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Remote organ injury after coronary artery bypass grafting

Ph.D. thesis

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Introduction

Remote organ failure leading to recidivism following cardiac surgery

In recent times, there have been significant improvement in the reduction of mortality after coronary artery bypass grafting (CABG). However, with older and sicker patients there stills remains significant morbidity due to remote organ dysfunction which may require re-admission to intensive care unit (ICU). Following cardiac surgery the use of ICU facilities varies amongst various institutions. Factors such as preoperative organ dysfunction in the patient, the institutions physical constraints, high costs, individual surgical practice styles and the type of cardiac operation influence the use of ICU facilities following surgery. There is increasing pressure to make ICU beds available for cardiac surgery. This may be achieved my increasing the resources available or reducing the time the patients stay in ICU after cardiac surgery. However, patient care cannot be compromised at any cost. Hence, it is becoming increasingly important to identify patients at high risk of returning to the ICU for organ support, for example intra-aortic balloon pump (IABP), haemofiltration, ventilation, etc. during the same admission after undergoing cardiac surgery. Although criteria have been described for discharging patients out of general ICUs, there is very limited literature on the successful use of such guidelines on the outcome for patients following cardiac surgery. Since readmission to the ICU may imply that such patients have been discharged prematurely, ICU readmission rates have been proposed as measures of quality indexes. In the present cardiac literature, the incidence of recidivism following cardiac surgery for remote organ dysfunction and criteria defining patients at high risk of requiring step-up care have not been well described.

IABP use to prevent remote organ dysfunction after high-risk OPCAB

The use of IABP for haemodynamic instability and/or coronary ischaemia after CABG is well recognised. However, the effect of IABP on cardiac as well as remote organ function when it is inserted pre-operatively for high-risk off-pump coronary artery bypass grafting (OPCAB) is less well established. Dislocation of the heart during OPCAB in high-risk patients may result in haemodynamic instability and/or coronary ischaemia. High-risk CABG has been considered as a contra-indication for OPCAB by some authors. However, improvements in the functional design of OPCAB stabilizing devices and anaesthesia has led to the application of OPCAB to high-risk CABG patients which were previously deemed unsuitable for this technique and therefore selected for conventional cardio-pulmonary bypass (CPB). Despite significant advances in OPCAB technology and techniques, these patients remain more susceptible to deterioration and conversion to CPB due to severe multi-vessel disease, left main stem (LMS) stenosis or poor cardiac contractility with recognized increase in distant organ failure and mortality. Intituively, it would make sense to elect to insert IABP pre-operatively when procedures like off-pump coronary endarterectomy (CE) are contemplated. The elective use of IABP in these patients may prevent this and thus avoid the institution of CPB with its attendant risks to multiple body organs which include inflammation and global ischaemia. Although one may be lead to assume improvement of cardiac performance in such a situation, whether there is any benefit on remote organ function, if any, is not known. Conversely, the use of IABP in such circumstances may be harmful in terms of renal and vascular complications.

Remote organ outcomes after beating heart coronary endarterectomy

In the current era, cardiac surgeons are being referred patients with increasing frequency with diffuse coronary artery disease for consideration for CABG. Despite the introduction of CE 40 years ago as a method of treatment of diffuse coronary artery disease, its application remains controversial as it carries a higher perioperative risk leading to distant organ dysfunction and poorer long-term survival. It is a technically challenging procedure leading to prolonged surgery and CPB time, which may result in some inexperienced surgeons avoiding to undertake it with consequent incomplete revascularisation. Associated peri-operative myocardial infarction (MI) may lead to low-output syndrome, use of IABP and ensuing multi-organ failure. More recently, although several authors have reported better short-term outcome for different organ systems and improved long-term survival, it is still performed in a small proportion of CABG patients, in contrast to earlier decades when it was performed more frequently. Furthermore, to avoid the institution of CPB with its attendant risks of inflammation and global ischemia, CE with OPCAB, which is again very challenging, is considered by some present day centres as the technique of choice for the surgical management of coronary artery disease, specially in patients who are at high-risk of multiple organ failure. Although the aim of CE is to achieve complete revascularisation, improperly done this may result in further intervention either in the form of percutaneous coronary intervention or redo-CABG on the beating or the arrested heart.

