ISSN: 2795-1952 (Print); ISSN: 2976-1107 (Online)

MedS Alliance
Journal of Medicine and Medical Sciences

CCREACH

Original Investigation

Predicting Length of Hospital Stay Following Adult Cardiac Surgery: A Prospective Observational Study

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ARTICLE INFO

Article history:
Received:2 July 2023
Revised: 19 August 2023
Accepted: 26 September 2023
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Citation:
Bashyal K,Baral RK, Khakural P, Kadel PB, Gurung A, Bhattarai A. Predicting Length of Hospital Stay Following Adult Cardiac Surgery: A Prospective Observational Study. MedS. J. Med. Sci. 2023;3(6):04-11

ABSTRACT

INTRODUCTION: Despite life-saving benefits, adult cardiac surgery presents challenges due to potential for extended hospital stays and resource strain. Accurately predicting length of stay (LOS) is crucial for efficient resource allocation and patient discharge planning. The study aims to assess factors associated with LOS following adult cardiac surgery and proposed a model for predicting LOS after adult cardiac surgery.**MATERIALS AND METHODS:** A prospective observational study was conducted at Manmohan Cardiothoracic Vascular and Transplant Center from September 2019 to May 2021, enrolling 249 adults undergoing cardiac surgery. A prospective observational study was conducted at Manmohan Cardiothoracic Vascular and Transplant Center from September 2019 to May 2021, enrolling 249 adults undergoing cardiac surgery.Non-probability consecutive sampling was employed and a standardized data collection form was used to record patient-related, cardiac-related, operation-related, and postoperative characteristics including LOS. Descriptive statistics and multivariate analysis were employed to meet the objectives.**RESULTS:** The study reported a median length of hospital stay as 10 days with interquartile range 6 days. Patients who experienced prolonged LOS (> 13 days) after cardiac surgery accounted for 21.70% of the total sample. In an adjusted relationships, only female sex (AOR= 1.957; 95% CI: 1.022 - 3.745), previous cardiac surgery (AOR: 2.684, 95% CI: 1.314 - 7.885), active IE (AOR: 23.187, 95% CI: 2.467 - 217.969), and ECA (AOR: 3.891, 95% CI: 1.135 - 13.332) were identified as significant predictors of prolonged postoperative LOS.**CONCLUSIONS:** By understanding the factors influencing LOS following cardiac surgery, clinicians can optimize care plans and resource allocation, ultimately improving patient outcomes.

Keywords: Cardiac surgery, LOS, Hospital stay, Nepal

https://doi.org/10.3126/mjmms.v3i6.66538

INTRODUCTION

Cardiac surgery, while often life-saving, poses significant challenges for both patients and healthcare systems due to the potential for prolonged hospital stays, complications, and resource utilization [1]. Accurately predicting length of hospital stay (LOS) after adult cardiac surgery is crucial for efficient healthcare resource allocation, cost management, and patient discharge planning. Several factors have been identified as influencing LOS, including patient demographics (age, comorbidities), cardiac function (left ventricular ejection fraction), type of surgery (coronary artery bypass grafting, valve replacement), and postoperative complication like re-exploration [2, 3]. Studies have shown that advanced age, female gender, comorbidities such as chronic lung disease and renal impairment, and poor pre-operative functional status are associated with prolonged LOS [2, 4-6]. Additionally, cardiac-related factors such as left ventricular ejection fraction (LVEF), recent myocardial infarction, and pulmonary artery hypertension have been linked to extended hospital stays [5, 7]. Furthermore, the type and urgency of surgery, as well as post-operative complications such as re-exploration, are significant determinants of LOS. Nonetheless, although risk factors have been identified for prolonged postoperative hospital LOS, few models are available to predict this important metric, and none are able to estimate continuous postoperative LOS with accuracy [8].

While previous research has identified factors influencing LOS after cardiac surgery accurately predicting LOS after adult cardiac surgery remains a challenge in Nepal. As existing models may not be generalizable to the specific patient population, there is a need for further investigation in specific patient populations. Developing a robust and generalizable prediction model for LOS in adult cardiac surgery patients at Manmohan Cardiothoracic Vascular and Transplant Center can improve resource allocation and patient care planning. The study aims to assess patient-related, cardiac-related, operation-related, and postoperative factors associated with LOS following adult cardiac surgery at Manmohan Cardiothoracic Vascular and Transplant Center.

