Acta Scientific Cardiovascular System

Volume 1 Issue 1 April 2022

Research Article

Reoperation after Cardiac Surgery: Risk Factors and Outcomes

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Received: January 17,2022

Published: January 31, 2022

Abstract

Objectives: To determine the risk factors for re-exploration after cardiac surgery and its most frequent cause, using propensity score matching, and to study the effect of re-exploration on mortality and ICU readmission.

Methods: Retrospective observational study of pre-surgical, intra-surgical and post-surgical data on participants derived from the prospective regional *ARIAM* database. Participants are consecutive patients undergoing cardiac surgery in a third level hospital in Spain, single center, between January 2014 and December 2018.

Results: Cardiac surgery was performed in 2,152 patients during the study period; 5.4% required re-exploration, mainly for cardiac tamponade (56%) or bleeding (19.8%). Non-re-explored and re-explored groups selected by propensity score matching did not significant differences in any study variable. The mortality risk did not differ between the matched groups (OR 1.17; 95% CI 0.61-2.25). Re-explored patients had a higher risk of ICU readmission in both the global series (OR 21.61; 95% CI 13.08-35.70) and matched cohort (OR 8.50; 95% CI 3.09-23.39).

Conclusions: In these cardiac surgery patients, the most frequent cause of re-exploration was cardiac tamponade. Re-exploration was associated with an increased risk of ICU readmission but not an increased risk of mortality. Figure 1.

Keywords: Cardiac Surgery; Re-Exploration; ICU Readmission

Introduction

Chest re-exploration is required in the immediate postoperative period by up to 5% of patients undergoing cardiac surgery [1]. The main indications are bleeding, hemodynamic instability (clinical suspicion of cardiac tamponade), and cardiac arrest [2,3]. Postoperative bleeding is associated with higher patient morbidity (sepsis, arrhythmia, low cardiac output, kidney failure, prolonged mechanical ventilation, longer ICU/hospital stay) and greater resource utilization [4,5]. Surgical or coagulopathic factors can be responsible for the bleeding [6]. Certain patient characteristics have also been identified as risk factors for re-exploration, including high age, low BMI, time on ECC, five or more anastomoses, and/or need for non-elective surgery [7].

The main objective of this study was to use propensity score matching to determine the risk factors for re-exploration and its most frequent cause. Secondary objectives were to evaluate the association of re-exploration with ICU readmission and mortality.

Methods

A retrospective observational study was conducted in consecutive patients undergoing cardiac surgery in a third-level hospital (Virgen de las Nieves Hospital, Granada, Spain) between January 2014 and December 2018, including: routine coronary surgery (on-pump and off-pump), valve procedures, complex aortic surgery, and procedures for congenital heart defects and post-infarction complications. Patients receiving transcatheter aortic valve implantation were excluded. Heart transplantation is not carried out at our center. The pre-operative antiplatelet and anticoagulation management and the transfusion and coagulation protocols at our center follow the recommendations and algorithms of the European Associations of Cardiothoracic Surgery and Cardiothoracic Anesthesiology [8] and are guided by thromboelastography results, with routine use of cell saver and administration of fibrinogen.

Study variables

Data were gathered by physicians responsible for entering data from our center in the ARIAM registry of the Andalusian Public Health Service and trained for this purpose [9].

Pre-operative data were gathered on: pre-surgery hospital department (ICU/ward), surgery type (elective, urgent, emergency), preoperative diagnosis, EuroSCORE, SAPS 3 score, age, sex, NYHA stage, and history/presence of anemia, antiplatelet, or anticoagulation therapy, percutaneous coronary intervention, cardiac surgery, obesity, hypertension, COPD, severe pulmonary hypertension, AMI, congestive heart failure, peripheral vascular disease, stroke, or kidney failure (creatinine > 1.2 mg/dl). Surgery was defined as elective when pre-planned, urgent when necessary, within 24-48 hours, and emergency when immediate intervention was required. Intraoperative data were collected on any major bleeding (transfusion of ≥ 4 units RBC), ECC time, circulatory arrest, and aortic cross-clamp time. Postoperative data were gathered on: complications, including cardiogenic shock, perioperative myocardial infarction, sternal dehiscence, sepsis, multiple organ failure, stroke, mechanical ventilation > 24h, and/or renal replacement therapy (continuous or intermittent dialysis); number and cause of re-explorations; time on mechanical ventilation time; and length of ICU stay of re-explored patients. Information was also collected on the mortality and need for ICU readmission, as outcome variables.