Remote organ dysfunction after redo-CABG on the beating & the arrested heart

Remote organ dysfunction and mortality associated with redo-CABG are higher than those for first-time CABG. Although there has been a considerable reduction in mortality associated with redo-CABG, remote organ morbidity remains significant. Factors implicated in higher risk include increasing age, left ventricle (LV) dysfunction and associated comorbidities. Redo-CABG poses increased risk of haemorrhage, graft injury and embolisation into native coronaries due to graft manipulation. Particular issues include availability of conduits, complete revascularisation, myocardial protection and use of blood products. Strategies to avoid the above problems include different approaches of re-entry, careful graft dissection to minimise graft atheroembolism and modification in myocardial protection techniques on the basis of coronary anatomy and graft patency. Off-pump coronary revascularisation is an alternative method that avoids the inherent risks of CPB and potential benefits in terms of cardiac and remote organ outcome. To avoid the particular hazards of re-sternotomy, redo-OPCAB through a thoracotomy has been advocated, especially for patients requiring revascularisation of the circumflex and/or left anterior descending (LAD) coronary arteries. Careful patient selection and modification of the operative technique are of paramount importance in such cases to avoid cardiac as well as remote organ dysfunction. On the contrary, as with the heart-lung machine there is more room to achieve haemodynamic stability and end organ perfusion, with OPCAB especially in the redo setting there is potential for cardiovascular compromise and organ damage, for example, gastro-intestinal, cerebral, renal and pulmonary complications. The risk-benefit assessment of OPCAB in this setting remains to be explored.

Gastro-intestinal complications after CABG on the beating & the arrested heart

Gastro-intestinal (GI) complications are difficult to diagnose early after CABG because symptoms may not be evident due to sedation, mechanical ventilation with or without muscle paralysis, and analgesia. The ability to identify patients who are at greater risk of developing GI complications may allow earlier detection and treatment, thereby increasing the probability of a successful outcome. Patients requiring recidivism after CABG, those undergoing high-risk OPCAB, CE with OPCAB and redo-CABG and those with IABP in-situ, may be particularly prone to develop GI complications after CABG. These complications are rare (0.4%–2%) but result in high mortality. Although many retrospective reviews have reported various GI complications after CABG, including GI bleeding, mesenteric ischaemia, pancreatitis, cholecystitis, perforated ulcers, and ileus, very few studies have assessed the risk factors for developing GI complications and associated mortality using multivariate analysis in the same series. In clinical experience, mesenteric ischaemia, especially has a grave prognosis with or without surgery. Identification of factors that lead to higher mortality after development of GI complications may result in design of interventions and further studies that could improve the outcome of these patients.

Research Objectives

The overall primary aim of my study was to identify the risk and the effects of remote organ dysfunction on the outcome after CABG. Secondarily, my objective was also to identify whether any intervention could prevent remote organ dysfunction in high-risk OPCAB and if the addition of CE to OPCAB and performing redo-CABG by OPCAB increased the risk of remote organ dysfunction.

AIM I To determine the rate of recidivism for remote organ dysfunction, its relationship with the primary length of stay in the ICU, the remote organs involved and the independent predictors leading to its occurrence.
AIM II To establish whether pre-operative elective insertion of IABP in high-risk OPCAB prevents remote organ dysfunction.
AIM III To evaluate remote organ dysfunction in patients undergoing OPCAB+ CE.
AIM IV To compare remote organ dysfunction and late outcome of redo-on pump coronary artery bypass grafting (redo-ONCAB) versus redo-OPCAB.
AIM V To determine the risk factors for developing GI complications and the associated mortality in patients undergoing first-time CABG.

