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Original Article

Hospital outcome and predictors of mortality of primary isolated on-pump coronary artery bypass grafting in acute coronary syndrome

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Abstract

Background

The effect of surgical treatment on patients with acute coronary syndrome (ACS) is disputable. The objective of the present study was to analyze the outcome, in-hospital mortality, and its predictors as well as major adverse cardiac and cerebrovascular events in patients referred to coronary artery bypass grafting (CABG) with ACS presentation.

Patients and methods

Hospital medical records of ACS presentation were retrieved from Madinah Cardiac Center database between November 2011 and August 2017. A total number of 630 patients who underwent primary isolated CABG for ACS presentation were identified. Of these, unstable angina (UA) pectoris was present in 277 patients (group I), 253 patients (group II) had non-ST-elevation infarction, whereas 100 patients (group III) had ST-elevation infarction. All preoperative, intraoperative, and postoperative data were analyzed. In-hospital mortality and its predictors were determined.

Results

Overall in-hospital mortality was 6.5% ($n = 41$), being 4% in UA ($n = 11$), 8.7% in non-ST elevation myocardial infarction (NSTEMI) ($n = 22$), and 8% ($n = 8$) in ST elevation myocardial infarction. Mortality was significantly higher only in NSTEMI compared with UA ($P = 0.05$). Although cardiac causes of death were significantly higher in ST elevation myocardial infarction compared with UA ($P = 0.04$), noncardiac causes were significantly higher in NSTEMI compared with UA ($P = 0.04$). Logistic regression analyses identified age more than 65 years, New York Heart Functional Association 3, ejection fraction less than 45%, and Logistic EuroSCORE more than 10 as significant predictors of in-hospital mortality.

Conclusion

Primary isolated on-pump CABG can be performed in patients with ACS presentation as a revascularization option with acceptable clinical results. However, clinical outcome differs among different groups of ACS. Therefore an individual risk stratification of each patient in ACS is necessary.

Keywords: Acute coronary syndrome, coronary artery bypass, mortality, outcome, predictors

Introduction

Acute coronary syndrome (ACS) is a spectrum of diseases including unstable angina (UA) pectoris, non-ST segment elevation myocardial infarction (NSTEMI), and ST segment elevation myocardial infarction (STEMI). Cardiogenic shock develops in ~ 5–10% of patients with acute myocardial infarction (AMI) presentation of ACS. It is caused by heart failure in ~ 80% of these cases, and the mortality in this group can be as high as 50–80% [1–3].

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The effect of surgical treatment on patients with ACS is disputable [4]. This is related to conflicting levels of risk, with mortality ranging between 5 and 30% in some historical series. As a consequence, the importance of coronary surgery in this patient group must be reevaluated. Obviously, the clinical outcome seems to be affected by the different subgroups, namely, patients with elevation MI (STEMI), NSTEMI, and UA [4–6].

In this retrospective study, our clinical results after surgical therapy of ACS were analyzed with a view of each subgroup, and we identified prognostic variables of in-hospital mortality. The number of bypass grafts and completeness of revascularization were also reported, and the latter was calculated by the use of the index of completeness of revascularization (ICOR): performed anastomosis/preoperative planned. Postoperative data, including all relevant data, representing the ICU course, use of inotropic drugs, intra-aortic balloon pump (IABP) use, in-hospital mortality, and postoperative complications, were recorded.

Patients and methods

At Madinah Cardiac Center, Kingdom of Saudi Arabia hospital, records of 630 ischemic heart disease patients who underwent coronary artery bypass grafting (CABG) from November 2011 and August 2017 with ACS presentation were reviewed, and these patients were categorized into three groups: UA, NSTEMI, and STEMI. This was according to the European Society of Cardiology and American College of Cardiology Committee redefinition of MI (AMI) [7]. UN was present in 43.9% (n = 277), 40.1% (n = 253) had NSTEMI, whereas 15.8% (n = 100) had STEMI.

In this study redo-CABG, salvage CABG (CPR in progress), any associated valvular heart disease, and any mechanical complications of MI were excluded. Regarding the timing of surgery, only patients presented with cardiogenic shock were revascularized emergently by CABG when their anatomy was deemed unsuitable for percutaneous coronary intervention (PCI), otherwise urgent CABG was done usually after 3–4 days of stabilization with preoperative use of IABP as dictated by patients' clinical condition and need.