MATERIALS AND METHODS

Study design and setting

This was a prospective observational study conducted over 20 months at Manmohan Cardiothoracic Vascular and Transplant

Center (MCTC), Maharajgunj in Kathmandu, Nepal. Patients were enrolled before surgery and their outcomes were monitored over time, without manipulation of variables from September 2019 to May 2021.

Participants, sample size and sampling technique:

Participants were adult patients (age more than 18 years) who were scheduled for cardiac surgery (isolated coronary artery bypass graft, repair/replacement valve surgery, surgery on thoracic aorta, myxoma excision or combination of any of above) at MCTC, Maharajgunj in Nepal. There were 262 cardiac surgery during the study period. Six of them were under 18 year's old age and 7 were Off-Pump Coronary Artery Bypass (OPCAB). Hence, 13 patients having cardiac surgery were excluded from the study based on inclusion criteria, and only 249 adults undergoing cardiac surgery were considered for the study. Non-probability consecutive sampling was employed to reach all eligible patients consenting to participate.

Data collection procedure and study variables:

Patients scheduled for adult cardiac surgery were approached for participation before surgery. Informed consent was acquired from each participant. A standardized data collection form was used to record baseline demographic and clinical variables, including age, biological sex, chronic lung disease, active infective endocarditis, extracardiac arteriopathy, poor mobility status, previous cardiac surgery, critical pre-operative state, renal impairment, and diabetes mellitus (DM) on insulin. Additional cardiac-related variables were documented, including New York Heart Association (NYHA) functional class, Canadian Cardiovascular Society (CCS) angina pectoris classification IV, left ventricular ejection fraction (LVEF), recent myocardial infarction, and pulmonary artery hypertension. Further, operation-related information on type of surgery performed, urgency for surgery and risk category as per European System for Cardiac Operative Risk Evaluation (EuroSCORE) II were collected [9]. After that, patients underwent cardiac surgery according to standard protocols at the study center and post-operative care was provided as per institutional guidelines. Following surgery, data on post-operative variables were recorded, including re-exploration rate and causes of re-exploration. The primary outcome variable, length of hospital stay (LOS) was finally documented for each participant in days. LOS was calculated from the day of surgery to the day of discharge. It was transformed into binary outcomes – prolonged LOS and not prolonged LOS using cut-off point as LOS exceeding 75th percentile value of > 13 days [8, 10, 11]. As LOS data are invariably right-skewed with extreme values in patients with prolonged stay (Figure 1), the choice of 75th percentile (LOS > 13 days) as the cut-off point disregards extreme values and increases the precision of continuous LOS prediction [12, 13].

Statistical analysis and data management:

Collected data were entered in Microsoft Excel 2016 and EuroSCORE II score was calculated by using calculator provided by official app of EuroSCORE [9, 14]. Data quality checks was performed regularly to ensure accuracy and completeness. After cleaning the data, it was imported into Statistical Package for Social Sciences (SPSS) 26 version for statistical analysis. The data was not normally distributed when tested through shapiro-wilk test (p-value<0.001). Descriptive statistics such as frequency, percentage, median, inter-quartile range (IQR), minimum and maximum values were reported to summarize study variables and LOS. Bivariate analysis such as chi-square or fisher exact tests were used to identify factors potentially associated with LOS at 95% confidence interval (CI) and 5% level of significance. As we were going to predict model, we carried those factors which were significant at p<0.20 into further analysis [15]. The Multivariable analysis techniques like binary logistic regression was employed to develop a predictive model for LOS. LOS was coded 0 for LOS ≤ 13 days and 1 for LOS > 13 days.

Ethical consideration:

Ethical approval was taken from Institutional Review Committee – Institute of Medicine [reference no. 378(6-11) E2/076/077] and permissions were obtained from the hospital administration. Written informed consent was obtained from all participants before enrollment and adhered to the tenets of the Declaration of Helsinki.

