similar, with 17.9% of isolated CABG patients having moderate to severe impairment compared with 16.7% in valve surgery cases.

Patient characteristics for the surgeons in the lowest and highest volume quartiles for valve surgery were more similar than those for isolated CABG operations. Lower volume surgeons were slightly more likely to perform emergency operations in patients with a marginally worse physiological state [Table 2].

Table 2 Pre-operative risk according to valve-specific surgeon volume.

Patient Variables	Low Volume[a]	High Volume[b]
Age, years (mean)	67.3	67.8
Male Gender (%)	63.0	62.5
Body mass index (% > 30 kg/m^2)	29.4	29.0
Chronic lung disease	15.9	17.3
Pre-operative renal failure/ impairment	4.6	3.1
Diabetes Mellitus	23.8	20.7
Peripheral Vascular Disease	18.6	20.8
Previous cardiac surgery	13.6	13.8
New York Heart Association Class		
I & II	52.9	53.2
III	35.3	37.3
IV	11.8	9.5
Ejection fraction estimate		
Normal/Mild (>46)	83.1	82.6
Moderate impairment (30-45)	12.7	12.5
Severe impairment (<30)	4.2	4.9
Urgency of procedure		
Emergency/salvage	6.6	4.2
Inotropic medication (pre-operatively)	3.4	2.5

a. LV Low volume surgeons (within the lowest quartile); b. HV High volume surgeons (within the highest quartile).

Patients excluded from analyses due to missing data were found to be similar to those included [Table 3]. Hierarchical logistic regression whilst omitting EF and NYHA variables, but including the patients with missing EF and NYHA values was performed. The results were unchanged from that of the primary analysis [Table 4].

Table 3 Comparison of observed information for exclude and included populations.

Patient Variables	Included	Excluded
Age, years (mean)	65.9	65
Male Gender (%)	72.2	73.6
Chronic lung disease	13.5	14.4
Pre-operative renal failure/ impairment	3.6	3.4
Peripheral Vascular Disease	19.4	19.5
Previous cardiac surgery	9.5	9.2
Urgency of procedure		
Emergency/salvage	6.6	8.1
Inotropic medication (pre-operatively)	2.6	2.7
Operative mortality	2.9	3.5
Complication	7.8	6.7

Outcomes

Crude operative mortality (and complication rates) were 1.7% (4.9%) and 4% (11%) in the isolated-CABG and valve-surgical populations respectively.

Within the isolated CABG population, risk-adjusted mortality rates ranged between 0% and 1.6% for CABG-specific hospital-specific surgeon mortality. There were no obvious gradients or trends in mortality rates for changes in hospital-specific surgeon volume [Figure 1].

Although the odds ratios indicate that as both total cardiac and CABG-specific hospital-specific surgeon volumes increase, the odds of 30-day mortality decrease, this is not significant ($p = 0.69$ and $p = 0.54$ respectively) [Table 5]. Likewise, no significant association was found between the hospital-specific surgeon volume and incidence of complications.

Crude overall mortality for patients undergoing a valve operation was 4.0%. The spread of risk-adjusted mortality rates according to hospital-specific surgeon volume ranged from 0 to 17%. Predicted 30-day mortality rates appear to follow a gentle negative gradient [Figure 2].

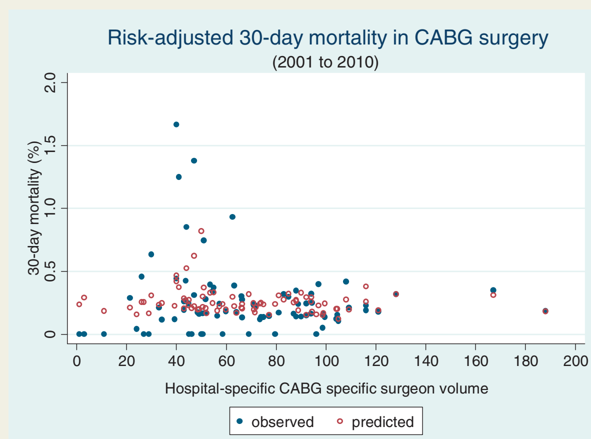

Figure 1 Scatter plot of observed v. predicted 30-day mortality in isolated-CABG surgery.

