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Research paper

Impact of post-procedural length of stay on short-term outcomes and readmissions after TAVR and MitraClip

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ABSTRACT

Background: Post-procedural hospital length of stay (P-LOS) is an important determinant of cost-related outcomes. In the present study, we aimed to assess the impact of P-LOS on short-term outcomes after transcatheter aortic valve replacement (TAVR) and MitraClip.

Methods: We performed a retrospective cohort study, retrieving data from the National Readmissions Database (NRD) for patients who underwent transfemoral TAVR and MitraClip between January 2014 and December 2017. We employed multivariable logistic regression to evaluate the association between P-LOS and 30-day all-cause mortality and readmissions.

Results: A total of 65,726 and 7347 patients underwent TAVR and MitraClip, respectively within the study period. After 30 days of discharge, 13.7% and 15.1% of TAVR and MitraClip patients were readmitted for any reason, while 0.5% and 0.9% died within the readmission hospitalization. A longer P-LOS was associated with an increased risk of 30-day all-cause readmission in both TAVR (OR = 1.027, 95% CI [1.023–1.032]) and MitraClip (OR = 1.025, 95%CI [1.012–1.038]) patients. This finding remained true for patients who developed or did not develop complications after both procedures. In terms of 30-day inhospital mortality, a longer P-LOS was associated with a higher risk in TAVR patients (OR = 1.039, 95%CI [1.028–1.049]), but no increased risk in MitraClip patients (OR = 1.014, 95%CI [0.985–1.044]). Other predictors of 30-day readmission after both procedures included heart failure, post-procedural acute kidney injury, and discharge with disability.

Conclusion: The current study shows that shorter P-LOS was associated with reduced risk of short-term readmission after both TAVR and MitraClip and reduced short-term mortality after TAVR (mainly in patients who developed post-procedural complications). Shorter P-LOS is a predictor of readmission and sicker patient group. Patients requiring longer LOS should be followed closely to prevent readmission and enhance better outcomes. Future studies evaluating P-LOS impact on long-term and patient-oriented outcomes are needed.

1. Introduction

Transcatheter aortic valve replacement (TAVR) has been approved for the management of aortic stenosis (AS) in low, intermediate and high surgical risk patients [1–3]. In mitral regurgitation (MR) patients, transcatheter edge to edge mitral valve repair using MitraClip technique has recently evolved as a promising treatment modality [4]. Growing operator experience and recent advances in devices, techniques together with better understanding of peri-procedural care have largely contributed to optimizing clinical outcomes and improving MitraClip

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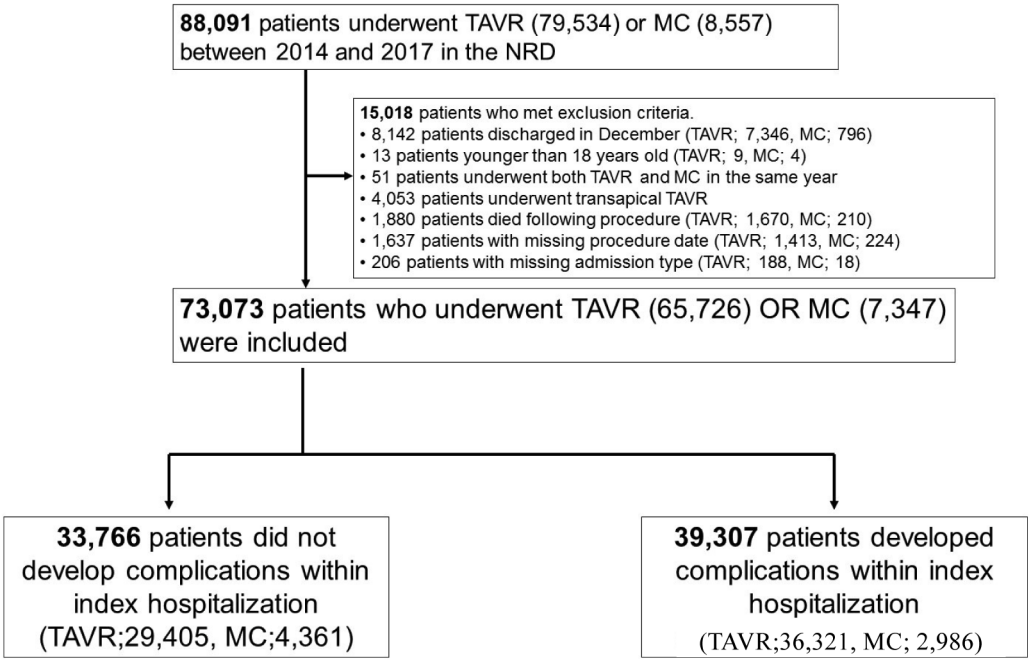

Fig. 1. Patients' selection flowchart.

and TAVR procedure complications [5,6].