Materials and methods

Study 1: Recidivism

From 8113 consecutive adult patients who underwent CABG, valve replacement or repair and combined valve+CABG surgery between January 1996 and December 2003, a total of 7717 patients who were discharged alive from the cardiac ICU were retrospectively studied. Three hundred and ninety six patients who died in theatre or during their primary ICU stay were excluded. Information for the study was obtained from the cardiac surgical 'Patient Analysis and Tracking system' (PATS) database and hospital records. All patients who needed recidivism to the ICU for pulmonary, cardiac or distant organ support were identified and the yearly rate of recidivism determined. The principal organ for which recidivism was required, length of stay in the ICU as well as hospital following recidivism, the occurrence of post-operative multiple organ complications and outcome in terms of mortality were also determined in all patients.

Study 2: IABP

Six hundred and twenty five consecutive patients who underwent OPCAB between 1996 and 2004 formed the study group. A total of 45 (7.2%) high-risk patients fulfilling two or more of the following criteria: left main stem (LMS) stenosis ≥70%, unstable angina Canadian Cardiovascular Society (CCS) class III-IV or poor left ventricular ejection fraction (LVEF) ≤30% (as assessed by left ventriculography) who underwent OPCAB were identified. High-risk patients who had an elective pre-operative IABP inserted (Group I; n=20) were compared with similar high-risk patients (Group II) who did not (n=25). Group II was operated between 1996 and 2000 whereas group I was operated between 2001 and 2004. The pre-operative risk factors including remote organ dysfunction were similar between the two groups. Cardiac catheterization was performed in all patients. The preoperative LVEF was measured from biplane ventricular angiography by the area-length method. Patients who suffered with myocardial infarction (MI) within 4 weeks, those requiring emergency surgery, on inotrope infusions, with ongoing ischaemia or shock pre-operatively were excluded from the study.

Study 3: Coronary endarterectomy

Betwee n January 1995 and May 2004, of 680 OPCAB patients, 70 (10.29%) underwent concomitant CE. Any patient suitable for OPCAB (which in our practice includes those with poor LVEF and LMS disease) was considered for off-pump endarterectomy. Although it was suspected before surgery that CE may be required after reviewing the angiogram, the final decision was made during the procedure. In all cases, once the decision was made to perform CE, this was pursued off-pump as long as CE was feasible and could be achieved with safety. Clinical data were prospectively collected and entered into the PATS database. Also, the clinical notes of these patients were reviewed. When the information provided by the clinical notes was not adequate, the patient's general practitioner was contacted by telephone. Postoperative MI was defined as persistent electrocardiographic (ECG) changes such as new Q waves, loss of R-wave progression, new intraventricular conduction defects, or new echocardiographic evidence of wall motion abnormality. ECGs were performed in all patients on day 1 and day 4 postoperatively and more frequently if required. The median follow-up was 4.91 years (range: 0.9-9.4 years). Eleven patients were followed up for more than 8 years. Four patients were in their 10th year of follow-up.

Study 4: Redo-CABG

From April 2001 to September 2006 isolated elective redo-CABG was performed in 110 patients (redo-ONCAB=50 and redo-OPCAB=60). Applying the propensity score, 43 OPCAB patients were matched with 43 ONCAB patients. All five surgeons who operated on these patients were accustomed to both OPCAB and ONCAB surgery. Information for the study was obtained from the cardiac surgical PATS database and hospital records. Cardiac catheterisation was performed in all patients. The preoperative LVEF was measured from biplane ventricular angiography by the area-length method. Patients who required emergency surgery (n=8) and those in cardiogenic shock (n=1) were excluded from the study. All the patients had previously undergone ONCAB. The mean age of redo-OPCAB was 65±7.9 years and was similar to that of redo-ONCAB (p=NS). The mean EuroScore was 5±4.7 and 5±3.4 for redo-ONCAB and redo-OPCAB, respectively (p=0.5). The number of diseased coronary arteries was 3±0.5 and 2±0.8 in redo-ONCAB and redo-OPCAB, respectively (p<0.01). There were no differences in other preoperative risk factors between the two groups. The threshold for extubation was similar in both the groups and followed a standard protocol. Postoperative MI was defined as persistent ECG changes such as new Q waves, loss of R wave progression, new intraventricular conduction defects or new echocardiographic evidence of wall motion abnormality. ECGs were performed in all patients on the day of surgery and day 4 postoperatively (more frequently if required).

