Off-Pump Coronary Artery Bypass (OPCAB) Surgery Reduces Risk-Stratified Morbidity and Mortality: A United Kingdom Multi-Center Comparative Analysis of Early Clinical Outcome

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Objective—Off-Pump Coronary Artery Bypass (OPCAB) surgery is gaining more popularity worldwide. The aim of this United Kingdom (UK) multi-center study was to assess the early clinical outcome of the OPCAB technique and perform a risk-stratified comparison with the conventional Coronary Artery Bypass Grafting (CABG) using the Cardio-Pulmonary Bypass (CPB) technique.

Methods—Data were collected on 5,163 CPB patients from the database of the National Heart and Lung institute, Imperial College, University of London, and on 2,223 OPCAB patients from eight UK cardiac surgical centers, which run established OPCAB surgery programs. All patients had undergone primary isolated CABG for multi-vessel disease through a midline sternotomy approach, between January 1997 and April 2001. Postoperative morbidity and mortality were compared between the CPB and OPCAB patients after adjusting for case-mix. The mortality of the OPCAB patients was also compared, using risk stratification, to the mortality figures reported by the Society of Cardiothoracic Surgeons of Great Britain and Ireland (SCTS) based on 28,018 patients in the national database who were operated on between January 1996 and December 1999.

Results—Morbidity and mortality were significantly lower in the OPCAB patients compared with the CPB patients and the UK national database of CABG patients, over the same period of time, after adjusting for case-mix.

Conclusion—This study demonstrates that risk stratified morbidity and mortality are significantly lower in OPCAB patients than CPB patients and patients in the UK national database. **(*Circulation*. 2003;108[suppl II]:II-1-II-8.)**

Key Words: coronary surgery ■ ischemic heart disease ■ coronary heart disease ■ cardiopulmonary bypass

Off-Pump Coronary Artery Bypass (OPCAB) surgery is gaining more popularity worldwide.[1] The theoretical and proven disadvantages of the use of the Cardio-Pulmonary Bypass (CPB) for multi-vessel Coronary Artery Bypass Grafting (CABG) has prompted many cardiac surgeons in the United Kingdom (UK) to convert to OPCAB practice in their units.[2] To date, no collective data on the initial OPCAB experience in UK is available.

The aim of this UK multi-center study was to assess the early clinical outcome of the OPCAB technique and perform a risk-stratified comparison with the established CPB technique.

Patients and Methods

Clinical Data Collection

All the clinical data were collected prospectively in line with the appended Minimum Dataset (MDS) defined by the Society of Cardiothoracic Surgeons of Great Britain and Ireland (SCTS). The current MDS, and its associated definitions, is compatible with all existing initiatives in the UK such as UK Heart Valve Registry, the Central Cardiac Audit Database (CCAD) and the British Cardiac Intervention Society database (BCIS). The definitions and data fields are also compatible with evolving European initiatives and the Society of Thoracic Surgeons, American College of Cardiology and the Healthcare Financing Administration (HCFA) in the US.[3]

Local validation of the collected data are performed regularly and external validation is being performed by the SCTS on 3 to 5-year cycle. An institutional approval was obtained for the study.

Patients Groups

OPCAB Group

Cardiac surgeons from 8 UK cardiac surgical centers that run established OPCAB surgery programs, using the Octopus® II or III suction/stabilization system (Medtronic Inc, Minneapolis, IN), were approached and asked to pool in the clinical data of their OPCAB

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Circulation is available at http://www.circulationaha.org DOI: 10.1161/01.cir.0000087440.59920.a1