Motivated by willingness to improve cost-related outcomes in interventional practice, the adoption of a "minimalist" care approach including conscious sedation, vascular access, post-operative monitoring based on rapid recovery strategies and optimizing discharge pathways has been investigated [7]. Because the post-procedural hospital length of stay (P-LOS) is an important determinant of peri-procedural costs, early discharge programs are increasingly considered [8–10]. Further, there have been few reports focusing on the impact of P-LOS on procedural outcomes that showed that a minimalist approach, including a shorter P-LOS improves healthcare cost utilization without impacting index 30-day outcomes when compared to standard strategies [11–13]. However, it remains unclear whether shortening P-LOS following TAVR and MitraClip is associated with an increased risk of 30-day inhospital mortality or unplanned 30-day readmissions.

Therefore, the aim of the present study was to assess the impact of P-LOS on 30-day outcomes in patients who undergo MitraClip and transfemoral TAVR procedures, using data from a large, nationwide representative database.

2. Methods

2.1. Study design and data source

We performed a retrospective cohort study following the STROBE checklist and using the NRD database, released by the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality (AHRQ) [14]. The NRD is a nationally representative database of hospital admissions in US non-federal hospitals. It includes up to 17 million discharges each year in up to 27 states, accounting for about 57% of all hospitalizations in the US and providing discharge weights that can be used to provide national US estimates [15]. The need for an institutional review board (IRB) approval was waived for this study because of the anonymized and de-identified nature of the publicly available data in the NRD.

2.2. Patient selection

We included patients who underwent either TAVR or MitraClip between January 2014 and December 2017. We excluded patients who were discharged in December, to allow for at least 30 days of follow-up for all patients because the NRD does not follow patients over years. In addition, we excluded patients younger than 18 years old, patients who underwent both TAVR and MitraClip in the same year, patients who underwent transapical TAVR, patients who died within the index hospitalization following the procedure, and patients whose data on procedure date and admission status (elective vs. urgent) was missing (Fig. 1). In order to identify patients matching our inclusion criteria, ICD-9 (International Classification of Diseases-9th Edition-Clinical Modification) codes were used before October 2015, whereas ICD-10 codes were used starting from October 2015. Supp. Table 1 lists the ICD codes used for these selections.

2.3. Patients' characteristics and study outcomes

We extracted the data of patients who underwent MitraClip and TAVR procedures during the study period of interest. We looked at the following baseline variables in the included patients: age, sex, admission type (elective vs. urgent), hospital procedural volume, and patient comorbidities. TAVR procedural volume was defined as the following: a hospital was considered low-, medium-, or high-volume if it performed less than 50, 50–99, or more than 99 TAVR procedures a year, respectively. MitraClip procedural volume was defined as the following: a hospital was considered low-, medium-, or high-volume if it performed 20 or less, 21–50, or more than 50 MitraClip procedures a year, respectively.

In addition, we assessed P-LOS, post-procedural complications (including stroke, acute myocardial infarction (AMI), acute kidney injury (AKI), blood transfusion, permanent pacemaker (PPM) implantation, intra-aortic balloon pump (IABP)), and patients' disposition following discharge. P-LOS was defined as the latency in days between the day of procedure and the day of discharge. The NRD categorizes patient disposition into the following categories: 1) routine discharge, 2) transfer to a short-term hospital, skilled nursing facility, intermediate care facility, or other facilities, 3) home health care, and 4) discharge against medical advice [16]. We defined "Discharge with disability" as any disposition category not reported as routine discharge. We further subdivided the included patients based on the development of any post-

Table 1
Baseline characteristics and outcomes of included patients who underwent TAVR or MitraClip (2014–2017).