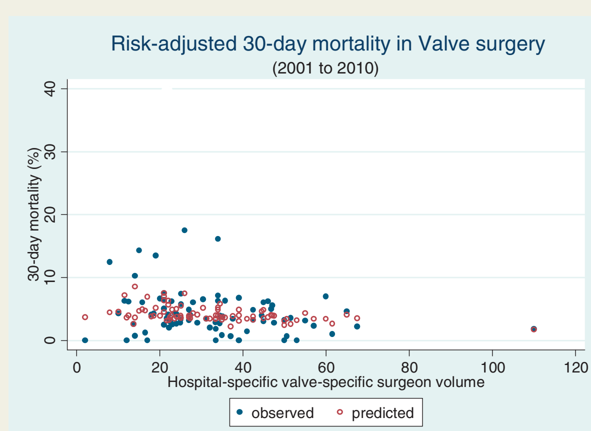

Figure 2 Scatter plot of observed v. predicted 30-day mortality in valve surgery.

Table 4 Sensitivity analysis assessing the effect of missing data.

Surgery	Outcome	Surgeon volume	OR	SE	99% C.I.	P
Isolated CABG	Inc. NYHA/EF	Total cardiac	0.99	0.02	0.96–1.03	0.69
		CABG-specific	0.99	0.02	0.94–1.03	0.54
	Mort30					
	Excl. NYHA/EF	Total cardiac	0.97	0.03	0.90–1.05	0.42
		CABG-specific	1.00	0.0002	0.9995–1.0005	0.73
	Inc. NYHA/EF					
		Total cardiac	0.98	0.02	0.94–1.02	0.36
		CABG-specific	0.97	0.02	0.93–1.01	0.18
	Complications					
	Excl. NYHA/EF	Total cardiac	0.97	0.02	0.92–1.03	0.25
		CABG-specific	0.9996	0.0002′	0.999–1.0002	0.04
Valve surgery		Total cardiac	0.98	0.03	0.93–1.03	0.45
		Valve-specific	0.84	0.05	0.74–0.95	0.003
	Mort30					
	Excl. NYHA/EF	Total cardiac	0.996	0.01	0.97–1.02	0.64
		Valve –specific	0.82	0.06	0.66–0.98	0.003
	Inc. NYHA/EF					
		Total cardiac	0.98	0.02	0.95–1.01	0.28
		Valve-specific	0.85	0.05	0.74–0.95	0.001
	Complications					
	Excl. NYHA/EF	Total cardiac	0.98	0.02	0.93–1.03	0.18
		Valve –specific	0.84	0.04	0.72–0.95	0.000

a: OR - Odds ratio per 20 extra operations; b: SE - standard error; c: C.I.: confidence interval.

Table 5 Relationship between hospital-specific surgeon volume and surgical outcomes in isolated CABG surgery.

Outcome	Surgeon volume	OR[a]	SE[b]	95% C.I.[c]	P value
30-day mortality	Total cardiac	0.99	0.02	0.96–1.03	0.69
	CABG-specific	0.99	0.02	0.94–1.03	0.54
Complications	Total cardiac	0.98	0.02	0.94–1.02	0.36
	CABG-specific	0.97	0.02	0.93–1.01	0.18

a: OR - Odds ratio per 20 extra operations; b: SE - standard error; c: C.I.: confidence interval.

Table 6 Relationship between hospital-specific surgeon volume and surgical outcomes in valve surgery.

Outcome	Surgeon volume	OR[a]	SE[b]	95% C.I.[c]	P value
30-day mortality	Total cardiac	0.98	0.03	0.93–1.03	0.45
	Valve-specific	0.84	0.05	0.74–0.95	0.003
Complications	Total cardiac	0.98	0.02	0.95–1.01	0.28
	Valve-specific	0.85	0.05	0.74–0.95	0.001

a: OR Odds ratio per 20 extra operations; b. SE standard error; c. C.I.: confidence interval.

The odds ratios reveal an interesting picture. Although both total cardiac and valve-specific surgeon volume have odds ratios below 1, implying that increasing volumes are associated with decreasing odds of dying within 30 days, the magnitude of the effect of total-cardiac surgeon volume is much smaller and also not statistically significant. This would suggest that experience in associated cardiac procedures such as CABG surgery did not translate across to improved valve surgery results. This is consistent for both 30-day mortality and also complication rates [Table 6].