Ethical considerations

Retrospective observational study based on data retrived from hospital database with token permission of the authority by the author.

Surgical management

The operative revascularization was performed by means of cardiopulmonary bypass (CPB) (on-pump CABG) with myocardial protection obtained by antegrade cold intermittent blood cardioplegia with systemic cooling to 32ºC.

Analyzed preoperative, intraoperative, and postoperative data

Preoperative data included all demographic data; comorbidities including chronic obstructive pulmonary disease (COPD), diabetes, cerebrovascular disease (any previous history regardless of severity), renal disease, hypertension, and peripheral vascular disease (PVD); Canadian Cardiovascular Society classification; and clinical status according to New York Heart Functional Association (NYHA) classification. Logistic EuroSCORE was used for operative risk assessment [8].

Intraoperative data included duration of operation, CPB, reperfusion and cross-clamp times, the use of the internal mammary artery, and the number of bypass grafts. Completeness of revascularization was calculated by the use of the ICOR: performed anastomosis/preoperative planned.

Postoperative data included all relevant data representing the ICU course such as the use of inotropic drugs and the IABP, in-hospital mortality, and postoperative complications.

Study end points

Primary end point of this study was in-hospital mortality, defined as death from any cause within 30 days after CABG or during the same time period of hospitalization. In addition, postoperatively major adverse cardiac and cerebrovascular events (MACCE) including in-hospital death, stroke [cerebrovascular accident (CVA)], perioperative MI, and coronary re-intervention were recorded. Perioperative MI was defined as any new Q wave or loss of R in the electrocardiogram, persistent ST-segment elevation, new akinetic/dyskinetic segment (identified at echocardiography), and associated significant increase in cardiac markers. In addition, postoperative low-cardiac output syndrome (LCOS) and cardiopulmonary resuscitation for cardiac arrest were also recorded.

Secondary study end points were other postoperative complications such as major bleeding with necessity for re-exploration and postoperative renal failure requiring dialysis.

Statistical analysis

Data were collected, revised, coded, and entered to the Statistical Package for Social Science (IBM SPSS, (IBM Corp., Armonk, NY, USA)), version 23. The quantitative data were presented as mean, SDs, and ranges when their distribution was found to be parametric. Moreover, qualitative variables were presented as number and percentages. The comparisons between groups with qualitative data were done by using χ^2 test. The comparison between more than two independent groups with quantitative data and parametric distribution was done by using one-way analysis of variance followed by post-hoc analysis using LSD test, whereas with nonparametric distribution was done by using Kruskal–Wallis test followed by post-hoc analysis using Mann–Whitney test. Logistic regression analysis was used to assess predictors of mortality in our study. The confidence interval was set to 95% and the

