Re-sternotomy for aortic valve replacement with patent coronary artery bypass grafts

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Abstract

Objective - The aim was to evaluate early and long-term outcomes of re-sternotomy for aortic valve replacement with previous patent coronary artery grafts. Methods - Data for re-sternotomy for aortic valve replacements (group 1 isolated AVR, group 2 AVR with concomitant procedure) were collected (2000-19). Logistic regression analysis was performed to identify predictors of in-hospital mortality and postoperative composite outcome (in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days). Survival curves were compared using log rank test. Cox proportion hazards model was used for predictors of long term survival. Results – Total 178 patients were included (groups 1 - 90 patients, group 2 - 88 patients). Mean age was 75±4 years and mean log EuroSCORE was 17±12% (15 ± 8% - group 1 vs 19 ± 14% - group 2, p=0.06). Mean follow up was 6.3±4.4 years. Cardiovascular injury occurred in 12%. LIMA was most commonly injured. In-hospital mortality was 7.8% (5% - group 1 versus 10.2% - group 2, p=0.247). NYHA class III-IV, perioperative IABP and cardiovascular injury were independent predictors of in-hospital mortality (HR; 13.33, 95% CI; 2.04, 83.33, p=0.007). Survival was significantly worse with cardio-vascular injury at re-sternotomy up to 5 years (46% versus 67%, p=0.025) and postoperative complications (p=0.023). Survival was significantly lower than age matched first time AVR and UK population. Conclusions – Long term survival is significantly impaired by cardiovascular injury and perioperative complications of re-sternotomy.

Introduction

Re-sternotomy for cardiac surgery remains a challenging procedure with associated morbidity and mortality (1,2). Re-sternotomy is more challenging with patent coronary artery bypass grafts (CABG) due to risk of graft injury and myocardial jeopardy. With increasing life expectancy and a wider use of biological prostheses, a greater number of patients would need re-sternotomy for aortic valve replacement (AVR) later in life. Transcatheter valve therapy now presents a compelling, safe option to avoid re-sternotomy especially in high to intermediate risk severe aortic stenosis patients with patent coronary grafts not needing any other concomitant procedures (3,4). The aim of this study was to evaluate early and long-term outcomes of patients who underwent AVR with a re-sternotomy with patent CABG.

Methods

This is a single centre, retrospective study. Data for re-sternotomy for AVR with or without another concomitant cardiac procedure were retrospectively collected from 2000 – 2019 from the hospital database (Patient Administration System, e-CAMIS, Yeadon, Leeds, UK). All patients with previous CABG who had re-sternotomy for AVR with or without another concomitant cardiac procedure were included. Emergency/salvage operations and infective endocarditis were excluded. Approval was obtained from the institutional review committee. Consent for individual use of data was waived due to the nature of the study and prior approval for use of such data at the time of consent for procedures.

Baseline demographic characteristics included variables used for risk stratification as previously defined for EuroSCORE (table 1). Data for previous operations was collected for number of previous sternotomies, type of previous surgery, left internal mammary artery (LIMA) use and patency and presence of other grafts. Operative and postoperative data included type and extent of surgery, injury to cardiac structures at re-sternotomy, myocardial protection, cross clamp time, total bypass time, re-exploration for bleeding/tamponade, new postoperative transient ischemic attack (TIA)/stroke, new hemofiltration, deep sternal wound infection, in-hospital mortality (death before hospital discharge) and length of stay (number of days from the date of operation to discharge).

The standard procedure of re-sternotomy at our institution was followed. The strategy of peripheral cannulation prior to re-sternotomy was based on surgeon preference and perceived risk of injury at re-entry. All re-sternotomies were performed with an oscillating saw. All cardiac injuries and catastrophic bleeding at re-entry were dealt with standard protocols. For patent LIMA, a strategy of endovascular balloon occlusion or isolation and clamping after re-sternotomy was employed. Myocardial protection was achieved with cold blood antegrade or retrograde cardioplegia with use of mild to moderate systemic hypothermia.