Study 5: Gastro-intestinal complications

Between April 2001 and December 2005, data were collected prospectively from 2,320 consecutive patients who underwent first-time CABG. Information for the study was obtained from our cardiac surgical PATS database and hospital records. Patients who had a MI within 4 weeks, those requiring concomitant valve or other surgery, and patients on inotropic infusions or in shock preoperatively were excluded from the study. All patients in our study were routinely started on proton-pump inhibitors postoperatively. Those who were already taking antacids, H^2 blockers, or proton pump inhibitors had their medication continued up to the day of surgery. Any suspicion of a GI complication was addressed by a GI surgeon or gastroenterologist. Paralytic ileus was diagnosed by a consultant general surgeon on the basis of clinical features (painless abdominal distension) and grossly distended bowel loops on plain abdominal radiographs. Once a complication was identified, a specialist referral was made immediately, and appropriate measures were taken. For upper and lower GI bleeding, both esophagogastroduodenoscopy and colonoscopy were performed. No patient required a laparotomy for GI bleeding. In suspected ischaemic bowel, the on-call general surgeon reviewed the patient, and if felt appropriate, a laparotomy was performed. Paralytic ileus was treated conservatively. Stepwise logistic multiple regression analyses were carried out to determine the independent predictors of GI complications and subsequent death. Two analyses were performed: the patients with GI complications were compared with those without GI complications; and the predictors of survival were determined in 51 patients who survived and 14 who died after GI complications.

Statistics

For study 1, statistics were obtained using the package STATISTICA for windows version 4.3, StatSoft Inc. USA. For the rest of the studies, statistical analysis was performed using SPSS software (version 12 for Windows for study 2-4 and version 15 for Windows for study 15; SPSS, Chicago, Illinois, USA). Preoperative and postoperative data are expressed as means±SD. Whilst continuous variables were compared between groups using the students 't' test or Mann Whitney U test, categorical data was compared between the two groups using the Fisher's exact test or chi-square test, where appropriate. To determine the influence of various factors on recidivism in study 1, patient variables that were considered to influence outcome were analysed using multiple regression analysis, with recidivism as a dependent variable. In study 4, the two techniques by the propensity score analysis. Propensity score matching of 50 redo-ONCAB and 60 redo-OPCAB patients was carried out using the psmatch2 command in STATA 9.2 (StataCorp, Texas, USA). A probit model was used with patients matched according to pre-operative variables. The model was then used to calculate a propensity score for each patient. This score was subsequently used to match patients in the on- and off-pump groups, using nearest-neighbour propensity score matching. Comparable patient groups were identified by matching 43 redo-ONCAB patients with 43 redo-OPCAB patients. In study 5, to determine the influence of various factors (including remote organ dysfunction on the incidence of GI complications and subsequent mortality, patient variables that might influence outcome were analysed using automated forward multiple regression analysis. Where appropriate, the Kaplan-Meier method was used to analyse actuarial survival and freedom from events (death, MI and repeat intervention). The log rank test was used to compare the survival and freedom from events between two groups. A value of $p < 0.05$ was considered significant in all statistical analyses.