Statistical analysis

In a descriptive analysis, absolute (n) and relative (%) frequencies were calculated for qualitative variables and means and standard deviations or, when the distribution was non-normal (by Kolmogorov-Smirnov test), medians and percentiles (Me [P25-P75]) were calculated for continuous variables. Bivariate analysis of re-exploration-related factors was performed using the Student's t-test or, when the distribution was non-normal, the Mann-Whitney test for numerical variables, and by means of Pearson's chi-square test or Fisher's exact test, as appropriate, for qualitative variables. A multivariate logistic regression model was developed, entering variables that were significant in the bivariate analyses ($p < 0.05$) and using a backward stepwise approach, with $p < 0.05$ and $p > 0.10$ as entry and exit criteria, respectively. The area under the receiver operating characteristic (ROC) curve was used to evaluate the predictive capacity of the final model.

Differences were observed in many characteristics between patients who underwent re-exploration and those who did not. Therefore, in order to minimize confounding bias, propensity score matching was applied to select a subgroup of non-re-explored patients that was as similar as possible to the re-exploration group, using the nearest neighbor matching approach without replacement. Variables that were significant in the multivariate logistic analysis were used for the matching process, *i.e.,* obesity, previous acute myocardial infarction, severe pulmonary hypertension, antiplatelet therapy in previous 24 hours, endocarditis, three-vessel coronary disease, aortic aneurysm, pre-surgical NYHA, nature of surgery (elective, urgent, emergency), major bleeding (≥ 4 RBC units), ICU complications, mechanical ventilation time, renal replacement therapy, hemoglobin level (<12g/dl), ECC time, aortic cross-clamp time, Euro SCORE, SAPS 3 score, and type of valve intervention.

Mortality and ICU readmission data for the matching cohorts were analyzed as outcome variables, calculating odds ratios (ORs) with 95% confidence interval (CI). SPSS version 19 (IBM, Armonk, NY) and Stata 12 software (College Station, TX: Stata Corp LP) were used for statistical analyses.

Results

Between January 2014 and December 2018, cardiac surgery was performed in 2,152 patients: 60.7% male, with a mean ± SD

age of 64.31 ± 12.31 years. The history/presence of hypertension was recorded in 62.9% of the patients, dyslipidemia in 46.9%, obesity in 32.3%, diabetes in 29.5%, chronic kidney disease in 24%, AMI in 15.4%, COPD in 12.5%, and severe pulmonary hypertension in 11.5%. The preoperative diagnosis was aortic stenosis in 39.5%, mitral regurgitation in 26.4%, aortic regurgitation in 24%, three-vessel disease in 12.2%, and type A aortic dissection in 2.9%. Before surgery, 67.7% of the patients were in NYHA I-II and 32.4% in NYHA III-IV. The surgery was elective for 73% of patients, urgent for 22.6%, and emergency for 4.4%. Re-exploration was performed in 5.4% of cases (n = 116). Table 1 displays the characteristics of the re-explored and non-re-explored groups. These groups did not significantly differ at baseline in age, sex, diabetes, hypertension, COPD, previous anticoagulant medication, or previous cardiac surgery; however, the re-explored group had a higher percentage of obese patients, patients with severe pulmonary hypertension, those receiving mechanical ventilation > 24 h, and those receiving emergency surgery, and the patients had a higher NYHA class, longer ECC time, greater intraoperative bleeding, and higher ICU readmission and mortality rates in comparison to the non-re-explored patients.

