Original Article

Determinants of Length of Stay in Surgical Ward after Coronary Bypass Surgery: Glycosylated Hemoglobin as a Predictor in All Patients, Diabetic or Non-Diabetic

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Abstract

Background: *Reports on the determinants of morbidity in coronary artery bypass graft surgery (CABG) have focused on outcome measures such as length of postoperative stay in the Intensive Care Unit (ICU). We proposed that major comorbidities in the ICU hampered the prognostic effect of other weaker but important preventable risk factors with effect on patients' length of hospitalization. So we aimed at evaluating postoperative length of stay in the ICU and surgical ward separately.*

Methods: *We studied isolated CABG candidates who were not dialysis dependent. Preoperative, operative, and postoperative variables as well as all classic risk factors of coronary artery disease were recorded. Using multivariate analysis, we determined the independent predictors of length of stay in the ICU and in the surgical ward.*

Results: *Independent predictors of extended length of stay in the surgical ward (> 3 days) were a history of peripheral vascular disease, total administered insulin during a 24-hour period after surgery, glycosylated hemoglobin (HbA1c), last fasting blood sugar of the patients before surgery, and inotropic usage after cardiopulmonary bypass. The area under the Receiver Operating Characteristic Curve (AUC) was found to be 0.71 and Hosmer-Lemeshow (HL) goodness of fit statistic p value was 0.88. Independent predictors of extended length of stay in the ICU (> 48 hours) were surgeon category, New York Heart Association functional class, intra-aortic balloon pump, postoperative arrhythmias, total administered insulin during a 24-hour period after surgery, and mean base excess of the first 6 postoperative hours (AUC = 0.70, HL p value = 0.94).*

Conclusion: *This study revealed that the indices of glycemic control were the most important predictors of length of stay in the ward after cardiac surgery in all patients, diabetic or non-diabetic. However, because HbA1c level did not change under the influence of perioperative events, it could be deemed a valuable measure in predicting outcome in CABG candidates.*

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Keywords: *Coronary artery bypass • Treatment outcome • Hemoglobin A, glycosylated • Length of stay*

Introduction

In a world of limited medical care resources, despite increasing demand for medical services, clinicians often need to identify patients that are likely to require a longer period of high dependency care after cardiac surgery. Coronary artery bypass graft surgery (CABG) has received particular attention as it is an expensive and commonly

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performed procedure.[1, 2] Indeed, detection of patients who are likely to need a longer postoperative length of stay (LOS) for CABG would allow operations on these patients to be spread over the operating week. This would maximize the chance of the availability of the Intensive Care Unit (ICU) beds for other sick patients and also prevent the cancellations of operations. Moreover, prolonged ICU and ward stay in patients undergoing CABG increases overall hospital costs.[3]

LOS in hospital after cardiac surgery is among the most important determinants of outcome to have been studied so far. Many studies have reported the factors affecting the length of postoperative ICU stay.[4-12] A few investigators have evaluated total hospital LOS,[13-16] but to our knowledge, no study has assessed such predictors at cardiac surgical wards. Although the total time of hospital stay contains the time of stay in the ward, prolonged stay in the surgical ward is important itself inasmuch as it limits the number of available ICU beds because of a reduced throughput in the surgical ward, and as a consequence in the ICU unit. We proposed that the predictors of a prolonged ICU stay might be different from the predictors of a long postoperative stay in the hospital ward.

Methods

We prospectively studied a total of 570 consecutive patients undergoing elective CABG at Tehran Heart Center during a period of five months. Patients who underwent CABG combined with a heart valve repair or replacement, resection of a ventricular aneurysm, or other surgical procedures were excluded. The study was approved by the division of cardiothoracic surgery and by the research department of the hospital.

Data were collected prospectively during the patients' admission by interviews and physical examinations on the following variables: age; gender; body mass index (BMI); educational level; New York Heart Association (NYHA) functional class; number of diseased vessels; and left ventricular ejection fraction (LVEF). A history of myocardial infarction, smoking, alcohol abuse, opiate dependency, diabetes, hypercholesterolemia, hypertension, peripheral vascular disease, cerebrovascular disease, respiratory failure, and renal failure were also noted.

Laboratory data included measured blood sugar in perioperative and glycated or glycosylated hemoglobin (HbA1c) at operation day.

The patients' data, risk factors, operation, and outcome data were recorded in a structured form. Perioperative medical characteristics were collected by research general practitioners. The data were transcribed onto the SPSS software by a data entry operator at a later date.

