

Early Rehospitalization After Prolonged Intensive Care Unit Stay Post Cardiac Surgery: Outcomes and Modifiable Risk Factors

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Background—Prolonged intensive care unit length of stay (prICULOS) following cardiac surgery (CS) in older adults is increasingly common but rehospitalization characteristics and outcomes are understudied. We sought to describe the rehospitalization characteristics and subsequent non-institutionalized survival of prICULOS (ICULOS ≥ 5 days) patients and identify modifiable risk factors to decrease 30-day rehospitalization.

Methods and Results—Consecutive patients from January 1, 2000 to December 31, 2011 were analyzed utilizing linked clinical and administrative databases. Logistic regression was used to identify risk factors associated with 30-day rehospitalization. Out of 9210 consecutive patients discharged from the hospital alive, 596 (6.5%) experienced prICULOS. Cumulative incidence of rehospitalization for the prICULOS cohort at 30 and 365 days was 17.5% and 45.6% versus 11.4% and 28.1% for non-prICULOS ($P < 0.01$). Over 40% of rehospitalizations for the entire cohort occurred within 30 days of discharge costing over \$12 million. The most common reasons for rehospitalization were heart failure (in prICULOS) and infection (in non-prICULOS). Rehospitalization within 30 days was associated with a 2.29-fold risk of poor 1-year noninstitutionalized survival for the entire cohort. Potentially modifiable factors affecting 30-day rehospitalization included lack of physician visits within 30 days of discharge (odds ratio 2.11; $P = 0.01$), and preoperative anxiety diagnosis (odds ratio 2.20; $P = 0.01$).

Conclusions—PrICULOS patients have high rates of rehospitalization that is associated with an increased rate of poor noninstitutionalized survival. Addressing modifiable risk factors including early postdischarge access to physician services, as well as access to mental health services may improve patient outcomes. (*J Am Heart Assoc.* 2017;6:e004072. DOI: 10.1161/JAHA.116.004072.)

Key Words: follow-up study • intensive care unit • mortality • rehospitalization • surgery

Complex cardiac surgical procedures are increasingly being offered to older adult patients with more comorbidities, resulting in an increasing proportion of patients needing prolonged intensive care unit length of stay (prICULOS).^{1,2} A recent study demonstrated a 57% increase in the number of patients needing prICULOS over a decade where the “functional survival” of these patients, defined as alive and not institutionalized, was 74% at 1 year.¹ It is known from the noncardiac surgery ICU literature that the 30-day

and 1-year post ICU discharge hospital readmission rates (not necessarily with prICULOS) are high at 16% and 41%, respectively.^{3,4} There is less data specific to cardiac surgery ICU patients. With the potential increasing number of patients requiring and surviving prICULOS after cardiac surgery, significant economic and resource burdens related to rehospitalization may be anticipated for the future.

Early rehospitalization (within 30 days of discharge), considered a metric of quality of care, is estimated to cost the United States Medicare Program \$26 billion per year.^{5,6} In 2012, the Hospital Readmissions Reduction Program was set up in the United States in an effort to decrease rehospitalization by financially penalizing hospitals that had observed early rehospitalization rates above expected for specific diagnoses.^{6–12} However, some have questioned whether early readmissions are due to poor pre-discharge hospital care as opposed to pre-existing patient factors (eg, socioeconomic) that are not directly in the hospital healthcare team’s control.^{10,13} Because of the costs and financial penalties associated with early rehospitalization, there has been significant interest in understanding the predictors and consequences of early rehospitalization following hospital

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An accompanying Data S1 is available at <http://jaha.ahajournals.org/content/6/2/e004072/DC1/embed/inline-supplementary-material-1.pdf>

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discharge and determining modifiable factors that decrease the need for rehospitalization.^{7–10,12,14–36}

Given the lack of information examining rehospitalization in cardiac surgery patients who have had prICULOS and have survived, the objectives of the study were the following: (1) to describe the rehospitalization characteristics and outcomes of cardiac surgery patients having suffered prICULOS during their initial cardiac surgery admission; and (2) to determine modifiable risk factors for early rehospitalization (within 30 days of discharge home).

Materials and Methods

This was a single-region, retrospective database study. Approval was obtained from the local research ethics board, and the Health Information Privacy Committee. Informed consent was waived for this retrospective, de-identified database study.