Discussion

This study hypothesised that, in accordance with current literature findings, a surgeon with greater experience in a certain procedure would have better results than a surgeon with lesser experience. The causality of the relationship, whether this was the chicken begetting the egg (ie. surgeons outcomes improving with greater experience) or the egg begetting the chicken (ie. surgeons with better results attracting more referrals) could not adequately be answered with the available data. We anticipated that this association would be stronger for the valve surgical populations as compared with patients undergoing isolated CABG operations, due to the increased complexity and consequently morbidity and mortality, associated with valve operations. This was confirmed by the findings of a significant association between procedure-specific volume and improved outcomes (both mortality and complications rates) for valve operations [Table 6], but not for isolated CABG operations [Table 5].

In the cardiac surgery research literature, data exploring the relationship between surgeon volume and outcome in cardiac surgery has been analysed in both isolated CABG and valve operations, but there is less data for valve surgery. Assessing the direct impact of immediate surgeon experience (as represented by procedure-specific surgeon volume) on outcomes, the existing literature tends to suggest a robust relationship between increasing surgeon volume and improved outcomes [5,11–25].

It could be hypothesised that isolated CABG operations and valve operations have sufficient overlap in both skill set and process that a surgeon's experience in one area would impact positively on their results in another area. That is, a surgeon with a high total-cardiac surgical volume would have lower mortality and complications rates for both isolated CABG operations and valve operations. This was not supported by the current study; total cardiac surgeon volume was not found to be significantly associated with outcomes for either procedure.

This suggests that surgeons can attain an acceptable level of proficiency in isolated CABG operations at lower volumes, and that increased immediate experience of both this procedure and other related cardiac surgical procedures may not result in further significant expertise, as measured by mortality and complication rates.

There is however evidence of more variability in outcomes for surgeons performing fewer valve operations and significantly lower mortality and complication rates for surgeons with a greater 'immediate' experience of valve surgery. This relationship is not paralleled by greater volumes of total cardiac surgical volumes, but is specific to volumes of the procedure (or in this case group of procedures) at hand. The suggestion here is that improved valve surgical outcomes can be attained by performing more valve operations. Focussing one's practice on the field of valve surgery or sub-specialising in the field of valve surgery may well result in lower mortality and morbidity rates.

This raises many questions, in particular for surgeons and governing bodies. What are the mechanics of this relationship and can these be affected? Should surgeons be encouraged to sub-specialise into different areas of cardiac surgery? Should there be a formal process of sub-specialisation into valve surgery, heart failure surgery, arrhythmia surgery etc.? Where does the critical balance of gaining enough experience in one area to become a 'super-specialist' and maintaining skills in the general cardiac surgical procedures lie? Further specialisation may impair the skill of the surgeon in managing emergency or salvage operations in areas external to their subspecialty.

Limitations

Finally, in interpreting the results of this study, it is important to consider the limitations of the analyses. Firstly the analysis only considered the immediate and not the long-term experience of surgeons, that is, the analysis included annual surgical volume in a 10-year window, but did not include any cumulative measure of surgery volume, either over these 10 years or the surgeon's operating lifetime. Secondly, data from the ANZSCTS registry, although enabling comprehensive risk adjustment, does not have complete capture of all cardiac surgical units in the region. This raises the question as to whether the participants and their outcomes within the registry are systematically different to participants that are not included. Additionally this results in an underestimation of total surgeon volume. Ideally, both hospital-specific surgeon volume and total surgeon volume should be controlled for in the analysis. However, as demonstrated by both Huckman and Carey [5,14] who found significant associations between hospital-specific surgeon volume and operative mortality following CABG surgery, total surgeon volume is probably less important than hospital-specific surgeon volume. Within the registry, there is the issue of incomplete data, resulting in a significant number of patients being excluded from the analysis. A sensitivity analysis was performed and did not alter the results obtained.

Conclusion

Our finding of an association between increased valve-specific surgeon volumes and with improved valve surgery outcomes, and absence of an association between these outcomes and annual total cardiac surgical experience of a surgeon supports the case for sub-specialisation of surgeons specifically within the field of valve surgery.

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