Statistical analysis

Categorical variables were presented as number and percentage. Univariable comparisons of preoperative, operative and postoperative variables were performed between patients who underwent re-sternotomy and isolated AVR (group 1) and re-sternotomy and AVR with a concomitant cardiac procedure(s) (group 2) using the chi-square test (categorical variables) or Mann-Whitney U test (continuous variables).

A multivariable logistic regression analysis, using a backward stepwise variables selection with $p<0.15$, was performed to identify predictors of in-hospital mortality and a postoperative (predischarge) composite outcome of in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days. Variables included were: gender; age; previous myocardial infarction; NYHA class; diabetes mellitus; hypertension; COPD; creatinine>200 µmol/l; extracardiac arteriopathy; LVEF<30%; use of IABP; previous left internal thoracic artery (LIMA); patent LIMA; injury at re-sternotomy (involving LIMA, vein graft(s), right atrium, right ventricle, aorta, pulmonary artery); LIMA injury; CPB established before re-sternotomy; isolated AVR, period (2000-2009 or 2010-2019). A p value of < 0.05 was considered statistically significant.

Long term survival statistics were collected from a combination of Patient Administration System (e-CAMIS) and the NHS Spine Portal Summary Care Records (SCR) which is an electronic database of GP medical records. Kaplan-Meier survival curves were plotted and compared using the log rank test.

Cox proportional hazards model with backward elimination with $p<0.15$ was used to determine predictors for long term survival (calculated from the date of discharge to death or last follow up). Proportionality assumption was checked using Schoenfeld residuals.

Subgroup survival analysis was performed for group 1 versus group 2, for those with and without the composite of perioperative complications and for those with and without cardiovascular injury at re-sternotomy. Cardiovascular injury was defined as injury to a graft/any mediastinal cardiac or vascular structure.

Survival data for the cohorts was compared with age matched survival data for first time AVR at our unit for the period and age-matched UK population data from the Office of National Statistics, UK.

Results

A total of 178 patients were included (90 – group 1 and 88 – group 2, Table 1). Mean age was 75 ± 4 years and the mean log EuroSCORE was 17 ± 12% (15 ± 8% - group 1 vs 19 ± 14% - group 2, p=0.06). Mean follow up was 6.3±4.4 years (range 0 - 18 years).

Majority of patients (97.7%) had single previous sternotomy (Table 1). Most common previous procedure was an isolated CABG (83%). A previous CABG and concomitant AVR/ root replacement was performed in 12%. The mean interval from previous operation was 11.4±6.4 years.

LIMA was present in 75% of the patients (134/178 patients) and patent in 95% (127/134 patients).

Perioperative outcomes

Peripheral cannulation and cardiopulmonary bypass prior to re-sternotomy were instituted in 16% (group 1 - 17%, group 2 – 15%, p=0.73). Cardiovascular injury during re-sternotomy was recorded in 21 cases (12%). LIMA was the most commonly injured structure (6.2%) (Table 2). Mean cardiopulmonary bypass time was 140 ± 67 min (111 ± 47 min, group 1 and 169 ± 72 min, group 2, p<0.001). Mean cross clamp time was 74 ± 36 min (56 ± 20 min, group 1 and 93 ± 40 min, group 2, p<0.001) (Table 2).

In-hospital mortality was 7.8%, 5%, in group 1 versus 10.2%, in group 2, p=0.247 (Table 3). There was no difference in the composite outcome of perioperative complications (overall 19.1% (34/178), 14.4%, group 1 versus 23.8% group 2, p=0.110)

On multivariable analysis, NYHA class III-IV, perioperative IABP and cardiovascular injury to a mediastinal structure at re-sternotomy were independent predictors of in-hospital mortality (HR; 13.33, 95% CI; 2.04 to 83.33, p=0.007) (Table 4). COPD, LVEF<30% and perioperative IABP were predictors of a worse composite outcome of perioperative complications (Table 4).

Long term survival

There was no difference in survival between group 1 and 2; survival was 87% versus 84%, p=0.575 at 1 year, 64% versus 66%, p=0.880 at 5 years, 33% versus 57%, p=0.062 at 10 years, respectively (Figure 1A and supplementary Table 1).

