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Is there a surgeon or hospital volume–outcome relationship in off-pump coronary artery bypass surgery?

Amir H. Sepehripour[a,b,*] and Thanos Athanasiou[a,b]

[a] Department of Cardiothoracic Surgery, Imperial College Healthcare, London, UK
[b] Division of Surgery, Imperial College London St. Mary's Hospital, London, UK

* Corresponding author. Division of Surgery, Imperial College London, St. Mary's Hospital, 10th Floor QEQM Building, South Wharf Road, London W2 1NY, UK. Tel: +44-07834697517; e-mail: amir.sepehripour@gmail.com (A.H. Sepehripour).

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Abstract

A best evidence topic was written according to a structured protocol. The question addressed was whether there is a surgeon or hospital volume–outcome relationship in patients undergoing off-pump coronary artery bypass surgery. A total of 281 papers were found using the reported searches, of which six represented the best evidence to answer the clinical question. The authors, date, journal, study type, population, main outcome measures and results are tabulated. The studies found analysed the outcomes of off-pump coronary artery bypass surgery in relation to surgeon or hospital volume and evaluated the presence of a volume–outcome relationship. Reported measures included mortality and major adverse cardiovascular and cerebrovascular events. The methodological quality and strength of each study for exploring volume–outcome relationships were quantitatively assessed using a predefined scoring system. Three studies analysed surgeon volume and three studies analysed hospital volume. The two largest and most recent studies presented a significant volume–outcome relationship in mortality and postoperative complications. Perhaps owing to the smaller sample size, this significant relationship in mortality was not observed in the four smaller studies; however, one of these studies demonstrated a significantly positive relationship for postoperative complications and another study demonstrated a similar significant relationship for the number of grafts and the degree of completeness of revascularization. While the volume–outcome relationship in coronary artery bypass graft surgery is very well-documented, the technically challenging nature of off-pump surgery, the length of the learning curve associated with the operation and the higher risk profile of patients undergoing off-pump surgery in comparison with routine on-pump surgery render these results difficult to interpret. Although our review does support the idea of a volume–outcome relationship in off-pump coronary artery bypass surgery, this relationship may not be so clearly defined and requires further analysis by higher-quality studies.

Keywords: Volume • Off-pump • Coronary artery bypass graft

INTRODUCTION

A best evidence topic was constructed according to a structured protocol. A clinical scenario relating to the volume–outcome relationship in off-pump coronary artery bypass surgery (OPCAB) was highlighted and used to generate a three-part question. A thorough literature search was conducted, the relevant studies were critically appraised, and a conclusion was presented with a clinical bottom line. This protocol is fully described in ICVTS [1].

CLINICAL SCENARIO

A symptomatic 76-year old lady with chest pain and shortness of breath on minimal exertion is referred for consideration of coronary artery bypass graft surgery (CABG). Her comorbidities include peripheral vascular disease, previous right femoral-politeal bypass graft surgery and end-stage renal failure requiring dialysis. Coronary angiography demonstrates a right-dominant system and critical mid-left anterior descending artery and distal right coronary artery lesions. Echocardiography demonstrates moderately impaired left ventricular systolic and diastolic function and no valvular pathology. Considering the strategies for coronary revascularization for this lady, you decide that an off-pump technique would be the best approach and contemplate whether she would benefit from referral to a high-volume surgeon in a specialized centre for off-pump CABG.

THREE-PART QUESTION

In [patients undergoing off-pump CABG] does [operation at a high-volume hospital or by a high-volume surgeon] result in superior [clinical outcomes]?