Table 1: Demographic and preoperative data of the study groups

	UA (*n*=277) [*n* (%)]	NSTEMI (*n*=252) [*n* (%)]	STEMI (*n*=100) [*n* (%)]	Test	*P*	*P*1	*P*2	*P*3
Age								
Mean±SD	58.54±9.74	58.19±9.86	57.05±9.30	0.863[a]	0.423	0.682	0.190	0.321
Range	35-84	9-84	31-77					
Sex								
Females	56 (20.2)	42 (16.7)	19 (19.0)	1.111*	0.574	0.294	0.794	0.602
Males	221 (79.8)	210 (83.3)	81 (81.0)					
Hypertension								
No	162 (58.5)	160 (63.5)	59 (59.0)	1.509	0.470	0.238	0.928	0.433
Yes	115 (41.5)	92 (36.5)	41 (41.0)					
DM type 1								
No	251 (90.6)	215 (85.3)	86 (86.0)	3.788	0.151	0.060	0.199	0.870
Yes	26 (9.4)	37 (14.7)	14 (14.0)					
DM type 2								
No	237 (85.6)	202 (80.2)	78 (78.0)	4.059	0.131	0.099	0.080	0.651
Yes	40 (14.4)	50 (19.8)	22 (22.0)					
COPD								
No	240 (86.6)	216 (85.7)	89 (89.0)	0.668	0.716	0.757	0.544	0.414
Yes	37 (13.4)	36 (14.3)	11 (11.0)					
PVD								
No	249 (89.9)	226 (89.7)	77 (77.0)	12.816	0.002	0.937	0.001	0.002
Yes	28 (10.1)	26 (10.3)	23 (23.0)					
CVA								
No	228 (82.3)	218 (86.5)	84 (84.8)	1.784	0.410	0.185	0.564	0.686
Yes	49 (17.7)	34 (13.5)	15 (15.2)					
Preoperative MI								
No	227 (81.9)	173 (68.7)	61 (62.2)	19.581	0.000	0.000	0.000	0.253
Yes	50 (18.1)	79 (31.3)	37 (37.8)					
Preoperative PCI								
No	236 (85.2)	221 (87.7)	74 (74.0)	10.442	0.005	0.402	0.012	0.002
Yes	41 (14.8)	31 (12.3)	26 (26.0)					
Smoking								
No	162 (58.5)	145 (57.5)	54 (54.0)	0.608	0.738	0.826	0.437	0.546
Yes	115 (41.5)	107 (42.5)	46 (46.0)					
Renal failure								
No	244 (88.1)	203 (80.6)	81 (81.8)	6.038	0.049	0.017	0.118	0.786
Yes	33 (11.9)	49 (19.4)	18 (18.2)					
NYHA								
1	87 (31.5)	44 (17.6)	12 (12.0)	43.348*	0.000	0.002	0.000	0.000
2	103 (37.3)	116 (46.4)	44 (44.0)					
3	60 (21.7)	68 (27.2)	18 (18.0)					
4	26 (9.4)	22 (8.8)	26 (26.0)					
Ejection fraction								
Mean±SD	55.92±5.12	51.56±4.37	51.03±4.18	72.170[a]	0.000	0.000	0.000	0.342
Range	40-68	44-89	43-64					
Atrial fibrillation								
No	252 (91.0)	209 (83.3)	89 (89.0)	7.412*	0.025	0.008	0.565	0.176
Yes	25 (9.0)	42 (16.7)	11 (11.0)					
cTnI								
Median (IQR)	0.03 (0.02-0.05)	15 (12-18)	25 (22.5-27)	520.024[b]	0.000	0.000	0.000	0.000
Range	0.01-0.09	10-29	15-30					
CK-MB								
Median (IQR)	12 (7-16)	46 (39-50)	49 (40-53)	467.703[b]	0.000	0.000	0.000	0.000
Range	2-17	28-52	33-55					

Contd...

Table 1: Contd...

	UA (n=277) [n (%)]	NSTEMI (n=252) [n (%)]	STEMI (n=100) [n (%)]	Test	P	$P$1	$P$2	$P$3
Left main disease								
No	122 (44.0)	102 (40.6)	47 (47.0)	1.340*	0.512	0.429	0.610	0.276
Yes	155 (56.0)	149 (59.4)	53 (53.0)					
Single-vessel disease								
No	252 (91.0)	237 (94.0)	92 (92.0)	1.791*	0.408	0.182	0.756	0.483
Yes	25 (9.0)	15 (6.0)	8 (8.0)					
Double-vessel disease								
No	169 (61.0)	207 (82.5)	79 (79.0)	32.937*	0.000	0.000	0.001	0.450
Yes	108 (39.0)	44 (17.5)	21 (21.0)					
Triple-vessel disease								
No	135 (48.7)	61 (24.3)	29 (29.3)	36.389*	0.000	0.000	0.001	0.336
Yes	142 (51.3)	190 (75.7)	70 (70.7)					
CCS								
Mean ± SD	3.26±0.61	3.21±0.64	3.17±0.71	0.907[a]	0.404	0.329	0.225	0.631
Range	2-4	2-4	2-4					
IABP								
No	277 (100.0)	219 (87.3)	80 (80.0)	49.692*	0.000	0.000	0.000	0.084
Yes	0	32 (12.7)	20 (20.0)					
Cardiogenic shock								
No	277 (100.0)	234 (93.2)	92 (92.0)	20.829*	0.000	0.000	0.000	0.687
Yes	0	17 (6.8)	8 (8.0)					
Catecholamine support								
No	277 (100.0)	235 (93.3)	91 (91.0)	22.260*	0.000	0.000	0.000	0.466
Yes	0	17 (6.7)	9 (9.0)					
Logistic EuroSCORE								
Median (IQR)	13 (9-17)	20 (14-30)	29 (18.5-38)	174.190[b]	0.000	0.000	0.000	0.004
Range	2-18	4-42	7-44					