Among patients who were discharged alive from hospital, those with postoperative complications had a lower survival compared with patients who had an uncomplicated postoperative course (p=0.023) (Figure 1C, supplementary Table 1). Survival was worse up to 5 years in those with a cardiovascular injury at re-sternotomy (46% versus 67%, p=0.025, Figure 1B and supplementary Table 1).

Postoperative complications, age and history of cerebrovascular accident were independent predictors of long term survival (Table 5).

The survival probability for the overall cohort with re-sternotomy was 85% (SE: 2.7%), 65% (SE: 3.7%), 44% (SE: 4.2%) and 17% (SE: 4.5%) at 1-year, 5-years, 10-years and 15-years, respectively, and was significantly lower than the age matched survival of patients who had first time AVR +/- other procedure(s) and the age matched survival of UK population (Figure 2).

Discussion

The present study tries to address the important question whether it is still reasonable to undertake a re-sternotomy for AVR in patients with patent CABG in the era of transcatheter valve therapy.

The reported mortality of re-sternotomy is 6-20% (5-7). Mayo Clinic reported 8% early mortality for conventional redo biological valve replacements over 20 years in a mixed series of aortic and mitral valve replacements. New York Heart Association functional class (hazard ratio, 2.1; 95% confidence interval, 1.06-4.3; P = 0.03) and prior CABG (hazard ratio, 3.5; 95% confidence interval, 1.2-10.9; P = 0.03) were independent predictors of early death (8). Survival at 5 and 10 years was 63% and 34% respectively. Patients with the combination of prior CABG and New York Heart Association functional class III or IV accounted for 46% of early deaths.

Our in-hospital mortality of 7.8% compares favourably with these results. We divided our patients into 2 subgroups based on the premise that group 1 (isolated AVR with re-sternotomy and no other concomitant cardiac procedure) have the option of TAVI. They can potentially avoid a risky and complex operation and have a reduced hospital stay and quicker recovery.

The in-hospital mortality in group 2 was almost twice that of group 1 (10.2%, group 2 versus 5%, group 1, p=0.247). Although, this did not reach statistical significance, a concomitant procedure does add to the complexity of surgery and increases risk.

These mortality rates are still remarkably high compared to isolated first time AVR with mortality of 0.5-1.9% (9-12). In addition to the hazard of surgery itself, there may also be the additional hazard associated with long standing ischemic heart disease in combination with aortic valve disease. Our analysis showed that the long-term survival of patients undergoing first time isolated AVR approaches that of an age-matched general population whereas it lags behind significantly after a re-sternotomy AVR in patients with previous surgical myocardial revascularisation.

Attempts to dissect and control LIMA increases risk of injury and operative mortality (13,14). Patent LIMA in a perfused heart bloodies the operative field with inconvenience of stitching on a beating heart. In conjunction with moderate to deep hypothermia on a fibrillating heart, this technique has been considered safe and avoids injury to LIMA (15,16). Systemic hyperkalaemia with adjunctive hypothermia, for diastolic arrest is a safe proposition, to avoid injury to LIMA when dissection is difficult due to adhesions.

Pre-sternotomy institution of cardiopulmonary bypass through peripheral cannulation is considered a safe strategy to manage any catastrophic bleeding. It decreases myocardial injury and complication rates, blood and blood product usage, hospital stay and hospital costs (17). In this analysis, our numbers may have been too small for estimation of the effects of LIMA injury and pre-sternotomy institution of cardiopulmonary bypass.

TAVI now provides a safe option for isolated AVR in patients with a hostile chest. These include previous multiple sternotomies, sternal infections and mediastinitis, prior irradiation, elderly, frail patients, calcified aorta/root. TAVI allows a shorter hospital stay and a lower postoperative morbidity rate compared to re-sternotomy (18,19). Stortecky et al reported that in elderly, high-risk patients after prior CABG, conventional AVR and TAVI are comparable treatment options. All-cause mortality was 2.5% in both groups and major adverse cardiac and cerebrovascular event rates were comparable (7.5% TAVI vs 17.5% S-AVR, $p = 0.311$) after 30 days. TAVI had a higher rate of permanent pacemaker implantation (30% vs 0%, $p < 0.001$) and grade II residual aortic regurgitation in 14%. Incidence of cerebrovascular events was 7.5% in SAVR vs 2.5% in TAVI ($p = 0.61$).