Baseline characteristics	TAVR (n = 65,726)	MITRA-Clip (n = 7347)
Age (years), median (IQR)	82 (76–87)	81 (73–86)
Gender		
Male (%)	35,500 (54)	3936 (53.6)
Female (%)	30,226 (46)	3411 (46.4)
Admission type		
Elective (%)	52,150 (79.3)	5509 (75)
Urgent (%)	13,576 (20.7)	1838 (25)
Hospital volume		
Low-volume hospitals	10,076 (15.3)	1350 (18.4)
Medium-volume hospitals	18,940 (28.8)	2511 (34.2)
High-volume hospitals	36,710 (55.9)	3486 (47.4)
Comorbidities		
Hypertension (%)	56,442 (85.9)	5777 (78.6)
Congestive heart failure (%)	47,675 (72.5)	5767 (78.5)
Atrial fibrillation (%)	21,783 (33.1)	3602 (49)
Diabetes mellitus (%)	23,097 (35.1)	1843 (25.1)
Liver disease (%)	1733 (2.6)	151 (2.1)
Renal failure (%)	20,591 (31.3)	2455 (33.4)
Dyslipidemia (%)	44,324 (67.4)	4167 (56.7)
Obesity/overweight (%)	11,578 (17.6)	681 (9.3)
Smoking (%)	23,583 (35.9)	3524 (34.4)
History of myocardial infarction (%)	7905 (12)	1099 (15)
History of cerebrovascular events (%)	8093 (12.3)	856 (11.7)
History of PCI (%)	13,670 (20.8)	1325 (18)
History of CABG (%)	12,349 (18.8)	1665 (22.7)
Post-procedural outcomes		
Post-procedural length of stay (days), median (IQR)	3 (2–5)	2 (1–4)
In-hospital stroke (%)	1185 (1.8)	55 (0.7)
In-hospital AMI (%)	1769 (2.7)	138 (1.9)
In-hospital AKI (%)	6955 (10.6)	944 (12.8)
Blood transfusion (%)	6248 (9.5)	547 (7.4)
PPM implantation (%)	7198 (11)	56 (0.8)
Intra-aortic balloon pump (%)	311 (0.5)	104 (1.4)
Discharge with disability (%)	29,471 (44.8)	2424 (33)
30-day post-discharge outcomes		
All-cause 30-day readmission (%)	8979 (13.7)	1113 (15.1)
30-day in-hospital mortality (%)	358 (0.5)	66 (0.9)

procedural complication or not. A complication was defined as any of the following: stroke, AMI, AKI, blood transfusion, PPM implantation, IABP, and discharge with disability. All patients were followed for 30 days following discharge.

We assessed two main outcomes: all-cause 30-day readmission; defined as any readmission within 30 days of discharge following index hospitalization, and all-cause 30-day in-hospital mortality; defined as in-hospital death within 30 days of discharge following index hospitalization within any later hospitalization.

2.4. Statistical analysis

Categorical variables were presented as numbers and percentages and were compared using the Chi-square test, while continuous variables were presented as median (interquartile range [IQR]) and were compared using the Mann–Whitney *U* test. Kaplan-Meier curves were constructed to show the survival function of 30-day readmission and 30-day inhospital mortality following each procedure and log-rank test was conducted to compare between groups. Patients were censored if they did not develop the event at 30 days. These outcomes were assessed in each group (TAVR and MitraClip) and were then assessed in patients who developed complications and patients who did not.

The predictors of all-cause 30-day readmission and all-cause 30-day in-hospital mortality were examined using multivariable logistic regression models. All variables of patient characteristics and procedural outcomes were included as covariates in the multivariable analyses. All tests were two-sided with a significance level of 0.05. All statistical analyses were conducted using IBM SPSS Statistics, version 26 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Baseline characteristics and post-procedural outcomes

Our study included 65,726 and 7347 patients who underwent TAVR and MitraClip, respectively, and met our selection criteria. TAVR patients were less likely to be admitted urgently (20.7% vs. 25%, P < 0.001) and more likely to be admitted to high-volume hospitals (55.9% vs. 47.4%, P < 0.001). The prevalence of different comorbidities in both patient groups is illustrated in Table 1.

A total of 29,405 and 4361 TAVR and MitraClip patients, respectively, who were discharged alive and without post-procedural complications were analyzed separately, and their baseline characteristics are summarized in Supp. Table 2.

3.2. 30-day outcomes following TAVR

After 30 days of discharge, 13.7% of TAVR patients were readmitted for any reason and 0.5% died within readmission hospitalization, as shown in Table 1. The survival and freedom from events curves for in-hospital mortality and all-cause 30-day readmission stratified by post-procedural complications are demonstrated in Fig. 2, respectively. The survival curves of all-cause 30-day readmission and 30-day inhospital mortality in the entire TAVR cohort are illustrated in Supplementary Fig. 1. After adjusting for age, sex, admission type, hospital procedural-volume, baseline characteristics, and post-procedural in-hospital outcomes, a longer P-LOS was associated with higher risks of both 30-day readmission (OR = 1.027, 95% CI [1.023–1.032], P < 0.001) and 30-