TABLE 1. The Preoperative Characteristics of the 2 Groups

Patient Characteristics	CPB n (N)	CPB %	OPCAB n (N=2223)	OPCAB %	*P*
Female gender	924	18.0	492	22.1	<0.001
	(5140)				
Age groups					
<40	65	1.3	30	1.4	<0.001
40–50	463	9.4	211	9.5	
50–60	1210	24.5	582	26.2	
60–70	2078	42.1	865	38.5	
70–80	1068	21.7	495	22.3	
≥80	47	1.0	49	2.2	
	(4931)				
Angina status					
CCS scores 0,1,2	2755	57.2	996	44.8	<0.001
CCS scores 3,4	2059	42.8	1227	55.2	
	(4814)				
Dyspnoea status					
NYHA scores 0,1,2	3821	80.0	1878	84.5	<0.001
NYHA scores 3,4	957	20.0	345	15.5	
	(4778)				
Operative priority					
elective	3733	72.6	1701	76.5	0.001
nonelective	1406	27.4	522	23.5	
	(5139)				
LV function (preoperative angiography)					
EF ≥50%	2998	63.1	1594	71.7	<0.001
EF=31–49%	1309	27.6	518	23.3	
EF ≤30%	443	9.3	111	5.0	
	(4750)				
Renal complications					
Cr >200 μmoL/L	66	1.4	43	1.9	0.22
Dialysis-dependent renal failure	48	1.0	22	1.0	
	(4770)				
Diabetes (types I, II)	912	18.9	392	17.6	0.21
	(4830)				
Hypercholesterolaemia	2483	54.0	1630	73.3	<0.001
	(4595)				
Hypertension	2377	49.4	1165	52.4	0.018
	(4815)				
Smoking	3294	69.0	1582	71.2	0.065
	(4775)				
COAD	319	6.6	222	10.0	<0.001
	(4821)				
Cerebrovascular disease	260	5.5	126	5.7	
	(4769)				0.71
Peripheral arterial disease	310	6.5	197	8.9	
	(4785)				<0.001
Preoperative IABP	94	1.9	36	1.6	
	(4848)				0.35

The number of CPB patients vary because of missing observations.

CPB, cardio-pulmonary bypass; OPCAB, off-pump coronary artery bypass; CCS, Canadian cardiovascular society; NYHA, New York Heart Association; LV, left ventricle; EF, ejection fraction; Cr, serum creatinine; COAD, chronic obstructive airway disease; IABP, intra-aortic balloon pump.

patients. These patients were operated on from the beginning of their programs (the earliest is January 1997) until April 2001. Data were collected on 2223 patients in total. Only patients undergoing primary isolated CABG for multi-vessel disease (more than 1 vessel) through a midline sternotomy approach were included. Re-operative OPCAB procedures or Minimally Invasive Direct Coronary Artery Bypass (MIDCAB) procedures were excluded.

The 8 UK centers that contributed the OPCAB data to the present study are: Harefield Hospital (London), Royal Brompton Hospital (London), Kings College Hospital (London), Manchester Royal Infirmary (Manchester), The Cardiothoracic Centre (Liverpool), University Hospital of Wales (Wales), Castle Hill Hospital (Hull), and The Royal Sussex County Hospital (Brighton).

CPB Group

Data were collected on 5163 patients from the local database of the National Heart and Lung institute, Imperial College, University of London, who underwent first time isolated CABG for multi-vessel disease (more than one vessel) using CPB through a midline sternotomy approach between January 1997 and April 2001. Some data for this group were missing so the totals displayed in the results are often less than 5163.

National Database

The SCTS report describes 28 018 patients who underwent first time isolated CABG between January 1996 and December 1999 in all UK hospitals that contribute to The National Adult Cardiac Surgical Database, which is managed by the SCTS.[3] The report does not differentiate patients into OPCAB and CPB groups and hence we undertook the task of collecting the OPCAB data from eight UK centers that run established OPCAB programs using the same technique and single-type suction/stabilization system. The report contains overall mortality values stratified by the Parsonnet scoring system.

Statistical Analysis

Morbidity and mortality of OPCAB patients were compared with that of the CPB patients and the patients in the UK national database, after adjusting for case-mix. The UK CABG Bayes risk scoring system was used for risk adjustment in the comparison between OPCAB and CPB groups as it had exhibited good calibration and discrimination for both groups of patients in previous studies.[3,4] The Parsonnet risk scoring system[5] was used for the national comparison since the values published in the SCTS report had been adjusted for case-mix using this system. It was only possible to calculate the Parsonnet score for 1515 patients in the OPCAB group due to the presence of missing values for some of the risk factors. The UK CABG Bayes score was calculated for every patient since it does not require all risk factor values to be present.[3,4]

To compare morbidity, we divided the patients into 3 risk groups: low risk ($<$2.5%), moderate risk (2.5% to 9.99%), and high risk ($\geq$10%), according to risk scores obtained using the UK CABG Bayes system. Postoperative complications were then compared between the CPB and OPCAB patients using either Pearson's Chi-square test or Fisher's Exact test within each risk group. In accordance with our analysis plan we performed a complete case analysis for each morbidity outcome, resulting in different denominators in the CPB group because of missing data.