Databases

The Manitoba Centre for Health Policy at the University of Manitoba's Faculty of Medicine in Winnipeg, Manitoba, Canada, houses several provincial clinical and administrative databases within the Population Health Research Data Repository. The clinical data for this study were from the Winnipeg Regional Health Authority ICU database and the Manitoba Cardiac Surgical Database as previously published.¹ Separation Abstracts data provided information about an individual's initial cardiac surgery hospitalization and any subsequent rehospitalization. Medical Claims (Physician Billings) data determined the degree of interaction a patient had with his/her physician following discharge. Long Term Care and Vital Statistics data provided an individual's functional status (alive and noninstitutionalized). Social Assistance data provided information on individuals requiring any income assistance before or after cardiac surgery. Publicly available Statistics Canada data provided neighborhood-level income data across the entire province of Manitoba. Each neighborhood was assigned into a provincial income quintile. Specifics of definitions used are provided in Data S1. The databases have been validated and used in a number of studies.^{1,37,38}

Patient Population

The study population included all surviving adults undergoing cardiac surgery from a single healthcare region (which is funded by a universal public healthcare system) with a catchment area of ≈ 1 million people who were discharged from the hospital alive between January 1, 2000 and December 31, 2011. The provincial databases only capture

(complete) long-term data on Manitoba patients, which comprised 90% of the patients that were operated on and represent the patients analyzed in this study. Patients requiring extracorporeal membrane oxygenation for postcardiotomy indications were included. Extracorporeal membrane oxygenation for any other indication was excluded from the analysis. The prICULOS cohort was defined as patients requiring 5 or more consecutive days in the ICU following their index cardiac surgery. The prICULOS population was compared to patients not needing prICULOS (ie, non-prICULOS). Patient outcomes examined were "functional survival" defined as alive and not institutionalized within 1 year postdischarge.

Hospitalization Costs

The costs of hospital readmissions were calculated utilizing the Resource Intensity Weight and Cost per Weighted Case variables from the Canadian Institute for Health Information. The Resource Intensity Weight is an estimate of the quantity of resources utilized in a given hospitalization relative to a standard inpatient hospital visit in Manitoba. This Resource Intensity Weight was assigned to each patient in our study. The Resource Intensity Weight was then multiplied by the annual Cost per Weighted Case, which is calculated annually in Manitoba to obtain an estimate of the cost for each unique hospitalization for each patient.^{39–41} All costs quoted in this study are expressed in 2013/2014 Canadian dollars.

Data Analysis

Continuous variables were compared using a *t* test (for parametric data) or Mann–Whitney test (for nonparametric data), and categorical variables were compared using a chi-square or Fisher exact test where appropriate. Rates of rehospitalization were calculated using cumulative incidence curves with a competing risk of death prior to rehospitalization for up to 1 year postdischarge and the values were compared between non-prICULOS and prICULOS patients using Gray's test.⁴²

In addition, a multivariable logistic regression model was developed to further characterize the factors associated with poor 1-year functional survival as well as readmission to the hospital within 30 days of hospital discharge for the entire study cohort as well as just the prICULOS cohort. All variables presented in Table 1 taken from both clinical and administrative data sources were considered for the final model. A stepwise selection method was used that considered the Score test criteria with a $P < 0.05$ for entry of variables into the model and the Wald test criteria with a $P > 0.05$ for removal of selected variables. Model fit was assessed with the Hosmer–Lemeshow test. Model discrimination was assessed by

Table 1. Selected Characteristics of Patients Rehospitalized Within 30 Days vs Not Rehospitalized Following PrICULOS After Cardiac Surgery

Variable	Not Rehospitalized in 30 Days (N=487)	Rehospitalized in 30 Days (N=109)	P Value
Preoperative variables (initial cardiac surgery admission)			
Age, y	72 (62–77)	72 (60–77)	0.83
Female	183 (37.6%)	34 (31.2%)	0.21
Cerebrovascular disease	72 (14.8%)	15 (13.8%)	0.78
Diabetes mellitus	146 (30.0%)	33 (30.3%)	0.95
Chronic obstructive pulmonary disease	68 (14.0%)	18 (16.5%)	0.49
Previous myocardial infarction	230 (47.2%)	53 (48.6%)	0.79
Congestive heart failure	88 (18.1%)	25 (22.9%)	0.24
History of arrhythmia	106 (21.8%)	32 (29.4%)	0.09
Peripheral vascular disease	124 (25.5%)	25 (22.9%)	0.58
Renal insufficiency (creatinine \geq 1.8 mg/dL)	55 (11.3%)	22 (20.2%)	0.01*
Any previous anxiety condition	46 (9.5%)	19 (17.4%)	0.02*
Social assistance prior to surgery	18 (3.7%)	6 (5.5%)	0.42
Intraoperative variables (initial cardiac surgery admission)			
CABG	221 (45.4%)	39 (35.8%)	0.30
Single non-CABG	92 (18.9%)	25 (22.9%)	
Two procedures	137 (28.1%)	37 (33.9%)	
Three procedures	37 (7.6%)	8 (7.3%)	
Elective surgery	355 (72.9%)	82 (75.2%)	0.62
Postoperative variables (initial cardiac surgery admission)			
Cerebral vascular accident	47 (9.7%)	6 (5.5%)	0.17
Cardiogenic shock	102 (20.9%)	22 (20.2%)	0.86
Congestive heart failure	63 (12.9%)	17 (15.6%)	0.46
Pericardial tamponade	19 (3.9%)	6 (5.5%)	0.43
Red blood cells transfused (units)	3 (2–6)	4 (2–7)	0.14
Acute renal insufficiency (creatinine \geq 1.8 mg/dL)	60 (12.3%)	10 (9.2%)	0.36
Acute renal failure (dialysis)	57 (11.7%)	22 (20.2%)	0.02*
Days on mechanical ventilation	5 (3–8)	6 (4–9)	0.25
Intensive care unit length of stay (days)	7.08 (5.89–10.95)	7.07 (5.94–11.11)	0.68
Total hospital length of stay (days)	28 (17–51)	28 (22–47)	0.44
Postdischarge variables			
Physician visits within 30 days of discharge			
No visits	55 (11.3%)	20 (18.4%)	0.02*
1 to 4 visits	331 (68.0%)	59 (54.1%)	
5 or more visits	101 (20.7%)	30 (27.5%)	
Social assistance required after surgery	21 (4.3%)	7 (6.4%)	0.35