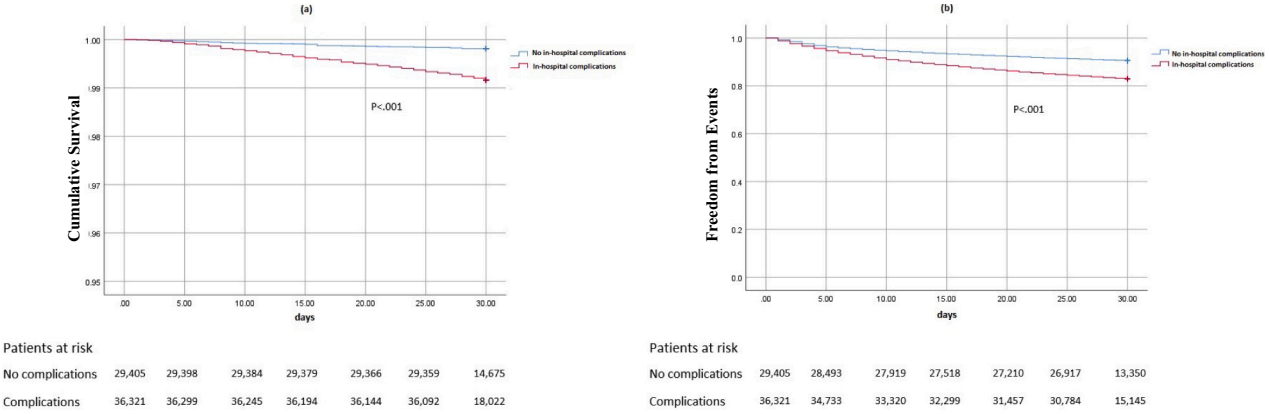

Fig. 2. Kaplan Meier survival curves of (a) 30-day in-hospital mortality and (b) 30-day readmission in TAVR patients grouped by post-procedural outcomes.

Table 2
Multivariate logistic regression of predictors of all-cause 30-day readmission and 30-day in-hospital mortality following TAVR.

	All-cause 30-day readmission		30-day in-hospital mortality	
	Odds ratios (95% CI)	P-value	Odds ratios (95% CI)	P-value
Post-procedural length of stay (in days)	1.027 (1.023–1.032)	<0.001	1.039 (1.028–1.049)	<0.001
Procedural volume (vs. low-volume)				
Medium-volume	0.979 (0.913–1.050)	0.554	1.131 (0.836–1.528)	0.425
High-volume	0.868 (0.814–0.926)	<0.001	0.723 (0.540–0.967)	0.029
Age (in years)	1 (0.997–1.003)	0.901	1.022 (1.007–1.038)	0.005
Female sex (vs. male)	0.976 (0.931–1.025)	0.333	0.694 (0.555–0.868)	0.001
Elective (vs. urgent admission)	0.818 (0.774–0.865)	<0.001	0.814 (0.640–1.034)	0.091
Hypertension (vs. no)	1.012 (0.945–1.083)	0.731	0.895 (0.665–1.202)	0.46
Congestive heart failure (vs. no)	1.156 (1.095–1.221)	<0.001	1.403 (1.057–1.863)	0.019
Atrial fibrillation (vs. no)	1.345 (1.283–1.410)	<0.001	1.516 (1.225–1.875)	<0.001
Diabetes mellitus (vs. no)	1.089 (1.037–1.144)	0.001	0.960 (0.763–1.208)	0.728
Liver disease (vs. no)	1.156 (1.009–1.325)	0.037	1.782 (1.024–3.100)	0.041
Renal failure (vs. no)	1.260 (1.200–1.324)	<0.001	1.153 (0.920–1.445)	0.216
Dyslipidemia (vs. no)	0.895 (0.852–0.940)	<0.001	0.935 (0.746–1.171)	0.556
Obesity/overweight (vs. no)	0.969 (0.910–1.032)	0.324	1.222 (0.920–1.624)	0.166
Smoking (vs. no)	1.016 (0.968–1.067)	0.527	0.699 (0.548–0.891)	0.004
History of cerebrovascular events (vs. no)	1.095 (1.024–1.172)	0.008	1.121 (0.823–1.526)	0.469
History of myocardial infarction (vs. no)	1.042 (0.971–1.119)	0.253	0.911 (0.646–1.285)	0.595
History of PCI (vs. no)	0.988 (0.932–1.047)	0.673	0.842 (0.632–1.123)	0.242
History of CABG (vs. no)	0.924 (0.868–0.983)	0.012	1.184 (0.899–1.559)	0.229
Post-procedural stroke (vs. no)	0.842 (0.716–0.990)	0.038	0.956 (0.537–1.702)	0.878
Post-procedural AMI (vs. no)	0.986 (0.867–1.122)	0.835	1.092 (0.671–1.779)	0.772
Post-procedural AKI (vs. no)	1.322 (1.234–1.417)	<0.001	1.633 (1.257–2.123)	<0.001
Post-procedural blood transfusion (vs. no)	1.417 (1.324–1.517)	<0.001	1.347 (1.025–1.769)	0.033
PPM implantation (vs. no)	1.014 (0.945–1.088)	0.698	1.204 (0.906–1.601)	0.201
Intra-aortic balloon pump (vs. no)	0.986 (0.743–1.310)	0.924	1.221 (0.516–2.891)	0.649
Discharge with disability (vs. no)	1.464 (1.393–1.539)	<0.001	2.674 (2.057–3.477)	<0.001