We used multiple logistic regression analysis to compare mortality between the OPCAB and CPB groups. We adjusted for case-mix by including indicator variables in the regression model to represent 6 patient risk groups, constructed using the UK CABG Bayes scoring system. The cut-points of 2.5%, 5%, 10% 20%, and 30% for these risk groups were chosen according to those used by the Society of Thoracic Surgeons (STS).[6] An indicator variable was also used to denote the OPCAB/CPB grouping. Likelihood ratio tests were used to assess statistical significance. For the national comparison the procedure was the same although we used indicator variables to adjust for case-mix based on the 5 Parsonnet risk groups presented in the SCTS report.[3]

TABLE 2. The Postoperative Outcome of Low Risk Subgroups (<2.5%)

Outcome	CPB n (N)	CPB %	OPCAB n (N=1781)	OPCAB %
Perioperative MI	40 (4001)	1.0	11	0.6
Low cardiac output	297 (4008)	7.4	83	4.7
Arrhythmias				
Other	918	22.9	350	19.7
VT/VF	41 (4002)	1.0	12	0.7
Reoperation for bleeding	112 (3708)	3.0	57	3.2
Ventilation >24 hours	142 (1645)	8.6	42	2.4
Pulmonary complications				
Extra-parenchymal (pneumothorax+pleural effusion)	274	6.9	60	3.4
Parenchymal (ARDS+PO+pneumonia)	399	10.0	74	4.2
Re-intubation/tracheostomy	85 (3981)	2.1	38	2.1
Neurological complications				
TIA	23	0.6	9	0.5
CVA	23 (4008)	0.6	3	0.2
Infective complications				
Septicaemia	33	0.8	17	1.0
Other (sternal+vein donor site infection)	284 (3989)	7.1	57	3.2
Renal complications				
Impairment	124	3.1	38	2.1
Dialysis	45 (4003)	1.1	13	0.7
Postoperative IABP insertion	63 (3030)	2.1	29 (1780)	1.6
Re-admission to ITU	86 (4205)	2.1	12	0.7

The number of CPB patients vary because of missing observations.

CPB, cardio-pulmonary bypass; OPCAB, off-pump coronary artery bypass; MI, myocardial infarction; ARDS, adult respiratory distress syndrome; PO, pulmonary oedema; TIA, transient ischaemic attack; CVA, cerebro-vascular accident; IABP, intra-aortic balloon pump; ITU, intensive therapy unit.

Probability values less than 0.05 indicate a statistically significant difference (at the 5% level) between the OPCAB and CPB outcomes. All analyses were carried out using the statistical software Stata 7 (Stata Corporation, College Station, TX).

Operative Technique

No randomization was involved in this cohort of patients and the individual operating surgeon made the decision to perform an operation as either OPCAB or CPB. The percentage of OPCAB practice in the units that contributed the OPCAB data ranged from 50% to 100%. Two of the eight units, who in total contributed 1100 (49.5%) patients, used OPCAB non-selectively for all patients.[2] All the surgeons that contributed in this study performed their OPCAB operations using a single type stabilizer, Octopus® II or III suction/stabilization system (Medtronic Inc). The operative technique was reported in detail elsewhere[7] and is beyond the scope of this study.

Definition of Preoperative Characteristics

Nonelective operative priority was defined as the necessity to operate on the patient in the next available operating list within the same week of referral (urgent cases), or the necessity to take the patient to theater out of normal working hours (09:00 AM to 17:00 PM) and before the next morning's operating list (emergency cases). Cerebrovascular disease was defined as the past occurrence of a single episode of Cerebro-Vascular Accident (CVA) or Transient Ischemic Attack (TIA). Peripheral vascular disease was defined by the presence of a clinical or angiographic evidence of an acute or chronic ischemia of the upper or lower limbs.