Regarding educational level, three levels of education were categorized: 1 = primary school or lower; 2 = secondary school; and 3 = university/college or equivalents. Current smoker was defined as anybody who had smoked within one month of surgery. Alcohol abuse was defined as the consumption of alcohol despite recurrent adverse consequences. Daily regular use of opium products was defined as opium dependency according to the DSM-IV criteria. (American Psychiatric Association. Diagnostic and statistical manual of mental disorders: DSM-IV-TR. American Psychiatric Publishing, Inc.; 2000) Any cerebral neurological deficit induced by both cerebrovascular accident and transient ischemic attacks or previous cerebral surgery was defined as cerebrovascular disease. Peripheral vascular disease was defined as a history or any evidence of aneurysm or occlusive peripheral vascular disease on physical examination. After surgery, the patients who stayed in the ward for more than 2 consecutive days on the initial admission were classified as having a prolonged ward stay. A long cardiac surgical ICU stay was defined as > 2 days.

The patients within the first 24 hours after bypass surgery were categorized into three groups according to the average amount of insulin intake: group 0 = zero U; group 1 = 1 to 9 U; and group 2 = 10 or more U of insulin. The operations were performed by seven surgeons. The surgeons, in terms of mean total in-hospital duration of stay for the patients of each individual surgeon, were classified into 3 groups, as follows: 1 = total LOS < 8 days; 2 = 8 ≤ total LOS < 10 days; and 3 = total LOS ≥ 10 days.[17] Central and peripheral circulations were measured by the amount of inotropic support and arterial blood gas parameters (base excess and pH in plasma), respectively. A wound infection was any wound infection in the sternum or leg incision following surgery. Postoperative arrhythmias were all observed rhythms that needed treatment rather than normal sinus rhythm.

The numerical variables are presented as mean ± SD, while the categorized variables are summarized by absolute frequencies and percentages. The continuous variables were compared using the Student t-test, and the categorical variables were compared using the chi-square (or the Fisher exact test, as required) and the Mantel-Haenszel chi-square test for trend. A multivariate forward stepwise logistic regression model for risk factors predicting LOS in the ICU and the surgical ward was constructed. Through the multivariate forward stepwise analysis, the variables were entered into the logistic regression model according to their statistical significance (entering criterion p value ≤ 0.15). The associations between the independent predictors and LOS in the ICU or the surgical ward in the final model were expressed as odds ratios (OR) with 95% CIs. Model discrimination was measured using the c statistic, which is equal to the area under the ROC (Receiver Operating Characteristic) curve. Model calibration was estimated using the Hosmer-Lemeshow (HL) goodness-of-fit statistic (higher p values imply that the model fits the observed data better). For the statistical analyses, the statistical software

SPSS version 13.0 for Windows (SPSS Inc., Chicago, IL) and the statistical package SAS version 9.1 for Windows (SAS Institute Inc., Cary, NC, USA) were used. All the p values were two-tailed, with statistical significance defined by p value ≤ 0.05.

Results

The baseline characteristics, preoperative data, and outcome variables of the CABG patients according to LOS in the ICU are presented in Table 1. Overall, 380/570 (66.7%) patients were discharged from the ICU in ≤ 48 hours, and 190 (33.3%) patients spent > 48 hours in the ICU. Table 2 shows the predictors of LOS in the ICU in the patients, undergoing bypass surgery. Three most important variables were intra-aortic balloon pump support, mean 24 hours' insulin intake of ≥ 10 units, and NYHA functional class, with odds ratios of 25.5, 2.3, and 2.2, respectively.

The relationship between the LOS in the ICU and the

Table 1. Baseline characteristics of the coronary artery bypass graft patients according to length of stay in the Intensive Care Unit