Patent grafts can also provide protection in cases of low coronary ostial heights especially for high profile transcatheter valves. There remain concerns for high paravalvular leak rates, permanent pacemaker implantation, sub-valvular leaflet thrombosis, need for anticoagulation and long-term durability of transcatheter valves (20-22).

There is a significant economic burden with re-sternotomies due to longer ventilation times, intensive care and hospital stay and need more intensive tests and treatments like inotropic support, hemofiltration, invasive and non-invasive ventilator support and intra-aortic balloon pumps. Our analysis did not evaluate the cost burden of these procedures. No direct cost comparisons are available between re-sternotomies and TAVI. With increasing TAVI volumes, greater operator experience and decreasing costs, TAVI remains an attractive option in this group of difficult surgical patients.

Best practice recommendations now include discussions in the Heart Valve Team to ensure the most appropriate procedure in terms of technical feasibility, safety and durability. Frail and comorbid patients may benefit from a less invasive intervention, however, in case of concomitant diseases, a complete treatment with a complex conventional surgical operation should not be avoided despite relatively high initial comorbidity.

Limitations

This is a single centre, retrospective analysis with inherent selection biases. The number of patients in the subgroup analyses' may have been small for evaluation of true effects and impact on perioperative outcomes and long-term survival. There was also a heterogeneity of techniques used for patent grafts and myocardial preservation, which makes comparisons difficult.

Conclusions

Re-sternotomy in the presence of patent grafts remains challenging with high morbidity, mortality and prolonged length of stay. Long term survival is significantly impaired by cardiovascular injury at re-sternotomy and perioperative morbidity of surgery. Survival is less than first time AVR and that for matched general population.

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Table 1. Preoperative patients' characteristics

	Overall (n = 178)	**Group 1 (n = 90)**	**Group 2 (n = 88)**	**P value**
	Mean ± SD or N (%)	Mean ± SD or N (%)	Mean ± SD or N (%)	
Gender M/F	139/39	75/15	64/24	0.087
Age (y)	75±8	76±6	73±8	0.033
Previous MI	55 (31%)	29 (32%)	26 (29%)	0.669
NYHA class III-IV	86 (48%)	43 (48%)	43 (48%)	0.885
IDDM	9 (5%)	5 (5%)	4 (5%)	0.972
Hypertension	135 (76%)	65 (72%)	70 (80%)	0.254
Smoking history	120 (67%)	60 (67%)	60 (68%)	0.829
COPD	30 (17%)	16 (18%)	14 (16%)	0.739
Creatinine>200 µmol/l	5 (3%)	3 (3%)	2 (3%)	0.980
Cerebral stroke	9 (5%)	4 (4%)	5 (6%)	0.972
Extracardiac arteriopathy	25 (14%)	10 (11%)	15 (17%)	0.255
LVEF<30%	11 (6%)	3 (3%)	8 (9%)	0.199
Logistic EuroSCORE (%)	17±12	15±8	19±14	0.059
Previous operation(s)				
Number of previous sternotomies 1 2	174 4	87 3	87 1	0.629