CCS, Canadian Cardiovascular Society grading of angina pectoris; CK-MB, creatine kinase-MB; COPD, chronic obstructive pulmonary disease; CtnI, cardiac-specific troponin I; CVA, cerebrovascular accident; DM, diabetes mellitus; IABP, intra-aortic balloon counter pulsation; MI, myocardial infarction; NSTEMI, non-ST elevation myocardial infarction; NYHA, New York Heart Association Functional Classification; PCI, percutaneous coronary intervention; PVD, peripheral vascular disease; STEMI, ST elevation myocardial infarction; UA, unstable angina. $P$1: UA group versus NSTEMI group. $P$2: UA group versus STEMI group. $P$3: NSTEMI group versus STEMI group. *χ^2 test. [a]One-way analysis of variance test. [b]Kruskal-Wallis test.

margin of error accepted was set to 5%. So, the P value was considered significant at P value less than 0.05, entered into a multivariate logistic regression analysis model.

Results

Preoperative data

As presented in Table 1, there were no significant differences in some demographic criteria such as age, sex, hypertension, diabetes mellitus type 1 or 2, COPD, smoking, CVA, left main disease, single-vessel disease, and Canadian Cardiovascular Society score when the three groups were compared. On the contrary, there were significant differences between some preoperative variables like higher incidence of PVD in STEMI compared with either UA or NSTEMI (P = 0.01 and 0.02, respectively), preoperative MI in NSTEMI compared with UA and STEMI with UA (P = 0.000 and 0.000, respectively), prior PCI in UA compared with STEMI and STEMI with NSTEMI (P = 0.012 and 0.002 respectively), higher mean NYHA in either NSTEMI or STEMI compared with UA and STEMI with NSTEMI, (P = 0.002, 0.000, and 0.000, respectively), poorer ejection fraction in either NSTEMI or STEMI compared with UA and STEMI with NSTEMI (P = 0.000 and 0.000, respectively), higher incidence of cardiogenic shock in either NSTEMI or STEMI compared with UA (P = 0.000 and 0.000, respectively). Similarly, both types of cardiac enzymes (cTnI and CK-MB) showed higher values in either NSTEMI or STEMI compared with UA and STEMI with NSTEMI (P = 0.000 and 0.000, respectively). Furthermore, the incidence of double-vessel disease was significantly higher in UA compared with either NSTEMI or STEMI (P = 0.000 and 0.001, respectively). On the contrary, the higher incidence of triple-vessel disease was noted in either NSTEMI or STEMI compared with UA (P = 0.000 and 0.001, respectively). As far as IABP and inotropic support use are concerned, they were used more in either NSTEMI or STEMI compared with UA (P = 0.000 and 0.000, respectively). Lastly, logistic EuroSCORE was higher in either NSTEMI or STEMI compared with UA and STEMI with NSTEMI (P = 0.000, 0.000, and 0.004, respectively).

Operative data

The operative-related variables are demonstrated in Table 2. We found no difference regarding the total operative, CPB, aortic

Table 2: Operative data of the study groups

	UA (n=277) [n (%)]	NSTEMI (n=252) [n(%)]	STEMI (n=100) [n (%)]	Test	P	$P1$	$P2$	$P3$
ICOR								
Mean±SD	0.82±0.13	0.8±0.16	0.81±0.16	0.879[a]	0.416	0.384	0.861	0.841
Range	0.4-0.9	0.2-0.9	0.2-0.9					
Operative time (m)								
Mean±SD	227.24±37.49	231.11±33.93	232.05±32.01	0.821[a]	0.441	0.507	0.519	0.971
Range	170-268	166-269	160-267					
Cardiopulmonary bypass time (m)								
Mean±SD	92.49±14.50	93.08±11.28	94.23±11.64	0.608[a]	0.545	0.884	0.513	0.715
Range	67-107	70-110	77-118					
Cross-clamp time(m)								
Mean±SD	47.93±10.14	46.35±9.54	48.65±12.08	2.424[a]	0.089	0.078	0.548	**0.059**
Range	20-60	25-59	23-61					
Reperfusion time (m)								
Mean±SD	20.69±4.59	19.73±4.63	20.97±7.14	2.804[a]	0.062	0.156	0.905	0.108
Range	11-27	10-27	9-29					
Number of distal anastomosis								
Mean±SD	2.73±0.84	3.02±0.80	3.05±0.94	9.659[a]	0.000	0.000	0.001	0.762
Range	1-4	1-4	1-4					
LIMA to LAD								
No	3 (1.1)	8 (3.2)	2 (2.0)	2.855*	0.240	0.092	0.492	0.550
Yes	274 (98.9)	244 (96.8)	98 (98.0)					
IABP								
No	261 (94.2)	214 (85.3)	69 (69.0)	41.019*	0.000	0.001	0.000	0.001
Yes	16 (5.8)	37 (14.7)	31 (31.0)					
Inotropes								
No	211 (76.2)	139 (55.4)	63 (63.0)	25.694*	0.000	0.000	0.011	0.192
Yes	66 (23.8)	112 (44.6)	37 (37.0)					