	ICU stay ≤ 48 hours (n=380)	ICU stay > 48 hours (n=190)	P value
Age (y)	58.44±8.80	60.21±9.20	0.026
Male sex	290 (76.3)	139 (73.2)	0.410
Body mass index (kg/m^2)	27.14±4.09	27.84±4.01	0.055
Surgeon category			0.017
1	218 (57.4)	102 (53.7)	
2	104 (27.4)	41 (21.6)	
3	58 (15.3)	47 (24.7)	
Cardiac risk factors			
Diabetes mellitus	159 (41.8)	74 (38.9)	0.508
Hypertension	178 (46.8)	104 (54.7)	0.076
Hyperlipidemia	264 (69.5)	136 (71.6)	0.605
Cigarette smoking	138 (36.3)	68 (35.8)	0.902
Family history of CAD	186 (48.9)	84 (44.2)	0.286
Prior MI	187 (49.5)	100 (52.9)	0.440
Prior CVA	10 (2.6)	12 (6.3)	0.031
History of PVD	100 (26.3)	58 (30.5)	0.290
NYHA functional class			0.032
1	141 (37.1)	60 (31.6)	
2	193 (50.8)	93 (48.9)	
3	46 (12.1)	37 (19.5)	
LVEF (%)	48.88±9.80	47.78±11.38	0.253
Number of diseased vessels			0.607
1	12 (3.2)	9 (4.7)	
2	73 (19.2)	35 (18.4)	
3	295 (77.6)	146 (76.8)	
Operative details and complications			
Pump time (min)	68.45±20.36	73.19±25.24	0.025
Number of grafts	3.70±0.94	3.79±0.99	0.265
Intraoperative IABP-support	1 (0.3)	11 (5.8)	< 0.001
Endarterectomy	27 (7.1)	12 (6.3)	0.725
Pacemaker dependents	33 (8.7)	20 (10.5)	0.475
Inotropic drug use	148 (38.9)	90 (47.4)	0.055
Arrhythmia	123 (32.4)	101 (53.2)	< 0.001
Perioperative MI	1 (0.3)	3 (1.6)	0.110
Respiratory failure	56 (14.7)	48 (25.3)	0.002
Wound infection	0	3 (1.6)	0.037
Arterial blood gas parameters			
Mean BE within 6 hours after surgery (mmol/l)	-5.42±2.55	-6.19±2.57	0.001
pH < 7.34 within 6 hours after surgery	74 (19.5)	59 (31.1)	0.002
Mean insulin intake within 24 hours after surgery			< 0.001
Zero U	193 (50.8)	69 (36.3)	
1 - 9 U	99 (26.1)	48 (25.3)	
≥ 10 U	88 (23.2)	73 (38.4)	

*Data are presented as mean±SD or n (%)

ICU, Intensive Care Unit; CAD, Coronary artery disease; MI, Myocardial infarction; CVA, Cerebrovascular accident; PVD, Peripheral vascular disease; NYHA, New York Heart Association; LVEF, Left ventricular ejection fraction; IABP, Intra-aortic balloon pump; BE, Base excess

Table 2. Predictors of length of stay in the Intensive Care Unit in patients undergoing bypass surgery

Predictors	Univariate analysis			Multivariate analysis		
	OR	95% CI	P value	OR	95% CI	P value
NYHA classification			0.05			0.02
2 vs. 1	1.13	0.76-1.67		1.17	0.77-1.79	
3 vs. 1	1.89	1.11-3.20		2.15	1.22-3.79	
Surgeon category			0.02			0.04
Group 2 vs. 1	0.84	0.54-1.29		0.69	0.43-1.12	
Group 3 vs. 1	1.73	1.10-2.71		1.47	0.91-2.38	
Intra-aortic balloon pump support	23.29	2.98-181.79	< 0.01	25.22	3.14-202.43	< 0.01
Postoperative arrhythmia	2.37	1.65-3.38	< 0.01	1.95	1.33-2.86	< 0.01
Mean BE within 6 hours after surgery	0.88	0.82-0.95	< 0.01	0.90	0.83-0.97	< 0.01
Mean insulin intake within 24 hours after surgery*			< 0.01			< 0.01
1 vs. 0	1.35	0.87-2.10		1.31	0.82-2.09	
2 vs. 0	2.32	1.53-3.51		2.27	1.45-3.55	

*Group 0 = Zero U
Group 1 = 1 to 9 U
Group 2 = ≥ 10 U
OR, Odds ratio; CI, Confidence interval; NYHA, New York Heart Association; BE, Base excess; AUC, Area under the Receiver Operating Characteristic Curve (c = 0.70)

Table 3. Durations of Intensive Care Unit, surgical ward and total hospital stay as well as in-hospital mortality rate for both study groups*

	Group A Patients with ICU stay ≤ 48h (n=380)	Group B Patients with ICU stay > 48h (n=190)	P value
ICU stay (hr)	27.38±9.30	85.79±34.87	
Surgical ward stay (d)	2.78±1.79	2.63±2.35	0.43
Total hospital stay (d)	7.21±2.84	9.85±7.36	< 0.01
In-hospital mortality	0	3 (1.6)	0.04

*Data are presented as mean±SD or n (%)