Definition of Postoperative Morbidity Outcomes

Peri-operative Myocardial Infarction (MI) was diagnosed when one of the following was observed: (1) new Q waves in the ECG (ECG); (2) CK-MB >50 with ECG changes; or (3) CK-MB >70 without ECG changes. Low Cardiac Output (LCO) was diagnosed when the systolic arterial blood pressure was persistently <90 mm Hg; or the mean arterial blood pressure was persistently below <50 mm Hg despite appropriate fluid management and requiring inotropic or vasoconstrictor therapy. Atrial Fibrillation (AF) was identified by cardiac monitoring and confirmed by 12-lead ECG. Pulmonary complications were diagnosed by chest radiograph. Neurological complications included transient strokes (TIA) in which symptoms lasted <24 hours and permanent strokes (CVA) in which symptoms were permanent and lasted >24 hours. Infective complications were diagnosed clinically, proved by laboratory culture and sensitivity tests and treated by appropriate antibiotics accordingly. Renal Impairment was identified by the postoperative rise in serum Creatinine (Cr) more than three times the preoperative level or the rise twice the preoperative level accompanied with poor urine output of <0.5 mL/Kg/hr, requiring diuretics or inotropes but not requiring dialysis.

Results

Evolution of the Off-Pump Technique Over Time

The number of OPCAB operations in our sample increased over time with 1,325 (59.6%) operations in 2000 compared with just 452 (20.3%) in 1999.

Preoperative Characteristics

The preoperative characteristics of the OPCAB and CPB groups are presented in (Table 1) to give an idea of the risk profiles of the 2 groups. We only focus on results that were both clinically and statistically significant. There were a higher percentage of octogenarians and patients with CCS scores 3 and 4, hypercholestrolaemia and Chronic Obstructive Airway Disease (COAD) in the OPCAB group. The CPB group had a higher percentage of patients with poor Left Ventricular (LV) function as reflected by having Ejection Fraction (EF ≤30%).

Postoperative Morbidity

The results for the morbidity outcomes in the 3 risk groups are presented in (Tables 2–4) respectively. Table 5 contains a summary of the differences observed for the morbidity outcomes and the associated probability values between the OPCAB and CPB patients, with significant probability values (at the 5% level) highlighted in bold. For the CPB patients there was a significantly higher percentage of cases with LCO, requiring ventilation for >24 hours, pulmonary and renal complications and readmission to the Intensive Therapy Unit (ITU), across all risk groups. There was a higher percentage of arrhythmia observed for the CPB patients

TABLE 3. The Postoperative Outcome of Moderate Risk Subgroups (2.5%–9.99%)

	CPB		OPCAB	
Outcome	n (N)	%	n (N=378)	%
Perioperative MI	14	2.3	7	1.9
	(616)			
Low cardiac output	129	20.8	39	10.3
	(620)			
Arrhythmias				
Other	202	32.7	88	23.3
VT/VF	15	2.4	11	2.9
	(617)			
Reoperation for bleeding	28	4.8	16	4.2
	(584)			
Ventilation >24 hours	49	21.1	22	5.8
	(232)			
Pulmonary complications				
Extra-parenchymal (pneumothorax+pleural effusion)	67	11.0	11	2.9
Parenchymal (ARDS+PO+pneumonia)	51	8.4	26	6.9
Re-intubation/tracheostomy	28	4.6	14	3.7
	(611)			
Neurological complications				
TIA	7	1.1	4	1.1
CVA	13	2.1	0	0
	(615)			
Infective complications				
Septicaemia	17	2.8	3	0.8
Other (sternal+vein donor site infection)	61	10.0	19	5.0
	(611)			
Renal complications				
Impairment	50	8.1	10	2.7
Dialysis	43	7.0	13	3.4
	(617)			
Postoperative IABP insertion	51	11.0	13	3.4
	(463)			
Re-admission to ITU	29	4.2	6	1.6
	(685)			

The number of CPB patients vary because of missing observations.