Results

Recidivism

From 7717 patients who were discharged out of the ICU following CABG, valve and combined CABG+surgery, 2.3% (182) of patients (65.4% (119) males) required re-admission to the ICU for cardiac and/or remote organ support. The mean age of patients requiring readmission to ICU was 70.4±8.35 years (range 30–90 years) and not significantly different from those who did not require readmission [mean age 66.2±7.5 years (range 29–91 years) (p=0.09)]. Whilst recidivism following CABG was 1.8% (101/5633), recidivism following valve replacement/repair±CABG was significantly higher at 3.9% (81/2084) (p=0.05). Although showing a downward trend, the overall yearly recidivism rate has not changed significantly.

Primary length of stay in the ICU and interval to recidivism: Mean length of primary stay in the ICU of patients subsequently requiring recidivism was 2.5±3.4 days (range 5 hours-22 days) and longer (although statistically may well be the same) compared to the primary length of stay of those patients who did not require recidivism, which was 1.6±2.2 days (range 1 hour-35 days; p=0.4). Interestingly, the primary length of ICU stay did not have a significant effect on the rate of ICU recidivism in the multiple regression analysis. The mean interval from ICU discharge to ICU recidivism was 6.6±8.4 days (range 6 hours-28 days).

Causes of recidivism: Although some patients may had multiple remote organ complications, we classified the causes of recidivism on the basis of the prinicipal organ complication that lead to readmission to the ICU. Pulmonary complications requiring re-intubation and ventilation lead to 54.9% (n=100) of readmissions to the ICU. These included hospital-acquired and aspiration pneumonia, inability to clear secretions and poor ventilator reserve leading to hypoxia or ventilatory failure. Cardiovascular instability (includes that secondary to dysrythmias) and heart failure, contributed to 23.2% (n=42) of the recidivism patients. For the purpose of this study, cardiac dysrhythmias include new-onset AF, supraventricular tachycardia and ventricular tachycardia/fibrillation.

Length of ICU and hospital stay: Mean length of stay in the ICU following recidivism for organ dysfunction was 6.65±6.2 days (range 4 hours-51 days), whilst the mean length of hospital stay following recidivism was 19.2±17.3 days (range 10–60 days). The mean length of hospital stay of patients who did not require recidivism was 8.2±7.3 days (range 4–122 days; p<0.05).

Thirty-day hospital mortality: The hospital mortality in patients requiring ICU recidivism for organ support was significantly higher compared to those patients who did not require such care, 32.4% (n=59/182) versus 2.05% (n=155/7535; p<0.05).

Predictors of recidivism: Multiple regression analysis showed that previous history of MI (p=0.01) was the only independent pre-operative risk factor for recidivism. During the primary post-operative ICU stay (i) respiratory problems (p=0.00001), (ii) low cardiac output state requiring post-operative IABP (p=0.00001), (iii) cardiac dysrhythmias (p=0.003), (iv) acute renal failure requiring haemofiltration (p=0.003) and (v) re-exploration for bleeding (p=0.02) were independent predictors of recidivism. Also, combined CABG+valve surgery emerged as an independent predictor of ICU recidivism (p=0.01).

Intra-aortic Balloon Pump

Mean age in group I was 64±9.4 years compared to 63±12.2 years in group II [p=not significant (NS)]. Group I consisted of 11 patients (55%) and group II 15 patients (60%, p=NS) with CCS class III/IV. There were 8 patients in each group with significant LMS disease. Poor LVEF was present in 18 patients (90%) in Group I and 17 patients (68%) in Group II (p=NS). Pre-operative creatinine was 113.2±24.3 μmol/L in group I and 113.1±20.3 μmol/L in group II. There were no significant differences in the number of patients with diabetes, cerebrovascular events, Q wave infarction and peripheral vascular disease between the two groups (p=NS). Mean Euroscore was 5.9±1.8 in group I and 5.7±2.0 in group II (p=NS). In the post-operative period, there were no significant differences between the two groups regarding the need for inotropic support with 9 patients requiring small doses of adrenaline in group I as compared to 11 patients in group II (p=NS) with a mean of 0.02 mcg/kg/min in both groups. Although the number of hours ventilated in the ICU was higher in group I (15.6±3.2 hours) versus group II (12.9±4.9 hours), this was not statistically significant. Patients in group I (with IABP) stayed longer on the ICU (27.7±15.3 hours) in comparison to group II (18.5±9.1 hours; $p<0.05$). There was a tendency towards earlier discharge in group I (6.5±2.0 days) compared to group II (7.2±4.2 days). Recidivism occurred in one patient in group I who required readmission to ICU for five days. New-onset AF occurred in 7 patients (35%) in group I and 9 patients in group II (36%; p=NS). None of the patients in group I had acute renal dysfunction (creatinine rise >200μmol/L). By contrast, 5 patients in group II had acute renal dysfunction/oliguria and 3 patients required hemofiltration ($p<0.05$). One patient returned to theatre for re-exploration for bleeding in group II. There were no other significant post-operative pulmonary, neurological, infective or GI complications. The IABP in group I was removed after a mean period of 1.6±0.8 days.