*Statistically significant. Categorical variables expressed as N (%) and compared using chi-square test; continuous variables expressed as median (interquartile range) and compared using Mann–Whitney test. Variables not statistically significant between the groups and thus not listed include the following: APACHE score, hypertension, cardiogenic shock preoperatively, cardiac arrest preoperatively, any previous mental health condition, income quintile, urban residence, plasma transfused, platelets transfused, nosocomial pneumonia, and arrhythmia postoperatively. CABG indicates coronary artery bypass graft; ICU, intensive care unit; PrICULOS, prolonged intensive care unit length of stay.

calculating the area under the receiver operating characteristic curve. Statistical analysis was undertaken using SAS software, Version 9.3 of the SAS System for Windows (copyright ©2011 SAS Institute Inc, Cary, NC).

“Modifiable” variables were defined as variables where one could intervene such as optimizing diabetes treatment or facilitating access to postdischarge services, as opposed to “nonmodifiable” variables such as age, sex, or established comorbidities such as dialysis-dependent renal failure.

Results

Comparison of Rehospitalized Versus Nonrehospitalized PrICULOS Patients

During the study period, 9210 Manitoban cardiac surgery patients were discharged from the hospital alive and were still alive at 30 days postdischarge. Of these, 596 (6.5%) experienced prICULOS. PrICULOS patients needing rehospitalization within 30 days (versus those not rehospitalized) tended to have higher rates of preoperative renal insufficiency, preoperative history of an anxiety disorder, postoperative renal failure requiring dialysis, and no physician visits or 5 or more physician visits (as compared to 1–4 physician visits) within the first 30 days postdischarge (Table 1).

Rehospitalization Rates and Description of Rehospitalized Patients

The 30- and 365-day cumulative incidence rehospitalization rates for the entire cohort were 11.7% and 29.2%, respectively. The cumulative incidence rehospitalization rates for the prICULOS cohort were nearly double those of the non-prICULOS cohort (17.5% and 45.6%, respectively, versus 11.4% and 28.1%, respectively— $P<0.001$; Figure 1).

The 30-day rehospitalization rate based on initial operative procedure type for the entire cohort was 11.0% for isolated coronary artery bypass graft (CABG), 13.1% for isolated valve, 16.7% for CABG+Valve, 13.2% for aortic procedure, and 12.5% for “other.” “Other” included all procedures that were not isolated CABG, CABG+Valve, or aortic cases and included procedures such as ventricular septal defect repair, resection of infarcted myocardium, pericardectomy, and infected graft resection. The procedure with the highest 30-day rehospitalization rate in the non-prICULOS cohort was CABG+Valve with a rate of 15.9%; however, the procedure with the highest 30-day rehospitalization rate in the prICULOS cohort was “other” at a rate of 27.6%.

The median (interquartile range) time to first rehospitalization for patients readmitted within 1 year of discharge was 51 (11–170) days for non-prICULOS patients, which was similar to 52 (16–150) days for prICULOS patients.