RESULTS

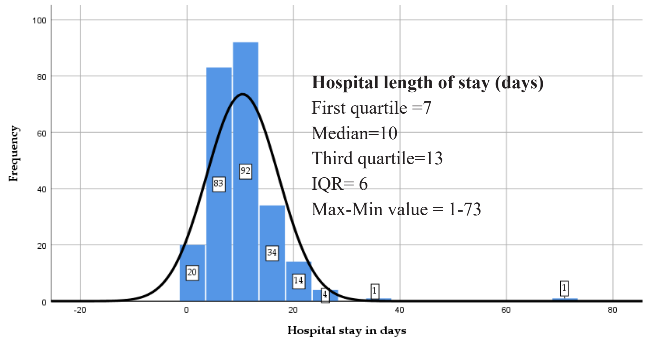

Figure 1: Histogram representing LOS including outliers.

The descriptive findings of the study reported the baseline demographic and clinical variables, cardiac-related, operation-related and post-operative characteristics of the 249 patients who participated in the study on predicting length of hospital stay following adult cardiac surgery. The analysis of LOS following adult cardiac surgery revealed that the median LOS was 10 days, with IQR 6 days (Figure 1). Furthermore, the third quartile of 13 days suggests that three-quarters (75%) of the patients were discharged by this time period. Patients who experienced prolonged LOS (> 13 days) after cardiac surgery accounted for 21.70% of the total sample.

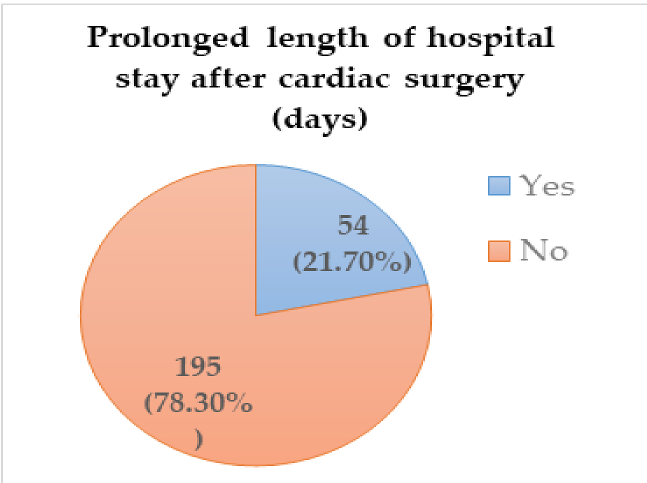

Figure 2: Prolonged length of hospital stay after cardiac surgery

Further, the study population comprised predominantly younger patients, with a median age of 51 years and an interquartile range (IQR) spanning from 39 to 60 years. The age range of participants varied widely, from 18 to 87 years old. As age of the participants did not show linear relationship with the logit transformation of the LOS when checked by Box-Tidwell test for linearity (p-value = 0.016), it was categorized into Adult (≤60 years) and Older adult (>60 years) as per data distribution (75th percentile =60 years); and based on World Health Organization (WHO)'s definition and previous evidences [6, 16, 17]. There was no statistically significant difference in LOS between adult and older adult groups (p-value = 0.853). Further, the study found a trend towards women having a longer length of stay (LOS) after cardiac surgery (females: 34.9%, males: 65.1%), although it wasn't statistically significant (p-value = 0.098). Pre-existing conditions like renal impairment (27.3%) and diabetes (20.9%) were common, but none significantly impacted LOS (p-values > 0.05) except for active infective endocarditis (2.0%, p-value = 0.008). Most patients had moderate limitations in physical activity and heart function. Interestingly, heart-related factors like NYHA class (66.7% Class II), CCS angina class (2.4% Class IV), recent MI (12%), and PAH (27.3% moderate, 7.2% severe) also didn't significantly affect LOS (p-values > 0.05). Added, adult cardiac surgery showed no significant impact of procedure type (valve: 47.8%, CABG: 38.2%, p=0.185), urgency (elective: 81.5%, urgent: 16.1%, emergent: 2.4%, p=0.597), or risk category (low: 46.2%, moderate/high: 30%, p=0.121) on LOS. Re-exploration (8.4%) also didn't affect LOS (p=0.158).As factors like sex, previous cardiac surgery performed, active IE, ECA, critical pre-operative state, type of surgery performed, re-exploration and risk category based on EuroSCORE II had p<0.20; they were carried into further the multivariable analysis to develop a predictive model for LOS [15]. In an adjusted relationships, female patients undergoing cardiac surgery had approximately two times higher odds of experiencing a prolonged LOS compared to male patients (AOR= 1.957; 95% CI: 1.022 - 3.745) and the association was statistically significant . Also, patients with a history of prior cardiac surgery had almost three times higher odds of experiencing a prolonged LOS following subsequent cardiac surgery compared to those