	Non-re-exploration N = 2036 (94.6%)	**Re-exploration N = 116 (5.4%)**	**P value**
Preoperative			
Age, Me[P_{25}-P_{75}]	67 [57-73]	68[59-74]	0.608
Female	793 (38.9)	53 (45.7)	0.148
Obesity	643 (31.6)	50 (43.1)	0.015
Diabetes	607 (29.8)	28 (24.1)	0.213
HBP	1270 (62.4)	78 (67.2)	0.247
P. myocardial infarct	319 (15.7)	13 (11.2)	< 0.001
P. congestive heart failure	452 (22.2)	26 (22.8)	0.882
Peripheral vascular disease	71 (3.5)	1 (0.9)	0.179
P. cerebrovascular event	107 (5.3)	6 (5.3)	0.998
Chronic lung disease	255 (12.5)	13 (11.4)	0.723
Severe Pulmonary Hypertension	226 (11.1)	22 (19.3)	0.008
P. kidney failure	483 (23.7)	33 (28.9)	0.205
P. hemoglobin, Me[P_{25}-P_{75}]	13.5[12.1-14.8]	12.9[11.3-14.5]	0.007
P. antiplatelet medication	739 (36.4)	31 (27)	0.041
P. anticoagulant medication	662 (32.6)	45 (39.1)	0.146
P. PCI	186 (9.1)	15 (12.9)	0.172
P. Cardiac surgery	210 (10.3)	17 (14.7)	0.139
Mitral incompetence	525 (25.8)	44 (37.9)	0.004
Mitral stenosis	215 (10.6)	15 (12.9)	0.421
Aortic incompetence	473 (23.2)	44 (37.9)	< 0.001
Aortic stenosis	810 (39.8)	41 (35.3)	0.342
Tricuspid incompetence	203 (10)	19 (16.4)	0.027
Endocarditis diagnosis	112 (5.5)	18 (15.5)	< 0.001
3-Vessel coronary disease	257 (12.6)	5 (4.3)	0.008
Aortic aneurysm	185 (9.1)	17 (14.7)	0.045
NYHA Scale			0.006
I	578 (28.5)	22 (19.3)	
II	807 (39.8)	41 (36)	
III	543 (26.8)	39 (34.2)	
IV	99 (4.9)	12 (10.5)	
Pre-Surgery Origin			0.002
Hospital ward	1878 (92.4)	98 (84.5)	
ICU	154 (7.6)	18 (15.5)	
Surgical Priority			0.001
Elective	1494 (73.4)	77 (66.4)	
Urgent	460 (22.6)	26 (22.4)	
Emergency	82 (4)	13 (11.2)	
EuroSCORE, mean ± SD	9.77 ± 11.29	13.83 ± 13.70	< 0.001
SAPS 3, mean ± SD	40.92 ± 10.88	45.84 ± 12.53	< 0.001

INTRAOPERATIVE			
Major bleeding (≥ 4 RBC)	315 (16.1)	31 (27)	0.003
ECC, Me[P_{25}-P_{75}]	105[80-139]	125[90-175]	< 0.001
Clamping, Me[P_{25}-P_{75}]	80[61-111]	94[68-138.5]	0.001
Circulatory stop, Me [P_{25}-P_{75}]	27.5[17-41]	24.5[19.2-36.5]	0.742
POSTOPERATIVE			
Death	201 (9.9)	33 (28.4)	< 0.001
Complications			
Cardiogenic shock	168 (8.5)	41 (35.3)	< 0.001
Perioperative myocardial Infarct	73 (3.7)	5 (4.3)	0.617
Sternal dehiscence	2 (0.1)	7 (6.0)	< 0.001
Sepsis	49 (2.5)	6 (5.2)	0.121
Multi-organic failure	105 (5.5)	20 (17.2)	< 0.001
Stroke	41 (2.1)	5 (4.3)	0.106
Mechanical ventilation > 24h	304 (15.5)	72 (62.1)	< 0.001
RRT	91 (4.6)	13 (11.2)	0.002
ICU readmission	50 (2.8)	36 (38.3)	< 0.001

Table 1: Cohort characteristics.

ECC: Extracorporeal Circulation; HBP: High Blood Pressure; P: Previous; PCI: Percutaneous Coronary Intervention; RRT: Renal Replacement Therapy.

Out of the 116 re-explored patients (Table 2), 56% were male, 86.2% had initially received elective or urgent surgery, which was valve or aortic surgery in 96.6% of cases. Re-exploration was for tamponade in 56%, bleeding in 19.8%, and sternal dehiscence in 11.2% of patients. When re-explorations were classified as early (≤ 48 h post-surgery) or late (> 48 h post-surgery), the most frequent reasons for the former were bleeding (in 30.6%) and tamponade (in 64.5%), whereas late re-exploration was most frequently carried out for tamponade (46.3%), sternal dehiscence (24.1%) and valve-related causes (14.8%). The hospital stay was also longer for late re-explorations (8 [3-15.5] vs. 13[7.5-25] days, p = 0.007). No difference in mortality rate was observed, being 27.4% for early re-explorations and 29.6% for late re-explorations (p = 0.792).