	Overall (n = 178)	**Group 1 (n = 90)**	**Group 2 (n = 88)**	**P value**
Interval time between actual and prior operations (years)	11.4 ± 6.4	10.9 ± 6.0	11.9 ± 6.8	0.349
Type of previous operations Isolated CABG Associated AVR Associated MVr/R Associated ARR	148 (83%) 20 (11%) 6 (3%) 2 (1%)	71 12 4 1	77 8 2 1	0.125 0.370 0.698 0.487
Type of conduits LIMA RIMA Radial artery Saphenous Vein	134 (75%) 2 (1%) 6 (3%) 162 (91%)	72 1 2 84	62 1 4 78	0.139 0.487 0.657 0.273
NYHA – New York Heart Association, IDDM – Insulin dependent diabetes mellitus, COPD – chronic obstructive pulmonary disease, LVEF – left ventricular ejection fraction, LIMA – Left internal mammary artery, RIMA – right internal mammary artery, CABG – coronary artery bypass grafting, MVr/R – mitral valve repair/ replacement, ARR – aortic root replacement,	*NYHA – New York Heart Association, IDDM – Insulin dependent diabetes mellitus, COPD – chronic obstructive pulmonary disease, LVEF – left ventricular ejection fraction, LIMA – Left internal mammary artery, RIMA – right internal mammary artery, CABG – coronary artery bypass grafting, MVr/R – mitral valve repair/ replacement, ARR – aortic root replacement,*	*NYHA – New York Heart Association, IDDM – Insulin dependent diabetes mellitus, COPD – chronic obstructive pulmonary disease, LVEF – left ventricular ejection fraction, LIMA – Left internal mammary artery, RIMA – right internal mammary artery, CABG – coronary artery bypass grafting, MVr/R – mitral valve repair/ replacement, ARR – aortic root replacement,*	*NYHA – New York Heart Association, IDDM – Insulin dependent diabetes mellitus, COPD – chronic obstructive pulmonary disease, LVEF – left ventricular ejection fraction, LIMA – Left internal mammary artery, RIMA – right internal mammary artery, CABG – coronary artery bypass grafting, MVr/R – mitral valve repair/ replacement, ARR – aortic root replacement,*	*NYHA – New York Heart Association, IDDM – Insulin dependent diabetes mellitus, COPD – chronic obstructive pulmonary disease, LVEF – left ventricular ejection fraction, LIMA – Left internal mammary artery, RIMA – right internal mammary artery, CABG – coronary artery bypass grafting, MVr/R – mitral valve repair/ replacement, ARR – aortic root replacement,*

Table 2. Chest re-entry, myocardial protection and performed procedures

	Overall	**Group 1**	**Group 2**	**P value**
	Mean ± SD or Number (%)	Mean ± SD or Number (%)	Mean ± SD or Number (%)	
Re-entry				
Patent LIMA	127 (71%)	69 (77%)	58 (66%)	0.1125

	Overall	**Group 1**	**Group 2**	**P value**
CPB before re-sternotomy	28 (16%)	15 (17%)	13 (15%)	0.7286
Injury at the re-entry Re-sternotomy LIMA Right atrium LIMA/Right ventricle Aorta Vein graft Isolation pre CPB institution LIMA Vein graft Pulmonary artery Isolation post CPB institution LIMA Vein graft	21 (12%) 8 4 1 1 1 1 9 5 3 1 4 2 2	4 (4%) 2 1 1 0 0 0 1 1 0 0 1 0 1	17 (19%) 6 3 0 1 1 1 8 4 3 1 3 2 1	0.0045
Myocardial protection				
LIMA occlusion External occlusion Endoballoon	58/127 (46%) 53 5	34/69 (49%) 33 1	24/58 (41%) 20 4	0.3736
Retrograde cardioplegia	27 (15%)	21 (23%)	6 (7%)	0.0021
Moderate hypothermia 20-28°C	21 (12%)	10 (11%)	11 (13%)	0.7740
Performed procedures				
Isolated AVR	90	90	-	
Associated procedures CABG MV surgery Aortic surgery Aortic root replacement	88 75 11 9 6	-	88	
CPB times (minutes)	140 ± 67	111 ± 47	169 ± 72	<0.0001
Cross clamp times (minutes)	74 ± 36	56 ± 20	93 ± 40	<0.0001
AVR – Aortic Valve replacement, CABG – Coronary Artery Bypass Grafting, CPB – Cardiopulmonary Bypass, LIMA – Left Internal Mammary Artery	*AVR – Aortic Valve replacement, CABG – Coronary Artery Bypass Grafting, CPB – Cardiopulmonary Bypass, LIMA – Left Internal Mammary Artery*	*AVR – Aortic Valve replacement, CABG – Coronary Artery Bypass Grafting, CPB – Cardiopulmonary Bypass, LIMA – Left Internal Mammary Artery*	*AVR – Aortic Valve replacement, CABG – Coronary Artery Bypass Grafting, CPB – Cardiopulmonary Bypass, LIMA – Left Internal Mammary Artery*	*AVR – Aortic Valve replacement, CABG – Coronary Artery Bypass Grafting, CPB – Cardiopulmonary Bypass, LIMA – Left Internal Mammary Artery*