day inhospital mortality (OR = 1.039, 95% CI [1.028–1.049], P < 0.001) (Table 2).

Other predictors of 30-day re-admission included heart failure (OR = 1.156, 95% CI [1.095–1.221], P < 0.001), atrial fibrillation (OR = 1.345, 95% CI [1.283–1.410], P < 0.001), DM (OR = 1.089, 95% CI [1.037–1.144], P = 0.001), liver disease (OR = 1.156, 95% CI [1.1.009–1.325], P = 0.037), renal failure (OR = 1.260, 95% CI [1.200–1.324], P < 0.001), post-procedural AKI (OR = 1.322, 95% CI [1.234–1.417], P < 0.001), blood transfusion (OR = 1.417, 95% CI [1.324–1.517], P < 0.001), and discharge with disability (OR = 1.464, 95% CI [1.393–1.539], P < 0.001).

Other predictors of 30-day inhospital mortality following TAVR included older age (OR = 1.022, 95% CI [1.007–1.038], P = 0.005), heart failure (OR = 1.403, 95% CI [1.057–1.863], P = 0.019), atrial fibrillation (OR = 1.516, 95% CI [1.225–1.875], P < 0.001), liver disease (OR = 1.782, 95% CI [1.024–3.100], P = 0.041), development of post-procedural AKI (OR = 1.633, 95% CI [1.257–2.123], P < 0.001), and discharge with disability (OR = 2.674, 95% CI [2.057–3.477], P < 0.001), as shown in Table 2.

A subgroup analysis of TAVR patients who did not develop complications during index hospitalization showed that 9.5% of TAVR patients were readmitted within 30 days of discharge whereas 0.2% died within 30 days (Supplementary Table 2). Fig. 2 shows the survival curves of all-cause 30-day readmission and 30-day inhospital mortality among TAVR patients with/without post-procedural complications. After adjusting for age, sex, admission type, hospital procedural volume, and baseline characteristics, a longer P-LOS was associated with a higher risk of 30-day readmission (OR = 1.076, 95% CI [1.054–1.099], P < 0.001) and a similar risk of 30-day in-hospital mortality (OR = 1.082, 95% CI [0.985–1.189], P = 0.1) (Supplementary Table 3). On the other hand, a subgroup analysis of patients who developed post-procedural complications, and after adjusting for the same variables in addition to complications, a longer P-LOS was associated with higher risks of both 30-day readmission (OR = 1.026, 95% CI [1.021–1.031], P < 0.001) and 30-day in-hospital mortality (OR = 1.038, 95% CI [1.027–1.049], P < 0.001) (Supplementary Table 4).

3.3. 30-day outcomes following MitraClip

After 30 days of discharge, 15.1% of MitraClip patients were readmitted for any reason and 0.9% died within hospitalization (Table 1). Fig. 3 shows the freedom from events curve of all-cause 30-day readmission and survival curve of 30-day inhospital mortality. After adjusting for age, sex, admission type, hospital procedural-volume, baseline characteristics, and post-procedural in-hospital outcomes, a longer P-LOS was associated with a higher risk of 30-day readmission (OR = 1.025, 95% CI [1.012–1.038], P < 0.001) and a similar 30-day mortality risk (OR = 1.014, 95% CI [0.985–1.044], P = 0.346). The survival curves of all-cause 30-day readmission and 30-day inhospital mortality in the MitraClip cohort are illustrated in Supplementary Fig. 2.

Other predictors of 30-day re-admission included female sex (OR = 1.198, 95% CI [1.046–1.373], P = 0.009), heart failure (OR = 1.219, 95% CI [1.020–1.456], P = 0.029), post-procedural AKI (OR = 1.578, 95% CI [1.304–1.910], P < 0.001), blood transfusion (OR = 1.449, 95% CI [1.165–1.802], P = 0.001), and discharge with disability (OR = 1.630, 95% CI [1.408–1.887], P < 0.001).