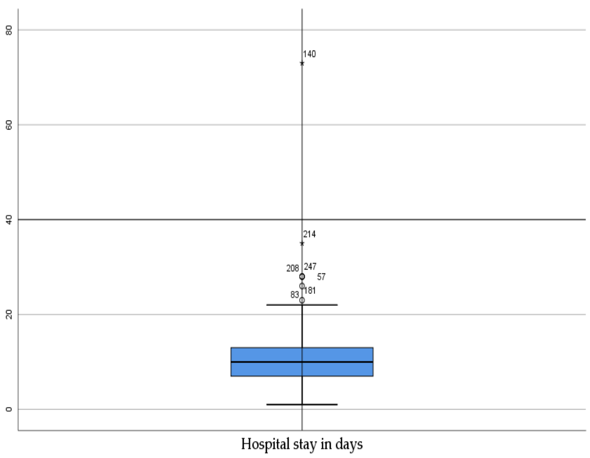

Figure 3: Boxplot of LOS after cardiac surgery with the outliers.

Table 1| Patient related characteristics

Variables	Total	Prolonged LOS		
	n=249 (%)	No n=195(%)	Yes n=54 (%)	p-value
Age group@ (years)				0.853
Adult (≤60)	196 (78.7)	153(78.1)	43(21.9)	
Older adult (>60)	53 (21.3)	42(79.2)	11(20.8)	
Median	51	52	49	
IQR = Q_3 –Q_1	60-39 =21	60-41=19	57-32=25	
Min-Max value	18 – 87	18 - 77	18 – 87	
Sex				0.098
Male	162 (65.1)	132(81.5)	30(18.5)	
Female	87 (34.9)	63(72.4)	24(27.6)	
Chronic Lung Disease				0.995
No	226 (90.8)	177(78.3)	49(21.7)	
Yes	23 (9.2)	18(78.3)	5(21.7)	
Active IE				**0.008***
No	244 (98.0)	194(79.5)	50(20.5)	(fisher's exact)
Yes	5 (2.0)	1(20.0)	4(80.0)	
ECA				0.190
No	235 (94.4)	186(79.1)	49(20.9)	(fisher's exact)
Yes	14 (5.6)	9 (64.3)	5(35.7)	
Poor mobility status				0.521
No	246 (98.8)	193(78.5)	53(21.5)	(fisher's exact)
Yes	3 (1.2)	2(66.7)	1(33.3)	
Previous cardiac surgery				0.117
No	232 (93.2)	184 (79.3)	48(20.7)	(fisher's exact)
Yes	17 (6.8)	11(64.7)	6(35.3)	
Critical pre-operative state				0.176
No	242 (97.2)	191(78.9)	51(21.1)	(fisher's exact)
Yes	7 (2.8)	4(57.1)	3(42.9)	
Renal impairment				0.748
CC-N	181 (72.7)	140(77.3)	41(22.7)	(fisher's exact)
CC-MOD	67 (26.9)	54(80.6)	13(19.4)	
CC-SEVERE	0	0	0	
On dialysis	1 (0.4)	1(100)	0	
DM on insulin				0.215
No	197 (79.1)	151(76.6)	46(23.4)	
Yes	52 (20.9)	44(84.6)	8(15.4)	

Note: @ Box-Tidwell test for linearity (p-value = 0.016); Q_3 – Third quartile; Q_1 – First quartile; CC - creatinine clearance; IE - Infective Endocarditis; ECA - Extracardiac arteriopathy; DM- Diabetes mellitus; Test applied-χ2/fisher's exact tests; *p-value≤0.05.

without such a history having population effect of 1.3 to 7.8 folds, after adjusting for other variables in the analysis (AOR: 2.684, 95% CI: 1.314 - 7.885). Likewise, the data showed statistically significant association between active IE and prolonged LOS. Patients having active IE were 23 times more likely tohave