CPB, cardio-pulmonary bypass; OPCAB, off-pump coronary artery bypass; MI, myocardial infarction; ARDS, adult respiratory distress syndrome; PO, pulmonary oedema; TIA, transient ischaemic attack; CVA, cerebro-vascular accident; IABP, intra-aortic balloon pump; ITU, intensive therapy unit.

TABLE 4. The Postoperative Outcome of High Risk Subgroups (≥10%)

	CPB		OPCAB	
Outcome	n (N)	%	n (N=64)	%
Perioperative MI	4	2.9	6	9.4
	(139)			
Low cardiac output	63	44.7	12	18.8
	(141)			
Arrhythmias				
Other	69	48.9	21	32.8
VT/VF	9	6.4	2	2.1
	(141)			
Reoperation for bleeding	4	3.0	5	7.8
	(132)			
Ventilation >24 hours	12	32.4	7	10.9
	(37)			
Pulmonary complications				
Extra-parenchymal (pneumothorax+pleural effusion)	16	11.5	3	4.7
Parenchymal (ARDS+PO+pneumonia)	16	11.5	4	6.3
Re-intubation/tracheostomy	20	14.4	4	6.3
	(139)			
Neurological complications				
TIA	2	1.5	0	0
CVA	2	1.5	0	0
	(135)		(57)	
Infective complications				
Septicaemia	12	8.8	4	6.3
Other (sternal+vein donor site infection)	12	8.8	4	6.3
	(136)			
Renal complications				
Impairment	20	14.4	4	6.3
Dialysis	25	18.0	3	4.7
	(139)			
Postoperative IABP insertion	32	28.1	3	4.7
	(114)			
Re-admission to ITU	14	9.2	1	1.6
	(153)			

The number of CPB patients vary because of missing observations.

CPB, cardio-pulmonary bypass; OPCAB, off-pump coronary artery bypass; MI, myocardial infarction; ARDS, adult respiratory distress syndrome; PO, pulmonary oedema; TIA, transient ischaemic attack; CVA, cerebro-vascular accident; IABP, intra-aortic balloon pump; ITU, intensive therapy unit.

(except for the VT/VF type arrhythmia in the medium risk group).

Postoperative Mortality

UK CABG Bayes Adjusted Comparison

The numbers of deaths observed in each of the 6 risk groups are presented for the CPB and OPCAB patients in (Table 6). The odds ratio for mortality for CPB patients compared with OPCAB patients was 2.34 (95% CI: 1.56 to 3.49), indicating that CPB patients were more than twice as likely to die, after adjusting for case-mix. This result was statistically significant ($P<0.001$). We note that the odds ratio may be interpreted as a risk ratio since the risk of mortality is relatively low. Near identical results were obtained when we risk adjusted using the Parsonnet score (results not shown).

Parsonnet-Adjusted National Comparison

The numbers of deaths observed in each of the 5 risk groups are presented for the CPB and OPCAB patients in (Table 7). The odds ratio for mortality for CPB patients compared with OPCAB patients was 1.85 (95% CI: 1.19 to 2.92), indicating that the risk of mortality for CPB patients was 85% higher than that for OPCAB, after adjusting for case-mix. This result was also statistically significant ($P=0.003$).

Discussion

This study, based on the first multi-center OPCAB data collected in the UK, concludes that OPCAB surgery is associated with a lower risk of both morbidity and mortality than the CPB technique. The conclusion is based on a risk-stratified comparison with CPB patients and with the UK national database of CABG surgery.

The findings of the present study conform with the results of two recently reported studies, performed on large-size multi-center database sets in the United States, that have suggested that OPCAB is associated with lower risk-adjusted early mortality than the CPB technique.[8,9] Furthermore, 1 of these studies[8] and 2 further US studies[10,11] demonstrated reduced risk-adjusted morbidity with the OPCAB technique in agreement with our findings. However, the present study provides two additional important contributions to the literature. Firstly, the study is risk-stratified rather than risk-adjusted and thus shows the distribution of the morbidity and mortality outcomes across low, moderate and high-risk groups. Secondly it describes the first multi-center comparative data at both UK national and European levels.