	Global Re-exploration N (%) 116 (100)	**Early Re-exploration N (%) 62 (53.4)**	**Late Re-exploration N (%) 54 (46.6)**	**P value**
Sex Female	51 (44)	23 (37.1)	28 (51.9)	0.110
Antiplatelet	36 (31)	22 (35.5)	14 (25.9)	0.267
Anticoagulant	39 (33.6)	17 (27.9)	22 (40.7)	0.146
Previous Surgery Priority Level				
Elective/Urgent	100 (86.2)	49 (81.7)	51 (94.4)	0.038
Emergency	14 (12.1)	11 (18.3)	3 (5.6)	
Type of Surgery				
CABG/Other	3 (2.6)	3 (4.9)	0 (0)	
Valve/Aortic	112 (96.6)	58 (95.1)	54 (100)	0.246
Re-exploration Causes				

Endocarditis	8 (6.9)	5 (8.1)	3 (5.6)	0.722
Bleeding	23 (19.8)	19 (30.6)	4 (7.4)	0.002
Cardiac tamponade	65 (56)	40 (64.5)	25 (46.3)	0.049
Valve	9 (7.8)	1 (1.6)	8 (14.8)	0.012
Coronary	3 (2.6)	2 (3.2)	1 (1.9)	1
Dehiscence	13 (11.2)	0 (0)	13 (24.1)	<0.001
Infection	5 (4.3)	0 (0)	5 (9.3)	0.020
Others	4 (3.4)	1 (1.6)	3 (5.6)	0.337
Complications				
MV time (Days), Me[P_{25}-P_{75}]	3[1-6]	4[1-8.25]	2[0-5.5]	0.012
Length ICU stay (Days), Me[P_{25}-P_{75}]	11[6-19.5]	8[3-15.5]	13[7.5-25]	0.007
Death	33 (28.4)	17 (27.4)	16 (29.6)	0.792

Table 2: Re-exploration Group characteristics.

CABG: Coronary Artery Bypass Graft; MV: Mechanical Ventilation

In the multivariate analysis, re-exploration was associated with obesity (OR 1.680; 95% CI 1.115-2.533), pre-surgical diagnosis of endocarditis (OR 2.636; 95% CI 1.422-4.888), valvular/aortic surgery (OR 4.366; 95% CI 1.358-14.034), and ECC time> 120 min (OR 1.853; 95% CI 1.233-2.783) (Table 3).

	OR (95% CI)	P value
Obesity	1.680 (1.11-2.53)	0.013
Endocarditis Diagnosis	2.636 (1.42-4.88)	0.002
Valve/Aortic Disease Surgery	4.366 (1.35-14.03)	0.013
Extracorporeal Circulation > 120 minutes	1.853 (1.23-2.78)	0.003

Table 3: Multivariate analysis of risk factors related to Re-exploration.

In order to compare mortality and readmission rates between non-re-explored and re-explored groups with minimum confounding effects, propensity score matching was carried out for the variables that differed between them. The matched groups comprised 98 re-explored patients and 98 non-re-explored patients, with no statistically significant between-group difference in any study variable (Table 4).

	Global cohort			Propensity – matched cohorts		
	Non-re-exploration N = 2036 (94.6%)	Re-exploration N=116 (5.4%)	P value	Non-re-exploration N = 98 (50.0%)	Re-exploration N = 98 (50.0%)	P value
Female Sex	793(38.9)	53(45.7)	0.148	42(42.9)	42(42.9)	1.000
Obesity	643(31.6)	50(43.4)	0.015	46(46.9)	43(43.8)	0.669
P. myocardial Infarct	319(15.7)	13(11.2)	< 0.001	8(8.2)	8(8.2)	1.000
Severe Pulmonary Hypertension	226(11.1)	22(19.3)	0.008	21(21.4)	21(21.4)	1.000

P. antiplatelet	739(36.4)	31(27)	0.041	25(25.5)	26(26.5)	0.871
Endocarditis	112(5.5)	18(15.5)	< 0.001	17(17.3)	16(16.3)	0.850
3-vessel coronary disease	257(12.6)	5(4.3)	0.008	4(4.0)	5(5.1)	0.735
Aortic aneurysm	185(9.1)	17(14.7)	0.045	13(13.2)	15(15.3)	0.685
Major bleeding	315(16.1)	31(27)	0.003	31(31.6)	25(25.5)	0.343
ECC , Me[P_{25}-P_{75}]	105[80-139]	125[90-175]	< 0.001	128[84.75-164.25]	123.5[90-170.5]	0.593
Clamping, Me[P_{25}-P_{75}]	80[61-111]	94[68-138.5]	0.001	95[72.75-127.25]	94[68-137.25]	0.865
MV >24h	304(15.5)	72(62.1)	< 0.001	61(62.2)	59(60.2)	0.771
RRT	91(4.6)	13(11.2)	0.002	17(17.3)	12(12.2)	0.317
Dead	201 (9.9)	33 (28.4)	< 0.001	23(23.4)	26(26.5)	0.621
ICU re-admission	50(2.8)	36(38.3)	< 0.001	5(6.6)	31(37.8)	< 0.001