IABP, intra-aortic balloon counter pulsation; ICOR, index of completeness of revascularization= performed anastomosis/preoperative planned; LIMA to LAD, left internal mammary artery anastomosis to left anterior descending artery; NSTEMI, non-ST elevation myocardial infarction; STEMI, ST elevation myocardial infarction; UA, unstable angina. $P1$: UA group versus NSTEMI group. $P2$: UA group versus STEMI group. $P3$: NSTEMI group versus STEMI group. *χ^2 test. [a]One-way analysis of variance test.

cross-clamp time, reperfusion times, the use of the internal mammary artery for grafting the left anterior descending artery territory, and ICOR when the three groups were compared. However, there was a higher number of distal anastomosis performed in either NSTEMI or STEMI compared with UA (P = 0.000 and 0.001, respectively). There was also more use of IABP in either NSTEMI or STEMI compared with UA and STEMI with NSTEMI (P = 0.001 and 0.000, respectively) respectively and more inotrope use in either NSTEMI or STEMI compared with UA (P = 0.000 and 0.011, respectively).

Hospital mortality and morbidity

Table 3 portrays the postoperative outcome. The overall in-hospital mortality was 6.5% (n = 41), being 4% in UA (n = 11), 8.7% in NSTEMI (n = 22), and 8% (n = 8) in STEMI. Mortality was significantly higher only in NSTEMI compared with UA (P = 0.05). Although cardiac causes of death were significantly higher in STEMI compared with UA (P = 0.04), noncardiac causes were significantly higher in NSTEMI compared with UA (P = 0.04). All other postoperative outcome variables were comparable except for ventilation hours, ICU, and hospital stay, which were significantly longer in either NSTEMI or STEMI compared with UA (P = 0.000, 0.000, 0.000, 0.000, 0.000, and 0.001, respectively). Moreover, it was found that hospital stay was longer in STEMI compared with NSTEMI (P = 0.001). Another similar trend of prevalence of stroke, MACCE, and LCOS was noted in either NSTEMI or STEMI compared with UA (P = 0.010, 0.018, 0.017, 0.009, 0.003, and 0.001, respectively).

Predicting variables of hospital mortality

Logistic regression analysis was used to assess predictors of mortality in our study. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the P value was considered significant at P less than 0.05, entered into a multivariate logistic regression analysis model. The following factors were identified as predictors of mortality as listed in Table 4:

(1) Age more than 65 years (Odds ratio: 4.217, 95% confidence interval: 2.126–6.410, P = 0.013).
(2) NYHA 3 (Odds ratio: 2.137, 95%, confidence interval, 1.105–3.071, P = 0.025).
(3) Ejection fraction less than 45% (Odds ratio: 1.520, 95% confidence interval, 1.001–2.039, P = 0.039).
(4) Logistic EuroSCORE more than 10 (Odds ratio: 2.314, 95% confidence interval: 1.210–3.517, P = 0.009).