SEARCH STRATEGY

Medline from 1948 to July 2012 using the PubMed interface 'volume' AND ('coronary artery bypass, off-pump' [MeSH Terms] OR ('coronary' AND 'artery' AND 'bypass' AND 'off-pump') OR

Table 1: Best evidence papers

Author, date, journal and country, Study type (level of evidence)	Patient group	Outcomes	Key results	Quality score	Comments
Lapar *et al*. (2012) J Thorac Cardiovasc Surg USA [2]	709 483 patients undergoing CABG: ONCAB: 439 253 OPCAB: 270 230	Relationship between surgeon volume and risk-adjusted mortality for OPCAB	*P* <0.01 overall Consistent for 3 time periods (*P* = 0.01; *P* = 0.0004; *P* = 0.0046)	8/18	A significant surgeon volume–outcome relationship exists for mortality after OPCAB
Retrospective multicentre cohort study (level 2 evidence)	Surgeon operative volume: ONCAB: 111 (66–155) OPCAB: 105 (56–156)	Estimated decrease in absolute probability of death after OPCAB performed by highest-volume surgeon	5%		
	Low hospital volume ONCAB: 2.9% OPCAB: 3.8%	Estimated decrease in absolute probability of death after ONCAB performed by highest-volume surgeon	3%		
	Medium hospital volume: ONCAB: 10.0% OPCAB: 11.0%				
	High hospital volume: ONCAB: 20.2% OPCAB: 21.5%				
	Very high hospital volume: ONCAB: 66.8% OPCAB: 63.7%				
Konety *et al*. (2009), J Thorac Cardiovasc Surg USA [3]	125 355 patients undergoing CABG: OPCAB: 99 344 ONCAB: 26 011	*Unadjusted outcomes*:		7/18	Outcomes are significantly better for OPCAB compared with ONCAB. The beneficial effects of OPCAB compared with ONCAB increase significantly as hospital volume increases
Retrospective multicentre cohort study (level 2 evidence).		Operative mortality	ONCAB: 3.3% (*P* < 0.001) OPCAB: 2.2%		
		Postoperative stroke	ONCAB: 1.1% (*P* < 0.001) OPCAB: 0.7%		
		Postoperative myocardial infarction (MI)	ONCAB: 1.8% (*P* = 0.009) OPCAB: 1.5%		
		Postoperative renal failure	ONCAB: 2.4% (*P* = 0.11) OPCAB: 2.3%		
		Postoperative bleeding	ONCAB: 5.7% (*P* < 0.001) OPCAB: 5.1%		
		Risk-adjusted outcomes: OPCAB vs ONCAB by volume quartiles			
		OPCAB hospital mortality (OR; 95% CI)	Low: 0.83 (0.62–1.11) (*P* = 0.18) Medium: 0.77 (0.6–1.01) (*P* = 0.09) High: 0.65 (0.51–0.81) (*P* <0.001) Very high: 0.48 (0.37–0.63) (*P* <0.001)		

Continued

Table 1: (*Continued*)

Author, date, journal and country, Study type (level of evidence)	Patient group	Outcomes	Key results	Quality score	Comments
		OPCAB postoperative complications (OR; 95% CI)	Low: 0.89 (0.76–1.06) ($P = 0.2$) Medium: 0.81 (0.7–0.94) ($P = 0.02$) High: 0.80 (0.71–0.91) ($P < 0.001$) Very high: 0.72 (0.62–0.83) ($P < 0.001$)		
Agostini *et al.* (2009), Heart Surg Forum Italy [4] Retrospective cohort study (level 2 evidence)	312 patients undergoing OPCAB 2 surgeon volume categories: Low (126 patients) High (186 patients)	*Outcomes by volume categories* Operative mortality Stroke MI Renal failure Conversion to ONCAB Grafts per patient Complete revascularization	 Low: 2 (1.6%) High: 2 (1.1%) ($P = 0.35$) Low: 1 (0.8%) High: 1 (0.5%) ($P = 0.48$) Low: 10 (7.9%) High: 4 (2.1%) ($P = 0.02$) Low: 20 (15.9%) High: 27 (14.5%) ($P = 0.74$) Low: 6 (4.8%) High: 6 (3.2%) ($P = 0.695$) Low: 2.0 High: 3.1 ($P < 0.0001$) Low: 78 (61.9%) High: 175 (94.1%) ($P < 0.0001$)	4/18	There is no surgeon volume–outcome relationship for OPCAB surgery for operative mortality and perioperative complications. This relationship does however exist for the degree of complete revascularization and perhaps consequently long-term outcomes of OPCAB
Plomondon *et al.* (2006) Ann Thorac Surg USA [5] Retrospective multicentre cohort study (level 2 evidence)	5076 patients undergoing OPCAB 4 hospital volume quartiles (average procedures in 6 months): 1: <10.2 (1322 patients, 25 hospitals) 2: 10.2–16.6 (1204 patients, 10 hospitals) 3: 16.6–30.2 (1067 patients, 5 hospitals) 4: >30.2 (1483 patients, 4 hospitals)	*Outcomes by volume quartiles* 30-day mortality 180-day mortality Perioperative morbidity Stroke	 1: 2.5% 2: 2.6% 3: 2.2% 4: 2.3% ($P = 0.9933$) 1: 5.1% 2: 4.0% 3: 4.1% 4: 4.5% ($P = 0.8266$) 1: 11.0% 2: 9.4% 3: 9.2% 4: 9.4% ($P = 0.9512$) 1: 2.3% 2: 1.5% 3: 1.6% 4: 2.1% ($P = 0.7979$)	7/18	There is no relationship between OPCAB hospital volume and short-term mortality, intermediate-term mortality and perioperative morbidity