Prospective randomized trials have shown that the relatively new OPCAB technique provides a comparable early clinical outcome to the established CPB technique that has been continuously refined over more than three decades.[12,13] However, they have not shown any conclusive evidence of superiority of one technique over the other. This may be because of the recruitment of cardiac surgical patients with relatively low surgical risk profiles, perhaps because of ethical considerations.[14] Therefore, multi-center observational studies, case-matched studies and retrospective series analyses involving large patient groups are useful in reflecting the full picture of the performance of the 2 techniques, and avoids the limitations of individual and local small comparisons that may yield no firm or conclusive results. Furthermore, it has been shown that over the last 2 decades, the results from large observational studies have not been significantly different from those of prospective randomized controlled trials in the medical literature.[15]

Risk models, by objectively stratifying patients according to the severity of their disease, provide important tools to

TABLE 5. Comparison of Postoperative Morbidity in the 3 Risk Subgroups

Outcome	Low Risk	Medium Risk	High Risk
	CPB-OPCAB % (P)	CPB-OPCAB % (P)	CPB-OPCAB % (P)
Perioperative MI	0.4	0.4	**−6.5**
	(0.15)	(0.65)	**(0.05)**
Low cardiac output	**2.7**	**10.5**	**25.9**
	(<0.001)	**(<0.001)**	**(0.001)**
Arrhythmias			
Other	**3.2**	**9.4**	**16.1**
VT/VF	**0.3**	**−0.5**	**4.3**
	(0.007)	**(0.006)**	**(0.03)**
Reoperation for bleeding	−0.2	0.6	−4.8
	(0.72)	(0.68)	(0.13)
Ventilation>24 hours	**6.2**	**15.2**	**21.5**
	(<0.001)	**(0.001)**	**(0.002)**
Pulmonary complications			
Extra-parenchymal (pneumothorax+pleural effusion)	**3.5**	**8.1**	**6.8**
Parenchymal (ARDS+PO+pneumonia)	**5.8**	**1.5**	**5.2**
Re-intubation/tracheostomy	**0.0**	**0.9**	**8.1**
	(<0.001)	**(<0.001)**	**(0.04)**
Neurological complications			
TIA	0.1	**0.0**	1.5
CVA	0.4	**2.1**	1.5
	(0.10)	**(0.002)**	(1.00)
Infective complications			
Septicaemia	**−0.2**	**2.0**	2.5
Other (sternal+vein donor site infection)	**3.9**	**5.0**	2.5
	(<0.001)	**(0.002)**	(0.65)
Renal complications			
Impairment	**1.0**	**5.4**	**8.1**
Dialysis	**0.4**	**3.6**	**13.3**
	(0.04)	**(<0.001)**	**(0.005)**
Postoperative IABP insertion	0.5	**7.6**	**23.4**
	(0.27)	**(<0.001)**	**(<0.001)**
Re-admission to ITU	**1.4**	**2.6**	**7.2**
	(<0.001)	**(0.02)**	**(0.04)**

CPB, cardio-pulmonary bypass; OPCAB, off-pump coronary artery bypass; MI, myocardial infarction; ARDS, adult respiratory distress syndrome; PO, pulmonary oedema; TIA, transient ischaemic attack; CVA, cerebro-vascular accident; IABP, intra-aortic balloon pump; ITU, intensive therapy unit.

analyze health outcomes retrospectively, identify and quantify the effects of changes of techniques or management and allow valid comparisons to be made across time between nations, institutions and even individual surgeons.[16] We decided to use two risk stratification systems in this study: The Parsonnet score and The UK CABG Bayes Model. The Parsonnet system was developed in the US and is probably the most widely used method of 'stratifying open heart operations into levels of predicted operative mortality' worldwide.[5] The UK CABG Bayes model is another risk score that was built by the SCTS to be used for CABG patients in the UK[3] and was validated on this database set in a recently reported study.[4] Using these two risk scores for risk stratification in this dataset showed significant reduction in the mortality of the OPCAB group. Applying the risk-stratified comparison to the morbidity outcomes, a similar significant reduction of the morbidity of the OPCAB group could be demonstrated.