The predictors of 30-day inhospital mortality following MitraClip included history of myocardial infarction (OR = 2.250, 95% CI [1.221–4.147], P = 0.009), post-procedural blood transfusion (OR = 2.817, 95% CI [1.546–5.132], P = 0.001) and discharge with disability (OR = 3.242, 95% CI [1.781–5.901], P < 0.001) (Table 3).

A subgroup analysis of MitraClip patients who did not develop complications during index hospitalization showed that 10.7% of MitraClip patients were readmitted within 30 days of discharge whereas 0.3% died within 30 days (Supp. Table 2). Fig. 3 shows the survival curves of all-cause 30-day readmission and 30-day inhospital mortality among MitraClip patients with/without complications. After adjusting for age, sex, admission type, hospital procedural-volume, and baseline characteristics, a longer P-LOS was associated with higher risk of 30-day readmission (OR = 1.060, 95% CI [1.011–1.112], P = 0.017) and no increased risk of 30-day in-hospital mortality (OR = 1.093, 95% CI [0.858–1.393], P = 0.472) (Supp. Table 5).

On the other hand, a subgroup analysis of patients who developed post-procedural complications, and after adjusting for the same variables in addition for complications, a longer P-LOS was associated with a higher risk 30-day readmission (OR = 1.023, 95% CI [1.010–1.036], P = 0.001) and a similar risk of 30-day in-hospital mortality (OR = 1.013,

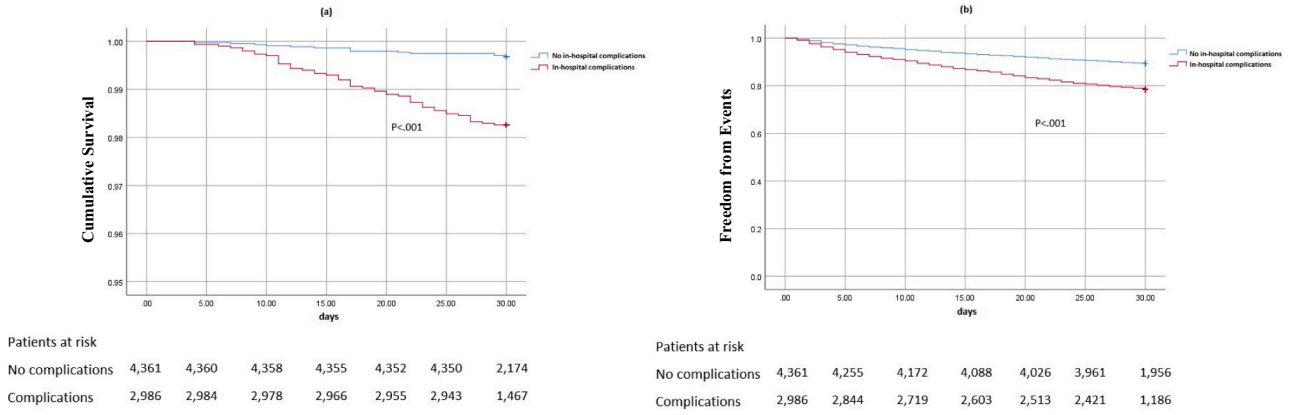

Fig. 3. Kaplan Meier survival curves of (a) 30-day in-hospital mortality and (b) 30-day readmission in MitraClip patients grouped by post-procedural outcomes.

95% CI [0.983–1.044], P = 0.386) (Supp. Table 6).

4. Discussion

Owing to the fact that, longer P-LOS is commonly associated with procedural and in-hospital complications, we explored the relation between P-LOS and our primary endpoints (30-day- inhospital mortality and readmission). In this US nationwide representative study of over 65,000 and 7000 TAVR and MitraClip patients, respectively, our findings are summarized as follows: The risk of 30-day re-admission was significantly increased with longer P-LOS after either TAVR or MitraClip (in both complicated and non-complicated groups). However, P-LOS could predict the risk of 30-day inhospital mortality in TAVR (complicated group only on subgroup analysis), but not in MitraClip group (regardless the occurrence of complications).

4.1. Post-procedural LOS and TAVR

We aimed to assess whether shorter or longer P-LOS would be associated with 30-day readmissions and inhospital mortality outcomes after TAVR. Regardless of the complexity of hospital course, the risk of readmission remained higher in patients with longer P-LOS. With this in mind, P-LOS after TAVR can be considered as a quality metric [17,9]. We found that both complicated and uncomplicated TAVR patients with shorter P-LOS were less likely to be readmitted at 30 days. These findings are in line with the FAST-TAVI trial reporting that longer LOS was an independent predictor of 30-day readmissions even after adjusting for baseline and procedural characteristics [10]. In addition, Kotronias et al. reported in a recent meta-analysis of eight studies that early discharge carries a lower risk of 30-day readmissions, compared to standard discharge [18].