Table 2| Cardiac-related characteristics

Variables	Total n=249 (%)	Prolonged LOS No n=195(%)	Prolonged LOS Yes n=54 (%)	p-value
NYHA functional class				0.684
Class I	1 (0.4)	1(100)	0	(fisher's exact)
Class II	166 (66.7)	131(78.9)	35(21.1)	
Class III	77 (30.9)	58(75.3)	19(24.7)	
Class IV	5 (2.0)	5(100)	0	
CCS IV				0.345
No	243 (97.6)	189(77.8)	54(22.2)	(fisher's exact)
Yes	6 (2.4)	6(100)	0	
LVEF				0.405
Good (>50 %)	134 (53.8)	104(77.6)	30(22.4)	(fisher's exact)
Moderate (31 – 50 %)	107 (43.0)	83(77.6)	24(22.4)	
Poor (21 – 30 %)	8 (3.2)	8(100)	0	
Very poor (≤ 20 %)	-			
Recent MI				0.811
No	219 (88.0)	171(78.1)	48(21.9)	
Yes	30 (12.0)	24(80.0)	6(20.0)	
PAH				0.394
Mild	163 (65.5)	128(78.5)	35(21.5)	(fisher's exact)
Moderate	68 (27.3)	55(80.9)	13(19.1)	
Severe	18 (7.2)	12(66.7)	6(33.3)	

Note: NYHA- New York Heart Association; CCS - Canadian Cardiovascular Society (CCS) angina pectoris classification; LVEF- Left Ventricular Ejection Fraction; MI- Myocardial Infarction; PAH- Pulmonary Artery Hypertension; Test applied-$\chi 2$/fisher's exact tests.

prolonged LOS following cardiac surgery in comparison to those not having active IE (AOR: 23.187, 95% CI: 2.467 - 217.969). Similarly, adults having ECA were about 300% increased odds of experiencing a prolonged LOS following subsequent cardiac surgery as compared to those not having ECA (AOR: 3.891, 95% CI: 1.135 - 13.332). The other variables such as critical pre-operative state, type of surgery performed, re-exploration and risk category based on EuroSCORE II were not statistically significant with prolonged LOS following cardiac surgery. The binary logistic regression depicts the following equation for the prolonged length of hospital stay following adult cardiac surgery:

$$Logit (\pi(y)) = -1.757 + 0.671X_1 + 0.987X_2 + 3.144X_3 + 1.359X_3$$

Where,

X_1 = Female sex

X_2 = Previous cardiac surgery

X_3 = Active Infective Endocarditis

X_4 = Extracardiac Arteriopathy

There was no problem of multicollinearity (minimum tolerance = 0.651, maximum VIF =1.536). Further, the predictive score model was tested by means of Hosmer-Lemeshow test. It reported that the logistic regression model was statistically significant [$\chi 2(3)$ = 0.448, p-value=0.930] and hence demonstrated a good discrimination. The model explained 51.6% (Nagelkerke R^2) of the variance in LOS and correctly classified 79.9% of cases.

DISCUSSION

The study observed a wide range of LOS among patients, with the first quartile at 7 days, median at 10 days, and third quartile at 13 days. Similar to the current study, previous literature often reported significant variability in LOS, typically indicating a first quartile around 7-8 days, median around 10-12 days, and third quartile around 13-15 days [5, 13, 18, 19]. This consistency

Table 3| Operation-related characteristics

Variables	Total n=249 (%)	Prolonged LOS No n=195(%)	Prolonged LOS Yes n=54 (%)	p-value
Type of surgery performed				0.185
Valve surgery	119(47.8)	90(75.6)	29(24.4)	(fisher's exact)
Isolated CABG	95(38.2)	79(83.2)	16(16.8)	
Surgery involving thoracic aorta only	17(6.8)	14(82.4)	3(17.6)	
Mixed procedures	17(6.8)	12(70.6)	5(29.4)	
Myxoma excision	1(0.4)	0	1(100.0)	
Urgency for surgery				0.597
Elective	203(81.5)	158(77.8)	45(22.2)	(fisher's exact)
Urgent	40(16.1)	31(77.5)	9(22.5)	
Emergent	6(2.4)	6(100)	0	
Salvage	-			
Risk category as per EuroSCORE II				0.121
Very low risk (<1 %)	96(38.6)	82(85.4)	14(14.6)	(fisher's exact)
Low risk (1-2.99 %)	115(46.2)	86(74.8)	29(25.2)	
Moderate risk (3-4.99 %)	18(7.2)	12(66.7)	6(33.3)	
High risk (≥ 5 %)	20(8.0)	15(75.0)	5(25.0)	