Continued

Table 1: (*Continued*)

Author, date, journal and country, Study type (level of evidence)	Patient group	Outcomes	Key results	Quality score	Comments
		Renal failure (dialysis)	1: 0.6% 2: 1.3% 3: 0.8% 4: 0.8% (*P* = 0.3480)		
		Reoperation for bleeding	1: 1.4% 2: 1.3% 3: 2.3% 4: 1.7% (*P* = 0.7163)		
		Repeat CABG	1: 0.1% 2: 0.4% 3: 0.6% 4: 0.2% (*P* = 0.0247)		
		Logistic regression model volume vs outcome (OR; 95% CI)			
		30-day mortality	0.94 (0.76–1.15) (*P* = 0.5191)		
		180-day mortality	0.92 (0.77–1.09) (*P* = 0.3177)		
		Perioperative morbidity	0.91 (0.81–1.02) (*P* = 0.1149)		
Glance *et al*. (2005) Chest USA [6] Retrospective multicentre cohort study (level 2 evidence)	36 930 patients undergoing CABG ONCAB: 31 723 OPCAB: 5207 Surgeon volume categories for ONCAB: Very low: <52 Low: 52–155 Medium: 156–273 Surgeon volume categories for OPCAB: Very low: <5 Low: 5–10 Medium: 11–31	Effect of surgeon volume on hospital mortality for ONCAB (OR; 95% CI) Effect of surgeon volume on hospital mortality for OPCAB (OR; 95% CI)	Very Low: 2.13 (1.38–3.29) (*P* <0.001) Low: 1.69 (1.24–2.29) (*P* = 0.002) Medium: 1.48 (1.12–1.95) (*P* = 0.005) Very low: 0.65 (0.18–2.38) (*P* = 0.51) Low: 0.97 (0.48–2.00) (*P* = 0.95) Medium: 0.78 (0.45–1.35) (*P* = 0.37)	7/18	For OPCAB, there is no relationship between surgeon volume and hospital mortality. However, for ONCAB, this relationship exists, whereby higher surgeon case volumes are associated with lower hospital mortality
Brown *et al*. (2001) Ann Thorac Surg USA [7] Retrospective multicentre cohort study (level 2 evidence)	16 988 patients undergoing CABG, of whom 2491 undergoing OPCAB were analysed Hospital volume categories: Low: < 100 High: >100	*Outcomes by volume categories* Operative mortality (mean ± standard deviation [SD]) Postoperative cardiac complications (mean ± SD) Postoperative neurological complications (mean ± SD) Postoperative renal complications (mean ± SD)	 Low: 2.87 ± 16.7 High: 2.85 ± 16.6 (*P* = 0.952) Low: 7.47 ± 26.28 High: 3.04 ± 17.18 (*P*<0.0001) Low: 1.45 ± 11.96 High: 0.83 ± 9.10 (*P* = 0.025) Low: 0.97 ± 9.80 High: 0.34 ± 5.85 (*P* = 0.005)	6/18	There is no relationship between hospital volume and mortality for OPCAB surgery; however, this relationship is significant for postoperative complications of OPCAB surgery