Table 3. Postoperative outcomes and survival

Sternal wound infection
Re-exploration for bleeding/tamponade
Renal replacement therapy
Cerebrovascular accident Permanent stroke TIA
LOS median [IQR] (days)
LOS > 30 days
Composite outcome*
Permanent pacemaker Pre discharge Post discharge
Overall in-hospital mortality LIMA patency Injury at the re-entry LIMA injury

Group 1 – re-sternotomy for isolated aortic valve replacement with patent coronary grafts Group 2 – re-sternotomy for aort

Table 4. Predictors of in-hospital mortality and composite outcome by multivariable logistic regression analysis and backward stepwise variable selection with p<0.15.

	P value	**Odds ratios**	**95% Confidence Limits Lower/Upper**	**95% Confidence Limits Lower/Upper**
In-hospital mortality	**In-hospital mortality**	**In-hospital mortality**	**In-hospital mortality**	**In-hospital mortality**
NYHA III-IV	0.026	7.81	1.28	47.62
LVEF<30	0.084	5.71	0.79	41.67
Previous LIMA	0.11	0.25	0.04	1.36
Cardiovascular injury at re-entry	0.007	13.33	2.04	83.33
Perioperative IABP	<0.001	38.46	6.76	250.00
Age (years)	0.13	1.09	0.98	1.21
Composite perioperative outcome*	**Composite perioperative outcome***	**Composite perioperative outcome***	**Composite perioperative outcome***	**Composite perioperative outcome***
Gender (Male)	0.058	2,69	0,97	7,52
NYHA III-IV	0.065	2,34	0.95	5,78
COPD	0.036	3,15	1,08	9,26
Creatinine>200µmol/l	0.111	5,10	0,69	38,46
LVEF<30%	0.005	8,40	1,88	38,46
Injury at the re-entry	0.097	2,66	0,84	8,40
Perioperative IABP	0.010	4,22	1,41	12,66

**Composite of in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association; IABP: intra-aortic balloon pump; LIMA: left internal mammary artery; LVEF: left ventricle ejection fraction*	**Composite of in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association; IABP: intra-aortic balloon pump; LIMA: left internal mammary artery; LVEF: left ventricle ejection fraction*	**Composite of in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association; IABP: intra-aortic balloon pump; LIMA: left internal mammary artery; LVEF: left ventricle ejection fraction*	**Composite of in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association; IABP: intra-aortic balloon pump; LIMA: left internal mammary artery; LVEF: left ventricle ejection fraction*	**Composite of in-hospital death, TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleeding/tamponade and length of stay >30 days COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association; IABP: intra-aortic balloon pump; LIMA: left internal mammary artery; LVEF: left ventricle ejection fraction*

Table 5. Cox proportional hazards analysis for predictors of long-term survival after discharge from hospital.

Variables
Age
Hypertension
COPD
History of CVA
LVEF<30
Postoperative complication(s)*
**Composite of postoperative TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-explora*

Supplementary table 1. Subgroup analysis of time stratified survival

Survival 1-year 5-years 10-years 15-years

Survival 1-year 5-years 10-years 15-years

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Postoperative TIA/stroke, renal failure requiring new hemofiltration, deep sternal wound infection, re-exploration for bleedin

Figures

Figure 1

A. Re-sternotomy for isolated aortic valve replacement (group 1) versus re-sternotomy for aortic valve replacement with another concomitant cardiac procedure (group2), log rank p= 0.205.

B. Comparison of composite outcome of perioperative complications of sternal wound infection, re-exploration for bleeding or tamponade, renal replacement therapy and/or length of stay >30 days (log rank p=0.023)

C. Cardiovascular injury versus safe entry at re-sternotomy,5 years, log rank p=0.025.

Figure 2

The survival for re-sternotomy was significantly worse compared to age matched first time isolated AVR (2000-2019) and the age matched general UK population, log rank p<0.0001