The incidence of pulmonary complications whether parenchymal or extra-parenchymal, and consequently the incidence

TABLE 6. UK CABG Bayes—Adjusted Comparison of Mortality

	OPCAB		CPB	
Risk Group	N	Deaths (%)	N	Deaths (%)
<2.5%	1781	12 (0.7)	4303	74 (1.7)
2.5%–4.99%	255	4 (1.6)	467	24 (5.1)
5%–9.99%	123	8 (6.5)	235	21 (8.9)
10%–19.99%	45	4 (8.9)	105	15 (14.3)
20%–29.99%	11	1 (9.1)	29	6 (20.7)
>30%	8	1 (12.5)	24	10 (41.7)
Total	2223	30 (1.4)	5163	150 (2.9)

OPCAB, off-pump coronary artery bypass; CPB, cardio-pulmonary bypass.

of re-intubation/tracheostomy and the requirement for artificial ventilation for more than 24 hours, was significantly higher in the CPB than OPCAB patients and consistently so across the 3 risk subgroups. The theoretical reasons for CPB-related mechanisms of pulmonary complications have been previously widely reported.[17,18] The reduced pulmonary complications in with the OPCAB technique found in this study is not in keeping with previously reported studies finding no effect of CPB on the alveolar-arterial gas exchange.[19,20] The recruitment of small numbers of low risk surgical patients could be a possible explanation in those studies.

Interestingly, the incidence of extra-parenchymal pulmonary complications, particularly pleural effusion, was persistently higher in the CPB. This could be due to the more postoperative blood loss in CPB.[21] The consistency of the significant difference in the extra-parenchymal complications across the three risk groups makes it difficult to attribute them to differences in local practice in terms of opening the pleurae or meticulous hemostasis.

The incidence of renal dysfunction following OPCAB was significantly lower than CPB across the three risk subgroups, which concurs with the previously suggested renal protective effect of OPCAB.[22]

The incidence of LCO was significantly and consistently higher in CPB across the three risk subgroups. Consequently postoperative IABP insertion reached statistical significance

TABLE 7. Parsonnet—Adjusted National Comparison of Mortality

	OPCAB		Patients on UK National Database	
Risk Group	N	Deaths (%)	N	Deaths (%)
0–4	843	3 (0.4)	14 850	149 (1.0)
5–9	326	5 (1.5)	7 285	219 (3.0)
10–14	218	8 (3.7)	3 922	176 (4.5)
15–19	98	3 (3.1)	1 401	84 (6.0)
>19	30	1 (3.3)	560	50 (8.9)
Total	1515	20 (1.3)	28 018	678 (2.4)

SCTS, The Society of Cardiothoracic Surgeons of Great Britain and Ireland; OPCAB, off-pump coronary artery bypass; CPB, cardio-pulmonary bypass.

in the moderate and high-risk subgroups. The difference in concept between the regional ischemia caused by OPCAB and the global ischemia caused by the CPB with aortic cross-clamping is thought to be the rationale behind the previously reported myocardial protective effects of OPCAB, which made it a safe alternative technique for surgical treatment of patients with recent acute MI.[23] It also has been used safely in patients with critical left main stem disease, who were previously thought of as a theoretical contraindication to the OPCAB technique.[24]

The higher incidence of serious postoperative complications, particularly requirement of postoperative IABP insertion, renal hemodialysis, mechanical ventilation and/or reintubation or tracheostomy, could be responsible for the significantly higher rate of re-admission to ITU for the CPB patients. The incidence of gross neurological complications, TIA and CVA, was not significantly different between the two groups except in the moderate risk group. This agrees with the results of a recently reported retrospective study of a large series of patients, where aortic manipulation, not CPB, was found to be an independent risk factor for CVA.[25]

Although this study is a retrospective review of prospectively collected data, it is likely to suffer from the inherent limitations of observational studies on nonrandomized patient groups. We attempted to control for imbalances between the various patient groups by stratification according to the predicted surgical risk using validated risk scoring systems. However, we were unable to control for other factors such as the patients' difference in extent or distribution of coronary artery disease and the difference in performance between individual surgeons and hospitals.

In conclusion, this study demonstrates that risk stratified morbidity and mortality are significantly lower in OPCAB patients than CPB patients and patients in the UK national database.

Acknowledgments

The statistical analysis was supported by a grant from the Garfield Weston Trust.

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