Given that procedural complications impact the LOS, morbidity and mortality burden following TAVR, we analyzed our data for 30-day outcomes with/without occurrence of complications. We found that with prolonged P-LOS, the risk of readmission remained high even after adjusting for in-hospital complications post-TAVR. This coincides with the multicenter FAST-TAVI trial that reported an association of longer LOS with nominal increase in 30-day readmissions among patients with uncomplicated post-operative course [10]. However, the literature has contradicting results in terms of whether shorter P-LOS is associated with favorable short-term outcomes. Kamioka et al. reported no significant difference in 30-day mortality between next day discharge (NDD) and non-NDD groups within a balloon-expandable TAVR cohort [8]. While Barbanti et al. found no significant differences in 30-day outcomes in early discharged patients compared to those with delayed discharge [19]. Overall, our results along with published literature, suggest that early discharge has superior (or at least similar) short-term outcomes to later discharge, regardless of in-hospital complications.

The association between prolonged length of hospital stay and worse outcomes is also documented following other cardiac procedures. Agarwal and colleagues reported a higher risk of long-term mortality in STEMI patients with long hospital stays after PCI [20]. Another report from the National Cardiovascular Data registry revealed a significant increase in adjusted mortality and MACE in older STEMI patients with longer hospital stays after PCI, in comparison to those with shorter hospital stays [21]. Similar findings after PCI were reported from the Nationwide Readmission database [22]. Other studies showed the safety and feasibility of same-day or next-day discharge in STEMI patients following PCI [23–25].

4.2. Predictors of early versus late discharge in TAVR

Former investigations attempted to identify the predictors of early and delayed discharge. Barbanti et al. reported advanced NYHA class and bleeding to be predictors of delayed discharge, while prior PPM was associated with shorter LOS [19]. Wayangankar et al. identified the presence of an intra-cardiac device, prior MI, CABG, valve in valve and endovascular approach to be predictors of early discharge, while age $\geq$ 85 years, African American and Hispanic race groups, patients with prior mitral valve procedures, presence of diabetes, NYHA class IV, AF, dialysis and CKD 4 or higher to be predictors of delayed discharge [17].

4.3. Post-procedural LOS and MitraClip

The benefits of P-LOS reduction in patients undergoing MitraClip include cutting hospital costs related to unnecessary hospitalization days and the positive effects of early mobilization. However, the dedicated assessment of MitraClip patients in which ED would be feasible has not been quite investigated yet. To our knowledge, there has been isolated reports that studied the safety and feasibility of shortening P-LOS in MitraClip patients. We investigated the predictors associated with 30-day readmissions and mortality in MitraClip patients with/without procedural complications. We found that patients with longer P-LOS were more likely to have 30-day readmissions in both complicated and uncomplicated MitraClip patients. Among post-procedural complications, AKI and blood transfusion were associated with higher 30-day readmissions.

4.4. Predictors of early versus late discharge in MitraClip

A former study by Tamburino et al. identified male gender and procedural year to be predictors of early discharge following MitraClip, whereas AF, Mitral Valve Academic Research Consortium (MVARC) bleeding, BNP levels and post-MitraClip MR grade were predictors of delayed discharge [11]. Indeed, patients with peri-procedural complications in both TAVR and MitraClip require additional care in order to

Table 3
Multivariate logistic regression of predictors of all-cause 30-day readmission and 30-day in-hospital mortality following MitraClip.