There were no IABP-related complications. Four patients (16%) in group II required post-operative insertion of IABP in ICU. At 30-days, one patient died in each group.

Coronary endarterectomy

Fifty-seven patients (81%) underwent right coronary artery endarterectomy (RCA) (conduit used: 4 radial arteries, 1 short saphenous vein, 52 long saphenous veins), 12 patients (17%) underwent LAD endarterectomy (conduit used; 8 left internal mammary arteries (LIMA), 4 long SVs) and 1 patient underwent obtuse marginal endarterectomy (conduit used: 1 long SV). Four patients (5.7%) had two vessels endarterectomised whereas the rest had single-vessel endarterectomy. The mean number of grafts was 2.01±0.44. No patient required pulmonary ventilation for more than 24 hours, and there were no conversions to CPB. A mean of 0.86±0.17 units of blood was transfused postoperatively and 70% of the patients required 1 unit or less. The 30-day mortality rate was 2.8%, and there were 9 late deaths. The follow-up was 95.7% complete (67 patients); 90% of patients were angina free at median follow-up of 4.6 years, and the actuarial survival at 10 years was 78.04%±7.6% (figure 3). The rest of the postoperative characteristics are listed in table 6. In our conventional CABG practice, 10.8% patients (n=125 of 1153) underwent CE. RCA endarterectomy was performed in 65%, LAD endarterectomy in 28%, and RCA plus LAD endarterectomy in 6.4%patients.

Redo-CABG

Twelve patients underwent redo-OPCAB through anterior thoracotomy (1 double and 11 single grafts): 8 LAD artery grafts (1 pedicled LIMA, 5 RAs and 2 long SVs) 3 circumflex artery grafts (3 long SVs) and 2 diagonal artery grafts (2 long SVs). The five RAs were anastomosed proximally to the subclavian artery and long SVs to the descending aorta. The remaining patients underwent median sternotomy. In one patient OPCAB was converted to ONCAB because of haemodynamic instability. The mean number of grafts performed was 3±0.8 in redo-ONCAB and 2±0.6 in redo-OPCAB ($p<0.05$). The need for postoperative insertion of an IABP was higher ($p=0.02$) in redo-ONCAB (n=9, 21%) than redo-OPCAB (n=1, 2%). The IABP was inserted for haemodynamic instability in all patients. However, there was no significant difference in inotrope use in the two groups (0.02±0.05 mcg/kg min in redo-ONCAB vs 0.01±0.002 mcg/kg min in redo-OPCAB; p=NS). The duration of postoperative lung ventilation was 55±98.7 h for redo-ONCAB and 10±12.8 h for redo-OPCAB (p=0.008). One patient in the redo-ONCAB group sustained a clinically significant perioperative MI (as determined by new Q waves and a rise in troponin I). No other differences were found in the incidence of postoperative AF, re-operation for bleeding, ARF, neurological injury, readmission to the ICU, wound infection and the length of hospital stay (p=NS) between the two groups. The 30-day mortality rate was 6.9% for redo-ONCAB (n=3) and 2.3% redo-OPCAB (n=1; p=NS) with an overall mortality of 4.6%. The mean follow-up for redo-ONCAB was 30±21.3 months (range 0.1-63 months) and that of redo-OPCAB was 37±19.2 months (0.1-62.5 months). Actuarial survival at 5 years was 87±5.5% for redo-ONCAB and 95±3.2% for redo-OPCAB (p=0.17). Event-free survival (death, MI and repeat intervention) was 71±8.0% for redo-ONCAB and 78±7.2% for redo-OPCAB (p=0.32).