Note: CABG - coronary artery bypass graft; EuroSCORE - European System for Cardiac Operative Risk Evaluation; Test applied-$\chi 2$/fisher's exact tests; *p-value≤0.05

Table 4| Post-operative characteristics

Variables	Total n (%)	Prolonged LOS No n=195(%)	Prolonged LOS Yes n=54 (%)	p-value
Re-exploration (n=249)				0.158
No	228(91.6)	176(77.2)	52(22.8)	(fisher's exact)
Yes	21(8.4)	19(90.5)	2(9.5)	
Causes of re-exploration (n=21)				0.952
Not known	16(76.2)	14(87.5)	2(12.5)	(fisher's exact)
Graft vessel bleed	2(9.5)	2(100.0)	0	
LA tomy	1(4.8)	1(100)	0	
LIMA bed venous ooze	1(4.8)	1(100)	0	
Sternal wire bleed	1(4.8)	1(100)	0	

Note: LA-Left Atrial; LIMA- Left Internal Mammary Artery; Test applied-$\chi 2$/fisher's exact tests; *p-value≤0.05

suggests that the patterns of postoperative hospital stay may be relatively consistent across different populations. Considering 75th percentile as cut-off (=13 days) like in studies conducted by Buschmann et al., (2022) and Cohen et al., (2009), patients who experienced prolonged LOS (> 13 days) after cardiac surgery accounted one-fifth of the total sample [5, 10, 11]. This proportion was smaller to the retrospective study done at the Instituto de Cardiologia do Distrito Federal hospital in Brazil and at a major referral hospital in Oman, where prolonged length of stay following cardiac surgery were 27.9% and 30.5% respectively [6, 13]. The relatively lower proportion of patients staying longer period in our study might be attributed to predominantly younger

Table 5|Binary logistic regression for prolonged length of hospital stay (n=249)		
Variables	COR (95% CI)	AOR (95% CI)
Sex		
Male		Ref
Female	1.676 (0.906-3.100)	1.957 (1.022- 3.745)*
Previous cardiac surgery		
No		Ref
Yes	2.091 (0.736-5.941)	2.684 (1.314-7.885)**
Active IE		
No		Ref
Yes	15.520 (1.697- 141.936)	23.187 (2.467-217.969)**
ECA		
No		Ref
Yes	2.109 (0.676-6.578)	3.891 (1.135-13.332)*
Critical pre-operative state		
No		Ref
Yes	2.809 (0.609-12.952)	2.937 (0.615-14.034)
Type of surgery performed		
Valve surgery		Ref
Isolated CABG	0.629 (0.318-1.242)	1.056 (0.457-2.441)
Surgery -thoracic aorta	0.665 (0.178-2.478)	0.450 (0.097-2.087)
Mixed procedures	1.293 (0.420-3.979)	1.144 (0.343-3.816)
Myxoma excision	-	-
Risk -EuroSCORE II		
Very low risk (<1 %)		Ref
Low risk (1-2.99 %)	1.975 (0.975-4.001) 2.929 (0.944-9.085)	1.617 (0.768-3.405)
Moderate risk (3-4.99 %)		2.605 (0.755-8.993)
High risk (≥ 5 %)	1.952 (0.612-6.228)	1.148 (0.262-5.027)
Re-exploration		
No		Ref
Yes	0.356 (0.080-1.580)	0.329 (0.070-1.537)

Note: IE - Infective Endocarditis; ECA - Extracardiac arteriopathy; CABG - coronary artery bypass graft; EuroSCORE - European System for Cardiac Operative Risk Evaluation; COR- Crude Odds Ratio; AOR- Adjusted Odds Ratio; CI-Confidence Interval; *p-value≤0.05; **p-value≤0.01; Ref – Reference category

patients with a median age of 49 years and IQR 25 years; and difference in study design, sample size and study period. The previous studies had relatively older population, larger sample size and longer study period employing retrospective design.