Table 3: Postoperative morbidity and mortality of the study groups

	UA (n=277) [n (%)]	NSTEMI (n=252) [n (%)]	STEMI (n=100) [n (%)]	Test	P	$P1$	$P2$	$P3$
ICU stay (h)								
Mean±SD	87.49±28.61	96.79±37.60	101.32±31.10	8.718[a]	0.000	0.003	0.000	**0.286**
Range	47-124	48-156	48-137					
Ventilation (h)								
Mean ± SD	29.54±12.28	36.65±21.19	37.15±19.00	13.454[a]	0.000	0.000	0.000	0.810
Range	12-48	15-72	12-66					
Re-exploration for bleeding								
No	268 (96.8)	241 (95.6)	94 (94.9)	0.782*	0.676	0.502	0.416	0.782
Yes	9 (3.2)	11 (4.4)	5 (5.1)					
Hospital stay (d)								
Mean ±SD	10.33±1.78	10.78±1.47	11.79±1.46	29.883[a]	0.000	0.001	0.000	0.000
Range	8-14	9-13	10-14					
In-hospital mortality								
No	266 (96.0)	229 (90.9)	90 (90.0)	7.042*	0.029	0.015	**0.024**	0.800
Yes	11 (4.0)	23 (9.1)	10 (10.0)					
Cardiac causes								
No	270 (97.5)	241 (95.6)	92 (92.0)	5.611*	0.060	0.244	0.016	0.174
Yes	7 (2.5)	11 (4.4)	8 (8.0)					
Noncardiac causes								
No	273 (98.6)	241 (95.6)	98 (98.0)	4.505*	0.105	0.043	0.703	0.289
Yes	4 (1.4)	11 (4.4)	2 (2.0)					
Stroke								
No	277 (100.0)	246 (97.6)	98 (98.0)	6.459*	0.040	0.010	0.018	0.829
Yes	0 (0.0)	6 (2.4)	2 (2.0)					
Postoperative MI								
No	271 (97.8)	241 (96.4)	94 (94.0)	3.417*	0.181	0.323	0.061	0.317
Yes	6 (2.2)	9 (3.6)	6 (6.0)					
Coronary re-intervention								
No	271 (97.8)	243 (96.8)	96 (96.0)	1.042*	0.594	0.466	0.328	0.705
Yes	6 (2.2)	8 (3.2)	4 (4.0)					
MACE								
No	261 (94.2)	221 (88.4)	86 (86.0)	8.169*	0.017	0.017	0.009	0.537
Yes	16 (5.8)	29 (11.6)	14 (14.0)					
LCOS								
No	269 (97.1)	228 (91.2)	89 (89.0)	11.389	0.003	0.003	0.001	0.525
Yes	8 (2.9)	22 (8.8)	11 (11.0)					
Renal failure (dialysis)								
No	270 (97.5)	246 (97.6)	97 (97.0)	0.111*	0.946	0.914	0.801	0.740
Yes	7 (2.5)	6 (2.4)	3 (3.0)					
Re-admission SWI								
No	270 (97.5)	250 (99.2)	100 (100.0)	4.537*	0.103	0.124	0.109	0.372
Yes	7 (2.5)	2 (0.8)	0 (0.0)					
Sternal resuturing								
No	272 (98.2)	247 (98.0)	97 (97.0)	0.533*	0.766	0.879	0.477	0.563
Yes	5 (1.8)	5 (2.0)	3 (3.0)					

LCOS, low-cardiac output syndrome; MACE, major adverse cardiac events; NSTEMI, non-ST elevation myocardial infarction; STEMI, ST elevation myocardial infarction; SWI, superficial wound infection; UA, unstable angina. $P1$: UA group versus NSTEMI group. $P2$: UA group versus STEMI group. $P3$: NSTEMI group versus STEMI group. *χ^2 test.

Discussion

The success of PCI as a modality of treatment of ACS made it the domain of interventional cardiologists for years and the gold standard of care especially in cases of STEMI. However, in the past few years, the scope of PCI performed had expanded to include NSTEMI indications [9]. However, the outcomes of the PRECOMBAT and SYNTAX trials, which presented

Table 4: Univariate logistic regression analysis to assess predictors of mortality

	B	SE	Wald	*P*	Odds ratio	95% CI for OR	
						Lower	Upper
Age >65 years	0.950	0.062	6.568	0.013	4.217	2.126	6.410
NYHA ≥3	0.036	0.016	5.007	0.025	2.137	1.105	3.071
EF<45%	0.020	0.010	4.260	0.039	1.520	1.001	2.039
EuroSCORE >10	0.615	0.07	7.512	0.009	2.314	1.210	3.517

B, regression coefficient; CI, confidence interval; EF, ejection fraction; NYHA, New York Heart Association Functional Classification; OR, odds ratio; SE, standard error of regression coefficient; Wald, test name.

comparable results of PCI and surgical revascularization in patients with important left main stem stenosis make it possible now to see a similar rise of cardiac surgery performed in this field.

Of note is that patients with ACS represented a high-risk group of patients who usually had a high frequency of preoperative risk factors as well as frequent postoperative complications and mortality [10]. Indications of surgical intervention as well as the optimum timing should be based not only on the guidelines but also on the experience of the heart team (the referring cardiologist and the heart surgeon), which plays a key role in the management of this sensitive group [2,11].