Table 4: Characteristic in the global cohort and propensity-matched cohorts**.**

ECC: Extracorporeal Circulation; Major Bleeding: ≥ 4 RBC Units; MV: Mechanical Ventilation; P: Previous; RRT: Renal Replacement Therapy

In the logistic regression analysis for mortality, re-explored patients had a higher risk of death in the global cohort (OR 3.61; 95% CI 2.35-5.54), but the mortality risk did not differ between the matched groups (OR 1.17; 95% CI 0.61-2.25). In the multivariate analysis for ICU re-admission, re-explored patients had a higher risk of readmission not only in the global cohort (OR 21.61; 95% CI 13.08-35.70) but also in the matched cohort (OR 8.50; 95% CI 3.09-23.39).

Discussion

In this study of cardiac surgery patients, re-exploration was associated in the global series with obesity, a previous diagnosis of endocarditis, valvular/aortic surgery, and EEC for more than 2 hours. However, risk factors did not differ between homogeneous groups of re-explored and non-re-explored patients selected by propensity score matching. In this comparison, re-exploration did not prove to be a risk factor for mortality, although it was a risk factor for ICU readmission.

Previous studies have associated prolonged ECC time (> 2 hours) in the initial surgery with the need for re-exploration [4,10,11]. However, obesity has not generally been associated with re-exploration; on the contrary, a low body mass index has been described as a risk factor [4,10]. Our finding may be influenced by the large proportion of obese patients, which was 32.2% in the global series and 43.1% in the re-explored patients. It is possible that both a high and a low body mass index increase the likelihood of re-exploration, underscoring the value of achieving a weight within the normal range before elective cardiac surgery. Nevertheless, after matching explored and non-re-explored patients to minimize confounding factors, no risk factors were significantly associated with re-exploration.

Re-exploration was performed due to instability of the patient with hypotension and hypoperfusion requiring vasoactive drugs, fluid therapy and transfusions. The most frequent reason for re-exploration was for tamponade in 56%, bleeding in 19.8%, and sternal dehiscence in 11.2% of patients. When re-explorations were classified as early or late, the most frequent reasons for the former were bleeding (in 30.6%) and tamponade (in 64.5%), whereas late re-exploration was most frequently carried out for tamponade (46.3%), sternal dehiscence (24.1%) and valve-related causes (14.8%).

Patients undergoing re-exploration > 48 h post-surgery had a longer ICU stay in comparison to those re-explored within 48 h, thherefore, close monitoring of the patient and repeated echocardiographic controls are important. Nevertheless, there was no difference between them in mortality rate. The shorter ICU stay may be explained by the lesser time with hemodynamic instability

(blood loss, tissue hypoxia, vasoactive drugs ...) and consequently lower degree of multiorgan dysfunction.

These data are in partial agreement with previous reports of a longer ICU stay, longer time on mechanical ventilation and higher mortality in patients undergoing late re-exploration, although this was defined as > 12 h post-surgery, which may explain the discrepancies with our study [7, 12]. Comparison with other studies is hampered by the wide variability in their definitions of "early" and "late" re-exploration.

In the global series of patients, the morbidity and mortality associated with re-exploration were similar to previous reports, including a higher mortality [4,13,14,11], longer time on mechanical ventilation [4,13,10], higher rate of acute kidney failure [4,13,10,11] and greater need for dialysis [10]. In the comparison between matched groups of re-explored and non-re-explored patients, however, re-exploration was not related to an increase in mortality risk. These results are consistent with the findings of Tambe., *et al*. [15], who observed no difference between re-explored and non-re-explored patients in mortality, acute kidney failure, or sternal wound infection; however, they are in disagreement with authors describing re-exploration for bleeding as a lethal and morbid complication of cardiac surgery [16].

We highlight the greater risk of ICU readmission in patients undergoing re-exploration, both in the global series and matched cohorts, which is associated with a higher consumption of resources. This may be attributable to the debilitating effects of two surgeries, delaying the mobilization of the patients and increasing their risk of post-surgical complications [16,17].

This study is limited by its single-center and retrospective design. However, the sample size was substantial, and the possibility of election and confounding biases was minimized by adopting a propensity score matching approach. As an experimental study, the combination of various statistical methods allowed results to be contrasted and combined from different perspectives, yielding more complete information [18].

Conclusions

Re-exploration after cardiac surgery is a relatively frequent complication, most commonly due to cardiac tamponade. No risk factor was significantly associated with re-exploration, which was not related to a higher mortality rate. However, re-exploration was associated with a higher risk of ICU readmission.

Declarations of Interest

none.

Funding Statement

None.

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