	All-cause 30-day readmission		30-day in-hospital mortality	
	Odds ratios (95% CI)	P-value	Odds ratios (95% CI)	P-value
Post-procedural length of stay (in days)	1.025 (1.012–1.038)	<0.001	1.014 (0.985–1.044)	0.346
Procedural volume (vs. low-volume)				
Medium-volume	0.940 (0.779–1.134)	0.518	2.088 (0.965–4.518)	0.062
High-volume	0.970 (0.812–1.159)	0.736	1.537 (0.707–3.342)	0.278
Age (in years)	0.998 (0.991–1.004)	0.473	1.022 (0.993–1.051)	0.138
Female sex (vs. male)	1.198 (1.046–1.373)	0.009	1.213 (0.722–2.037)	0.465
Elective (vs. urgent admission)	0.846 (0.724–0.989)	0.036	0.805 (0.461–1.406)	0.445
Hypertension (vs. no)	1.014 (0.855–1.203)	0.87	0.746 (0.398–1.396)	0.359
Congestive heart failure (vs. no)	1.219 (1.020–1.456)	0.029	2.666 (0.944–7.529)	0.064
Atrial fibrillation (vs. no)	1.094 (0.957–1.252)	0.188	0.993 (0.593–1.664)	0.979
Diabetes mellitus (vs. no)	1.114 (0.956–1.298)	0.168	0.810 (0.441–1.486)	0.496
Liver disease (vs. no)	0.987 (0.630–1.546)	0.955	2.388 (0.770–7.409)	0.132
Renal failure (vs. no)	1.104 (0.956–1.275)	0.177	1.405 (0.821–2.404)	0.215
Dyslipidemia (vs. no)	0.873 (0.760–1.002)	0.054	0.731 (0.431–1.239)	0.244
Obesity/overweight (vs. no)	0.954 (0.757–1.201)	0.686	0.746 (0.261–2.133)	0.584
Smoking (vs. no)	0.970 (0.843–1.118)	0.677	1.253 (0.739–2.126)	0.403
History of cerebrovascular events (vs. no)	1.120 (0.917–1.367)	0.266	0.374 (0.116–1.208)	0.1
History of myocardial infarction (vs. no)	0.926 (0.760–1.128)	0.445	2.250 (1.221–4.147)	0.009
History of PCI (vs. no)	1.063 (0.889–1.271)	0.503	0.560 (0.256–1.225)	0.147
History of CABG (vs. no)	1.023 (0.864–1.212)	0.789	1.429 (0.781–2.614)	0.246
Post-procedural stroke (vs. no)	1.071 (0.569–2.016)	0.832	2.882 (0.801–10.365)	0.105
Post-procedural AMI (vs. no)	0.939 (0.608–1.449)	0.775	0.344 (0.045–2.646)	0.305
Post-procedural AKI (vs. no)	1.578 (1.304–1.910)	<0.001	1.736 (0.940–3.207)	0.078
Post-procedural blood transfusion (vs. no)	1.449 (1.165–1.802)	0.001	2.817 (1.546–5.132)	0.001
PPM implantation (vs. no)	0.309 (0.120–0.795)	0.015	–	0.997
Intra-aortic balloon pump (vs. no)	0.674 (0.399–1.141)	0.142	0.557 (0.071–4.366)	0.578
Discharge with disability (vs. no)	1.630 (1.408–1.887)	<0.001	3.242 (1.781–5.901)	<0.001

optimize outcomes. However, our study proposes that longer P-LOS is not necessarily associated with better outcomes. On the contrary, after stratifying the studied cohort to with/without complications, we showed that longer P-LOS is associated with worse 30-day inhospital mortality and readmission among both TAVR and MitraClip, even after adjusting for in-hospital complications, compared to shorter P-LOS.

4.5. Limitations and future research recommendations

The present study has some limitations. First, we employed a retrospective observational design, which is subject to potential coding bias. Second, although we adjusted for all available baseline characteristics and comorbidities in the NRD database, some other factors may confound our results, including procedural details (e.g. valve type) and concurrent medications. Our study only targeted short-term outcomes not including out of hospital 30-day mortality which has shown to constitute up to 1/3 of 30-day mortality among TAVR patients [26]. Future studies should analyze these endpoints at mid- and long-term. Further, the impact on P-LOS on patient-oriented outcomes and quality of life should also be evaluated.

5. Conclusion

The current study shows that shorter P-LOS is a predictor of readmission and sicker patient group. Patients requiring longer LOS should be followed closely to prevent readmission and for better outcomes. Future studies evaluating P-LOS impact on long-term and patient-oriented outcomes are needed.

CRediT authorship contribution statement

Omar M. Abdelfattah: Conceptualization, Methodology, Draft writing. **Abdelrahman Abushouk:** Data curation, Data collection, Data analysis, Writing - Original draft preparation. **Anas Saad:** Data curation, Data collection, Analysis. **Mohamed M. Gad:** Data curation, Data collection, Analysis. **Toshiaki Isogai:** Data curation, Data collection, Analysis. **Yehia Saleh:** Supervision, Editing original draft. **Shashank Shekhar:** Editing original draft, Supervision. **Mina Iskander:** Revision of original draft, Supervision, Validation. **Mohamed Omer:** Revision of original draft, Supervision, Validation. **Ryan Kaple:** Revision of original draft, Supervision, Validation. **Amar Krishnaswamy:** Writing - Reviewing and editing. **Samir Kapadia:** Writing - Reviewing and editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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