Various guidelines described the indications and timing of surgical interventions in patients with ACS, and these guidelines are revised regularly. The last update was done for myocardial revascularization in 2015 for NSTEMI and 2017 for STEMI [12,13].

In this study, an overlook of preoperative, intraoperative, and postoperative variables led to drawing some important conclusions. To begin, higher risk profile was noted in AMI (NSTEMI and STEMI groups) as opposed to UA, and this was exemplified by significantly higher incidence of preoperative MI, higher NYHA class, lower ejection fraction, higher overall Logistic EUROscore, more frequent cardiogenic shock, as well as higher need for preoperative catecholamine support and balloon use, and as expected, this AMI group had significantly higher incidence of LCOS, higher mortality, more frequent cardiac causes of mortality, MACCE, stroke, more lengthy ventilation hours, and increased ICU and hospital stay. Second, on comparing NSTEMI and STEMI together, we found that STEMI had significantly higher incidence of PVD, prior PCI, higher NYHA class, higher cardiac enzymes, higher logistic EUROscore, higher intraoperative use of IABP, and lengthier hospital stay.

Similar to our findings, Alexiou *et al*. [8] found a higher incidence of PVD in NSTEMI compared with STEMI or UA. Moreover, they reported a higher incidence of prior PCI in AMI (NSTEMI and STEMI) group compared with UA (P = 0.03). More importantly, in their study, they pointed to a correlation between higher NYHA, poor left ventricular function, higher use of IABP and inotropes, higher cardiogenic shock incidence, EuroSCORE, and higher postoperative MACCE and LCOS in AMI group; P values were 0.0001, 0.0001, 0.0003, 0.004, 0.02, 0.001, 0.04, and 0.04, respectively. In contrary to our findings, their results did not show any significant difference in the number of diseased vessels, number of distal anastomosis, ICU stay, and hospital stay (P = 0.72, 0.91, 0.95, and 0.07, respectively).

Moreover, in our study, we found a higher prevalence of two-vessel disease in UA compared with AMI and higher prevalence of triple-vessel disease in the latter as opposed to the former. This, in turn, led to a decrease in the number of distal grafts in the former in comparison with the latter, with no statistical difference in ICOR, which was the golden standard strategy adopted.

As far as in-hospital mortality is concerned, some previous studies like VANQWISH [14] showed that CABG in patients with UA is associated with high risk of mortality. Nevertheless, recent studies demonstrated that CABG in this high-risk group can be performed with comparable results to that of stable angina. This can be exemplified by the mortality figures of FRISC II and TACTICS-TIMI for CABG patients with UA (2 and 1.7%, respectively) [15,16]. These results are comparable to the outcome of elective CABG done for stable angina, with an average mortality risk lower than 3% [17]. Although in this study UA mortality is 4%, UA did not represent an independent risk factor for in-hospital mortality.

The data shown in our study confirmed that CABG can be performed with good clinical results in AMI. The overall in-hospital mortality observed in this study was 6.5% (n = 41), being 4% in UA (n = 11), 8.7% in NSTEMI (n = 22), and 8% (n = 8) in STEMI, which is comparable with the results from other clinical reports [6,18–21], in which mortality is reported between 5 and 14%.

The relatively acceptable mortality in the AMI group can be explained by considering the reasonable total ischemic time and good myocardial preservation and insisting on complete revascularization strategy as a standard of care.

We observed that patients with NSTEMI have a similar mortality compared with the patients with STEMI. This is in concordance with the results of the interventional trial which also reported comparable mortality in the STEMI and NSTEMI group [22]. The univariate analysis of prognostic risk factors confirmed that surgical treatment of ACS is particularly affected by preoperative morbidities and clinical status. Some recent reports showed that the cTnI level is an independent variable predicting for hospital mortality and MACCE rate after CABG in STEMI and NSTEMI [23,24]. In contrary, our study did not reveal that, which can be explained by the interaction between variables.

There are also a group of studies that compared CABG and PCI in the setting of ACS, such as a recent study by Yerokun *et al*. [25]. They referred to the underuse of CABG in NSTEMI (11% approximately vs. 43.6%

for PCI whereas 76.2% underwent angiography). They attributed that to the great variability in practice worldwide and the individualized approach to every single patient management in spite of some good evidence of superiority of CABG in three-vessel disease and LMD and high SYNTAX score in stable IHD situations [2].