The findings of the study reported the baseline demographic and clinical variables, cardiac-related, operation-related and post-operative characteristics of the 249 patients participating in the study on predicting length of hospital stay following adult cardiac surgery; where none of the variables showed significant differences except active infective endocarditis. Various studies around the globe reported different factors that showed association with the LOS; nevertheless, the factors associated were not consistent throughout the world [1-8, 11, 12, 18, 19]. This might indicate that the factors affecting are context-based and need to assess in various sub-population. While the lack of statistically significant associations for most variables may seem surprising, it's essential to interpret the findings within the context of the study's limitations and potential sources of variability. The study might have had a relatively small sample size due to shorter data collection period, which could limit the statistical power to detect significant associations between certain variables and LOS. With a larger sample size, it's possible that some associations might have reached statistical significance. Moreover, the study might have categorized variables in a way that masked potential associations with LOS. For example, categorizing continuous variables into discrete groups could lead to loss of information and reduced statistical power. Additionally, the specific thresholds used for categorization could have influenced the results. However, whatever done in the study – age categorization or considering cut-off points were all done on the basis of prior evidences [8, 10-13, 15].

In an adjusted relationships, female sex, previous cardiac surgery, active infective endocarditis and extracardiac arteriopathy were identified as significant predictors of prolonged LOS following cardiac surgery. Previous research has suggested that female sex is associated with increased postoperative morbidity in cardiac surgery, possibly due to smaller coronary artery size, hormonal factors, and differences in disease presentation [2, 4, 6]. Therefore, it's coherent that female sex may also be associated with prolonged LOS; however, more research is needed to confirm this association and understand the underlying reasons. Further, previous cardiac surgery and active infective endocarditis can complicate recovery due to altered anatomy and systemic inflammation, respectively; where as extracardiac arteriopathy, such as peripheral vascular disease, may exacerbate perioperative complications and delay recovery increasing the length of hospital stay. These associations are supported by previous studies, and are consistent across the globe [1-7, 12, 20]. Healthcare providers can use these predictors to identify high-risk patients who may be more likely to experience prolonged LOS following cardiac surgery. By recognizing these risk factors early in the preoperative assessment process, clinicians can tailor their management strategies to optimize patient care and mitigate potential complications.

The findings revealed that most patients related variables such as age, chronic lung disease, poor mobility status, critical pre-operative state, renal impairment, and DM on insulin; cardiac-related variables such as NYHA functional class, CCS IV, LVEF, recent MI, and PAH; operation-related variables such as type of surgery performed, urgency for surgery and risk category as per EuroSCORE II; and post-operative characteristics such as re-exploration rate and causes of re-exploration; assessed in this study did not have a significant association with prolonged LOS following adult cardiac surgery, suggesting that they may have less influence on postoperative recovery duration in this patient population. These results imply that factors other than these characteristics might play a more prominent role in determining postoperative LOS in our context. Clinicians and researchers should consider other patient-related, cardiac-related variables, operation-related, and postoperative factors when predicting and managing LOS in adult cardiac surgery patients. Further research might be warranted to explore additional factors that could influence LOS in this patient population.

CONCLUSIONS

This study on predicting length of hospital stay following adult cardiac surgery revealed a significant variability in post-operative stay, with a median length of stay of 10 days in Nepal. Patient related factors such as female sex, previous cardiac surgery, active infective endocarditis, and extracardiac arteriopathy are identified as significant predictors of prolonged hospital stay. This will help in identifying patients at higher risk for prolonged LOS, allowing for better clinical decision-making and resource allocation in cardiac surgery settings in Nepal to improve overall patient outcomes.

ADDITIONAL INFORMATION AND DECLARATIONS

Acknowledgements: Authors wish to thank all the participants for all their supports during this study.

Competing Interests: The authors declare no competing interests.

Funding: No funding was received for this research.

Author Contributions: Concept and design: K.P.B, R.K.B, A.B, and A.G; Statistical analysis: K.P.B, P.Kh, Writing of the manuscript: K.P.B, R.K.B., A.B, P.Kh, P.Ka; Data collection: K.P.B; Revision and editing: All have involved during revision and editing work. All authors have read and agreed with the contents of the final manuscript towards publication.

Data Availability: Data will be available upon request to corresponding authors after valid reason.

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