Continued

Table 1: (*Continued*)

Author, date, journal and country, Study type (level of evidence)	Patient group	Outcomes	Key results	Quality score	Comments
		Logistic regression model High- vs low-volume			
		operative mortality	OR–1.2932 ($P = 0.076$)		

CABG: coronary artery bypass graft; OR: odds ratio; ONCAB: on-pump coronary artery bypass; CI: confidence interval; OPCAB: off-pump coronary artery bypass; SD: standard deviation.

'off-pump coronary artery bypass' OR ('off' AND 'pump' AND 'coronary' AND 'artery' AND 'bypass') OR 'offpump coronary artery bypass'). Related articles and references were screened for suitable articles.

SEARCH OUTCOME

Two hundred and eighty-one articles were found using the reported search strategy. From these, six articles [2–7] were identified that provided the largest and most recent analysis of outcomes of OPCAB in relation to volume categories, providing the best evidence to answer the question. These are presented in Table 1.

RESULTS

The methodological quality and strength of study for exploring the volume–outcome relationship for OPCAB were quantitatively assessed using a predefined scoring system (Table 2), specifically designed to determine the magnitude and nature of the relationship between volume and outcome. This system was initially developed by Halm *et al*. [8, 9] and later modified by our group from Mayer *et al*. [10].

Lapar *et al*. [2] conducted a retrospective multicentre cohort study of 709 483 patients undergoing CABG (270 230 OPCAB). They stratified the sample population according to both surgeon and hospital volume and used surgeon volume in the assessment of the volume–outcome relationship. The relationship between risk-adjusted mortality and surgeon volume in OPCAB surgery was statistically significant and remained so over three separate time periods. Estimation of the decrease in the absolute probability of mortality when operation is carried out by the highest-volume surgeon revealed a higher decrease for OPCAB compared with on-pump coronary artery bypass (ONCAB) surgery. The authors concluded that a significant surgeon volume–outcome relationship exists for mortality in OPCAB surgery.

Konety *et al*. [3] conducted a retrospective multicentre cohort study of 125 355 patients undergoing CABG (26 011 OPCAB). They revealed significantly superior outcomes in terms of mortality and postoperative complications for OPCAB compared with ONCAB. Using hospital volume quartiles, they revealed that the benefits of OPCAB over ONCAB for mortality and postoperative complications increase significantly as hospital volume increases, concluding that there is a significant hospital volume–outcome relationship in OPCAB surgery.

Table 2: Methodology quality scoring system

Question	Characteristic	Score
1. Representativeness	Not representative	0
	Representative	1
2. Number of hospitals or surgeons	Hospitals <20 and surgeons <50	0
	Hospitals ≥20 or surgeons ≥50	1
	Hospitals ≥20 and surgeons ≥50	2
3. Total sample size (cases)	<1000	0
	≥1000	1
4. Number of adverse events	<20	0
	21–100	1
	>100	2
5. Unit of analysis	Hospital or surgeon	0
	Both separately	1
	Both together	2
	Both together + further component	3
6. Appropriateness of patient selection	Not measured	0
	Measured separately	1
	Measured and analysed	2
7. Volume	Two categories	0
	Multiple categories	1
8. Risk adjustment	None	0
	Administrative data only	1
	Clinical data only clinical + 0 1 2 3	2
	Clinical data + C >0.75 and Hosmer–Lemeshow test positive	3
9. Clinical processes of care	Not measured	0
	1	1
	2	2
	≥2	2
10. Outcomes	Single outcome measured	0
	≥2 outcomes measured	1

Agostini *et al*. [4] conducted a retrospective cohort study of 312 patients undergoing OPCAB at a single centre. Based on surgeon operative volume, they demonstrated no difference in mortality, postoperative complications and conversion to ONCAB between low- and high-volume surgeons. However, there was a significant difference demonstrated in the mean number of grafts per patient and the degree of completeness of revascularization in favour of high-volume surgeons.