In the NSTEMI group, the increased risk of stroke is reduced or even eliminated after CABG compared with PCI, despite the fact that it should increase in CABG. Furthermore, CABG can offer a very important advantage over PCI in terms of more adequate and complete revascularization. Moreover, a recent publication reported that the use of PCI was associated with statistically significant more frequent major adverse cardiac events (mortality, MI, or target lesion revascularization (re-intervention) after 1 year compared with CABG among patients with NSTEMI [26].

Another important fact to bear in mind on contemplating a decision in this category of ACS is that certain groups of patients may benefit more from CABG such as older patients with NSTEMI and diabetic ones. For the former, it appeared that there is improved outcomes with CABG compared with PCI, evidenced by a recent article that demonstrated a lower 5-year mortality rate (24.2 vs. 33.5%) for patients with NSTEMI who were found to have significant coronary disease on angiography and underwent CABG compared with PCI [27]. For the latter, the evidence comes from FREEDOM trial, which randomized diabetic patients who had a multivessel disease to PCI or CABG, and it showed a survival advantage in the CABG cohort [28].

Owing to the matter of fact that decision making following hospital presentation of ACS is complex before choosing CABG as a modality of treatment, integrated decision making with heart team is needed to optimize the concomitant medical treatments and the preoperative, perioperative, and postoperative for patients with ACS who undergo CABG and again; decisions on the method of revascularization for ACS patients with multivessel coronary disease should be individualized and dictated by the patient's condition and the clinical situation [25].

Another recommendation that was made clear in more recent revascularization guidelines in this matter is the use of a heart team in clinical decision making [2,12]. This multidisciplinary decision-making approach came from the SYNTAX trial, which insisted that eligible patients should be evaluated by an interventional cardiologist and a cardiac surgeon [29]. Although not supported by data [30], an integrated, multidisciplinary decision-making approach involving both cardiologists and cardiac surgeons should be the preferred approach and that was the case in our study.

The individual outcome for each patient can be predicted by the use of the risk stratification system EuroSCORE [31,32]. In this study, the EuroSCORE confirmed the different risk profile of patients with UA and patients with AMI. Of note, the risk profile for STEMI was higher than NSTEMI and UA. The predictive influence of comorbidities, therefore, determines the clinical outcome of UA, NSTEMI, and STEMI groups. Likewise, Voisine *et al.* [33] demonstrated that an inter-individual risk was present and this profile, comorbidities, and the clinical status of the patients determine the outcome after surgical revascularization of patients with ACS.

The univariate analysis of prognostic risk factors in our study confirmed that surgical treatment of ACS is especially affected by preoperative morbidities and clinical status. It revealed that four factors of advanced age, NYHA class more than or equal 3, ejection fraction less than 45%, and logistic EuroSCORE more than 10 were directly linked to mortality. In contrary, the study done by Alexiou *et al.* [8] disclosed more risk factors for mortality for the entire study population. He identified COPD, preoperative renal disease, CVA, preoperative catecholamine support, cardiogenic shock, and rhythm disturbance as predictors of mortality by univariate analysis. Furthermore, when they did the CART analysis, they identified three independent prognostic factors in multivariable analysis for the AMI (NSTEMI and STEMI) cohort, namely, age more than 75 years (odds ratio: 5.36, 95% confidence interval: 1.64–21.68; $P = 0.028$), COPD (odds ratio: 23.04, 95% confidence interval: 4.33–158.61; $P = 0.003$), and renal disease (odds ratio: 7.01, 95% confidence interval: 1.81–34.62; $P = 0.007$).

Limitations

The first and foremost limitation is the retrospective design, which may have affected outcome analysis and the selection bias. General conclusions and comparisons are restricted owing to a limited and unequal number of patients in each group, and the low incidence of lethal events. This also affects the identification of statistically significant predicting variables. Second, we did not look at the timing of CABG after ACS presentation, regarding which some authors already proved its effect on the outcome [8].

Conclusion

Primary isolated on-pump CABG can be performed in patients with ACS with good clinical results, but a substantial mortality and morbidity remain in NSTEMI/STEMI subgroup compared with UA. Our data demonstrated that patients with ACS represent a heterogeneous risk group for CABG, with a need of individualized management approach. Therefore, an individual risk stratification of each patient in ACS is necessary.

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Conflicts of interest

There are no conflicts of interest.

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