Table 4. Comparison of patients with regard to LOS in ward after CABG*

	Ward stay ≤ 3 days (n=426)	Ward stay > 3 days (n=144)	P value
Male sex	336 (78.9)	93 (64.6)	< 0.01
Body mass index (kg/m^2)	27.13±3.96	28.12±4.31	0.01
Education class**			< 0.01
1	218 (51.2)	94 (65.3)	
2	133 (31.2)	36 (25.0)	
3	75 (17.6)	14 (9.7)	
Diabetes mellitus	153 (35.9)	80 (55.6)	< 0.01
Family history of CAD	191 (44.8)	79 (54.9)	0.04
History of PVD	104 (24.4)	54 (37.5)	< 0.01
Inotropic drug use	166 (39.0)	72 (50.0)	0.02
Postoperative arrhythmia	179 (42.0)	45 (31.3)	0.02
HbA1C at operation day	5.83±1.58	6.55±1.90	< 0.01
Last fasting blood sugar	103.58±30.41	119.45±46.88	< 0.01
Mean insulin intake within 24 hours after surgery***			< 0.01
0	220 (51.6)	42 (29.2)	
1	100 (23.5)	47 (32.6)	
2	106 (24.9)	55 (38.2)	
Mean BG within the first 24 hours after surgery (mg/dl)	167.41±26.28	176.49±28.10	< 0.01
Blood urea nitrogen (mg/dl)	38.86±11.56	42.19±12.92	< 0.01
Total cholesterol (mg/dl)	157.97±43.89	169.19±47.32	< 0.01

*Data are presented as mean±SD or n (%)
**1 = primary school or lower; 2 = secondary school; 3 = university/college or equivalents
***Group 0 = Zero U; Group 1 = 1 to 9 U; Group 2 ≥ 10 U
LOS, Length of stay; CABG, Coronary artery bypass surgery; CAD, Coronary artery disease; PVD, Peripheral vascular disease; HbA1C, Glycosylated hemoglobin; BG, Blood glucose

Table 5. Predictors of length of stay at surgical ward in patients undergoing bypass surgery

	Univariate analysis			Multivariate analysis		
	OR	95% CI	P value	OR	95% CI	P value
Peripheral vascular disease	1.858	1.241-2.781	< 0.01	1.568	1.013-2.426	0.04
HbA1c	1.268	1.133-1.419	< 0.01	1.210	1.074-1.362	< 0.01
Last fasting blood sugar	1.011	1.006-1.016	< 0.01	1.009	1.003-1.014	< 0.01
Inotropic drug use	1.566	1.071-2.291	0.02	1.638	1.088-2.465	0.02
Postoperative arrhythmia	0.627	0.420-0.937	0.02	0.531	0.343-0.822	0.01
Mean insulin intake within 24 hours after surgery*			< 0.01			< 0.01
1 vs. 0	2.462	1.525-3.973		2.455	1.487-4.054	
2 vs. 0	2.718	1.709-4.321		2.708	1.648-4.450	

*Group 0 = Zero U
Group 1 = 1 to 9 U
Group 2 ≥ 10 U
OR, Odds ratio; CI, Confidence interval; NYHA, New York Heart Association; HbA1c, Glycosylated hemoglobin

surgical ward was investigated through a comparison of the average ICU, surgical ward, and total hospital stay as well as in-hospital mortality rate between two groups of ICU stay (≤ 48 and > 48 hours) as listed in Table 3. The overall in-hospital mortality rate was 0.5%.

In all the patients studied, the LOS at the cardiac surgical ward ranged from 1 to 14 days (mean ± SD, 2.73 ± 1.99 days) with a median of 2 days. Patients with a prolonged surgical ward stay (144/570, 25.3%) were more likely to be women and have diabetes, family history of coronary artery disease, history of peripheral disease, and lower educational level.

Table 4 compares the patients' characteristics by taking into consideration the LOS in the ward after cardiac surgery. Among the important factors that were significantly different between the two groups, i.e. LOS > 3 days and LOS ≤ 3 days, five factors were independent predictors. Three predictors were indices of glycemic control (Table 5). The area under the Receiver Operating Characteristic Curve (AUC) was found to be 0.71, which showed a good predictive accuracy in the variables included in the model. The model was also found to fit the data well since the Hosmer-Lemeshow p value was 0.88 ($p < 0.05$ indicated a poor fit).