Gastro-intestinal complications

Sixty-five major GI complications were identified in 65 patients; the incidence of GI complications was 2.8%. The hospital mortality from any cause in patients who suffered GI complications was significantly higher than in those without GI complications. Mortality was highest in patients with mesenteric ischaemia (10/12; 83.3%). Multivariate analysis identified female sex, preoperative serum creatinine >200 μmol/L, previous history of GI pathology, perioperative low cardiac output, readmission to ICU, postoperative pulmonary complications, arrhythmias, postoperative need for haemofiltration and reoperation for bleeding or tamponade as independent predictors of GI complications. Pulmonary complications included hospital-acquired and aspiration pneumonias, inability to clear secretions, and poor ventilatory reserve leading to hypoxia or ventilatory failure. For the purpose of this study, cardiac dysrhythmias included new-onset AF, supraventricular tachycardia and ventricular tachycardia or fibrillation. Use of CPB was not significant. Univariate risk analysis for prediction of death after GI complications was also performed. On multivariate analysis, independent risk factors for death were readmission to the ICU, the need for haemofiltration, reoperation, and ischaemic bowel. The main cause of readmission to the ICU was cardio-pulmonary compromise.

Conclusion

In this thesis, my primary aim was to study remote organ outcomes after high-risk ONCAB and OPCAB. In the first study, I examined the subject of reinstitution of step-up care (recidivism) due to adverse remote organ outcome following cardiac surgery. I, therefore, studied 8113 consecutive patients who underwent cardiac surgery to determine the reasons for readmission to ICU and independent predictors of recidivism. I found that the overall incidence of recidivism was 2.3% and this was higher for CABG+Valve (3.9%) versus CABG alone (1.8%). The principal reasons for recidivism were (i) pulmonary (54.9%) (ii) cardiac (23.1%) (iii) re-exploration for tamponade/bleeding (7.7%) (iv) renal (6.6%) (v) GI complications requiring laparotomy (6.0%) and (vi) sepsis (1.1%). Multivariate analysis showed that, during primary ICU stay, pulmonary complications, low cardiac output state, dysrhythmias, ARF requiring haemofiltration and re-exploration for bleeding were independent predictors of recidivism. Following recidivism the 30-day in-hospital mortality was 32.4%. Patients who required mechanical support to maintain vital functions following surgery were most prone to recidivism. Hence, efforts should be made to treat cardio-respiratory problems early in this group of patients to reduce ICU recidivism. Since this study was conducted, there have been considerable changes in cardiac surgical practice like increasing use of IABP and OPCAB surgery which my conclusions. Next, I examined the effects of elective insertion of IABP in high-risk OPCAB patients on organ systems. Six hundred and twenty five patients who underwent OPCAB formed the study group. High-risk patients (fulfilling ≥2 of the following: LMS >70%, unstable angina and poor LVEF) who had elective insertion of IABP pre-operatively by the open technique (Group I; n=20) were compared with a similar high-risk group who did not (Group II; n=25). Post-operatively, there were no significant differences in the mortality, inotropic need, period of ventilation, arrhythmias, cerebrovascular, GI and infective complications (p=NS). However, ARF requiring haemofiltration was higher in Group II (n=5; $p<0.05$). Although ICU stay was longer in Group I (27.6±15.3 vs 18.6±9.1 hours; $p<0.05$), patients in Group I were discharged earlier from hospital. Here, I concluded that in high-risk patients undergoing OPCAB, routine