Plomondon *et al*. [5] conducted a retrospective multicentre cohort study of 5076 patients undergoing OPCAB and analysed the effects of hospital volume on operative outcomes. They demonstrated no difference between the four quartiles of hospital volume in terms of short-term mortality, intermediate-term mortality and perioperative morbidity.

Glance *et al*. [6] conducted a retrospective multicentre cohort study of 36 930 patients undergoing CABG (5207 OPCAB). Analysing surgeon operative volume, they demonstrated no difference in mortality between three volume categories for OPCAB; however, there was a significant surgeon volume–outcome relationship demonstrated for ONCAB surgery.

Brown *et al*. [7] conducted a retrospective multicentre cohort study of 16 988 patients undergoing CABG (2491 OPCAB), comparing hospital volume and operative outcomes. They demonstrated no relationship between hospital volume and mortality in OPCAB; however, this volume–outcome relationship did exist for postoperative complications of surgery.

CLINICAL BOTTOM LINE

The evidence presented represents a very large cohort of patients (309 327) undergoing OPCAB across a wide range of centres. There is also an equal divide between the studies in terms of the unit of analysis of volume; three studies focusing on surgeon volume and three on hospital volume. However, based on our assessment of the methodological quality and strength of the study, the quality of studies analysed is not very high and the most reliable sources of evidence come from some large and medium-sized studies from administrative databases. While the volume–outcome relationship has been very well documented for CABG, our review demonstrates that, surprisingly, this relationship may not be so clearly defined for OPCAB. The two largest and most recent studies [2, 3] do present a significant volume–outcome relationship in mortality and postoperative complications following OPCAB. However, the four smaller studies [4–7] do not reach similar conclusions for mortality, although one study [7] does report a significant relationship for postoperative complications and another study [4] reports a significant relationship for the number of grafts and the degree of completeness of revascularization following OPCAB. One possible explanation for the discrepancy in outcomes (and specifically mortality) between large and small studies is the wide variation in sample size, an issue which requires analysis by larger, higher-quality studies. Off-pump coronary artery bypass poses a technically challenging operation and one may have a long learning curve. It is also widely accepted that the greatest benefits from OPCAB are observed in the high-risk patient; hence, populations studied here will have a significantly higher risk profile than those undergoing routine CABG, in whom a volume–outcome relationship is far easier to predict. Our findings do somewhat support the idea of a volume–outcome relationship with OPCAB; however, the results will need to be interpreted with caution and there is certainly a need for larger, higher-quality studies addressing training and surgeon experience in OPCAB, case selection for OPCAB, timing and effect of conversion to on-pump surgery and the impact of the degree of revascularization.

Conflict of interest: none declared.

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eComment. Quality management and learning curve after coronary artery off-pump heart surgery

Authors: ***Petros Bougioukakis, Martin Mandewirth, Joerg Babin-Ebell and Anno Diegeler***

Heart and Vessels Clinic, Bad Neustadt an der Saale, Germany,

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We congratulate the authors on the interesting topic regarding surgeon-department cases volume and their relationship to surgical outcome concerning off-pump coronary artery heart surgery [1]. We concur and present our personal experience on the subject.

We believe that mortality as well as morbidity (as expressed by perioperative ischaemia/myocardial infarct, need for reoperation, perioperative stroke, perioperative renal failure requiring dialysis) following off-pump heart surgery is highly associated with the volume of cases operated in each centre and by each surgeon seperately. We have observed that an experienced on-pump surgeon, commencing to deal with off- pump surgery requires a learning curve period necessary for aquiring method-specific surgical skills of about two years and 200-250 cases. The same goes for the whole surgical team, which needs to be trained so that all perioperative procedures, from induction to anaesthesia until transfer to the intensive care ward become fully standardized. After this point, there is a significant improvement in results regarding the aforementioned parameters of morbidity and mortality, to a point where these are comparable or even better than the ones of