Discussion

In the current study, we included preoperative, intraoperative, and immediate postoperative variables to find LOS determinants in 570 CABG patients after bypass surgery. The six variables of intra-aortic balloon pump (IABP), NYHA functional class, postoperative arrhythmia, 24-hour average insulin intake, mean 6-hour BE, and surgeon category were found to be the independent predictors of an ICU LOS greater than 48 hours. We also found five predictors to be the independent risk factors for an increased cardiac surgical ward LOS. Considerable reports have been published on the predictors of LOS in the ICU following CABG[4-12] and some studies have investigated factors increasing postoperative hospital stay.[13-16] To our knowledge, however, no study has focused on the determinants of the LOS of cardiac surgical wards. Thus, we think that our study may contribute to the literature in this regard.

Over the past two decades, attempts have been made to find the determinants of postoperative LOS in CABG patients. Be that as it may, a great disparity in type and number of independent variables analyzed has been reported. Although most of outcome studies with the focus on LOS have investigated only preoperative and intraoperative variables, there are some outcome research reports with immediate postoperative variables included.[6, 13]

Poor cardiac output states, as reflected by the need for an IABP and inotropic therapy, have been identified as a predictor of a prolonged ICU stay in several studies.[6, 8, 9] In the present study, use of IABP was an ICU stay predictor, whereas inotropic support was a surgical ward stay predictor. Additionally, both reflected cardiac output.

Need for an IABP was identified as an independent risk factor for ICU stay longer than 48 hours in three studies.[18-20] In contrast, Doering et al. showed that only early hemodynamic instability was indicative of an ICU stay longer than 24 hours, whereas postoperative IABP and use of inotropic drugs were not.[9] Michalopoulos et al. also noted that the number of inotropes, rather than inotrope use itself, was the significant factor.[6]

These differences may result from different treatment protocols or the way in which variables such as the use of inotropes were defined. Michaloupolous et al. used a 6- hour window for starting inotropic support after surgery and did not consider vasodilators.[6] By contrast, in the Doering et al. study, a 3-hour period was adopted and after-load reducers such as nitroprusside were considered in the definition of inotropic support.[9] Christakis et al. did not consider inotropic support alone, adding to IABP support in defining low output state.[7]

Some disparities in study results may be due to various study populations and treatment protocols, different cut-offs used to define a prolonged stay in the ICU (from ≥ 2 to 10 days),[5, 14, 21-23] differences in variables definitions, and the large number of variables that could be considered.[4]

The main difference between our study and those described above is that we took into account surgeon category and amount of insulin administered during a 24-hour period after CABG. We found that a patient's surgeon could potentially influence the duration of ICU stay and that there were differences in the average length of ICU stay between the surgeons at our hospital.[17] It may indicate the necessity of using a unique protocol for discharging the patients from the ICU and hospital after surgery. We also found that the LOS in the ICU and ward depended predominantly on the amount of insulin received by the patients during the first 24-hour postoperative period. In addition, we could not show any association between the LOS in the ICU and that in the surgical ward (Table 3). As a result, a prolonged stay in the ICU probably is not an independent predictor of surgical ward stay.

We found that the blood glucose control indices, including HbA1c and last fasting blood sugar (FBS) before surgery, were the risk factors for an extended LOS in surgical wards in patients undergoing CABG, diabetic or non-diabetic. Finding both HbA1c and FBS as the determinants of the LOS in the surgical ward suggests that HbA1c is an independent predictor of hospital stay regardless of the level of blood sugar. However, as HbA1c is an index of glycemic control during previous months, its level is independent of perioperative events. It may, therefore, be a more stable and reliable perioperative marker. HbA1c has been used as a marker of short-term glycemic control in diabetic patients for many years. Recently, the American Diabetes Association included HbA1c in diabetes mellitus diagnosis criteria.[24] The role of HbA1c in predicting morbidity and mortality in non-diabetic healthy people has been suggested by some population-based studies.[25, 26] However, there is limited knowledge about the prognostic role of HbA1c for perioperative outcome, and the relationship between HbA1c and postoperative outcome in cardiovascular surgery is controversial.[27-30]

Our study revealed that HbA1c could predict postoperative LOS in the surgical ward and not in the ICU. This may be explained by the hampering effect of more important strong cofactors such as IABP and NYHA functional class.

Conclusion

Among the five predictors of the LOS in the surgical ward, three were the indices of glycemic control. HbA1c is the most reliable marker of outcome because its level is not influenced by perioperative events. Taking these findings into consideration, the prognostic role of HbA1c for the LOS following CABG is promising. We would, therefore, recommend its use as a simple predictor of outcome after cardiac surgery in daily practice.

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