pre-operative insertion of IABP electively reduces the incidence of ARF and results in earlier discharge. In the next phase of my research, I decided to examine whether OPCAB with CE is feasible with acceptable remote organ outcomes. Out of 680 OPCAB patients, 70 (10.2%) underwent concomitant CE. Eighteen patients (35%) had impaired LVEF. Fifty-seven patients (81%) underwent RCA endarterectomy and 12 patients (17%) underwent LAD endarterectomy (8 LIMA used as conduits). The 30-day mortality rate was 2.85% (n=2). Three patients (4.3%) suffered from postoperative MI and 3 patients (4.3%) required postoperative IABP. Fourteen patients (20%) had postoperative AF and only 1 patient (1.42%) each had a transient stroke , reopening for bleeding and ARF requiring haemofiltration. The actuarial survival at 10 years was 78.04±7.6%. I concluded that OPCAB with coronary endarterectomy has minimal cardiac as well as remote organ morbidity including cerebral, pulmonary, GI and renal outcomes. This procedure achieves surgical revascularisation in patients with diffuse coronary artery disease which if performed inadequately may lead to the need of redo-CABG in the form of redo-OPCAB or redo-ONCAB. After this, I set to compare redo-CABG on the beating versus the arrested heart in primarily in terms of remote organ outcomes. A total of 110 patients formed the study cohort (redo-ONCAB, n=50; redo-OPCAB, n=60). Applying the propensity score, 43 OPCAB patients were matched with 43 ONCAB patients. Twelve patients underwent OPCAB through anterior thoracotomy while the rest of the patients (n=74) underwent median sternotomy. Mean number of grafts performed was 3±0.8 in redo-ONCAB and 2±0.6 in redo-OPCAB ($p<0.05$). The need for postoperative insertion of IABP was higher ($p=0.02$) in redo-ONCAB (n=9, 21%) than redo-OPCAB (n=1, 2%). The duration of postoperative pulmonary ventilation was 55±98.7 h for redo-ONCAB and 10±12.8 h for redo-OPCAB ($p = 0.008$). No differences were found in the incidence of other renal or neurological complications. The 30-day mortality rate was 6.9% for redo-ONCAB (n=3) and 2.3% redo-OPCAB (n=1; p=NS). Actuarial survival at 5 years was 87±5.5% for redo-ONCAB and 95±3.2% for redo-OPCAB ($p=0.17$). Event-free survival was 71±8.0% for redo-ONCAB and 78±7.2% for redo-OPCAB ($p=0.32$). Here, I established that redo-CABG on the beating versus the arrested heart leads to improved cardiac as well as pulmonary outcomes and redo-OPCAB did not lead to increased GI, cerebral or renal adverse outcomes. In the last study of my PhD thesis, the main objective was to determine the independent risk factors (including remote organ dysfunction) of GI complications and the associated mortality afterr CABG. Data was collected prospectively from 2320 consecutive patients. There were 65 major GI complications identified in 65 (2.8%) patients: paralytic ileus in 15, mesenteric ischaemia in 12, upper GI haemorrhage in 16, lower GI haemorrhage in 8, small bowel obstruction in 5, pseudoobstruction in 5, and others in 4. Thirty-day mortality was 21.5% (14 patients). Female sex, preoperative creatinine >200 µmol/L, previous GI pathology, low cardiac output, readmission to the ICU, postoperative pulmonary complications, arrhythmias, haemofiltration, and reoperation were independent predictors of major GI complications. Independent risk factors for death were readmission to the ICU, the need for haemofiltration, reoperation and ischaemic bowel. Here, I determined that with CABG being performed in older and sicker patients with multiple organ derangements, a higher level of vigilance is mandatory to ensure swift referral of suspected cases to specialists for early diagnosis and rapid treatment of GI complications.

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