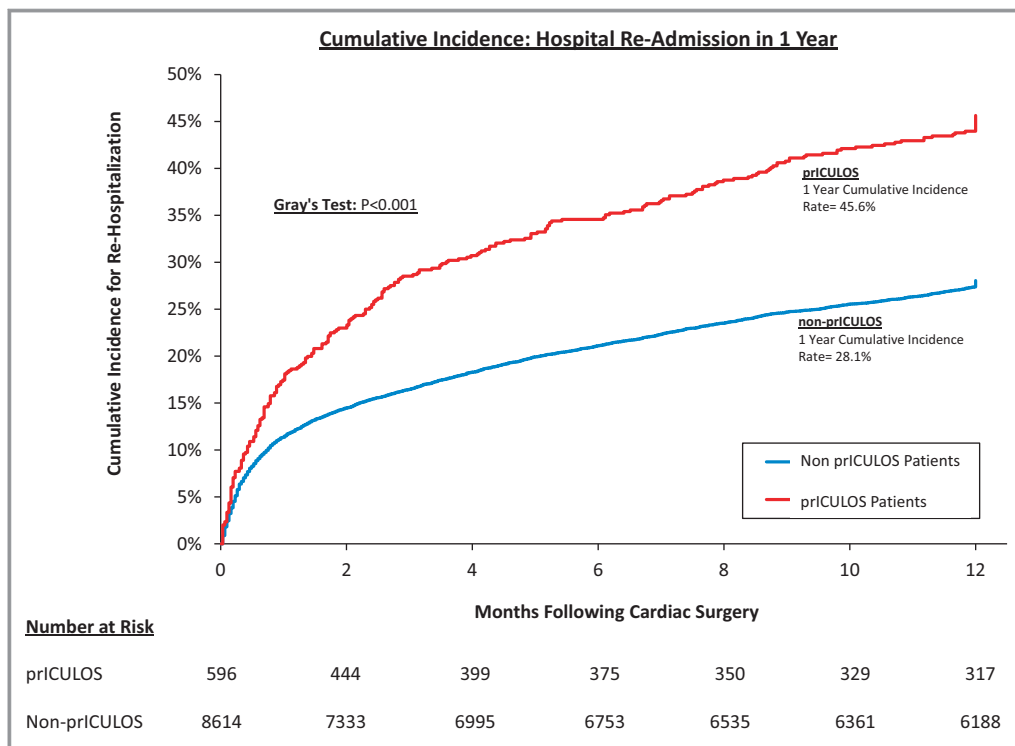


Figure 1. Patients with prolonged intensive care unit length of stay (prICULOS) had significantly higher rehospitalization rates compared to patients with nonprolonged ICU length of stay.

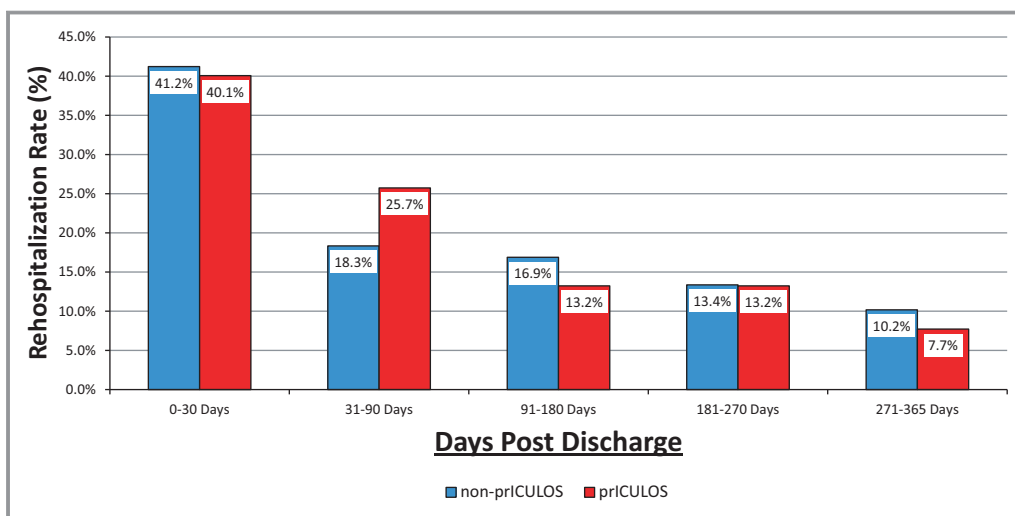


Figure 2. Most rehospitalizations occur early postdischarge, with ≈60% of rehospitalizations for both prolonged intensive care unit length of stay (prICULOS) and non-prICULOS patients occurring within 90 days from discharge home.

Of all patients rehospitalized within 1 year of discharge, 996/2416 (41.2%) of the non-prICULOS patients and 109/272 (40.1%) of the prICULOS patients were rehospitalized within 30 days of discharge (Figure 2). The median hospital LOS for the first rehospitalization in these patients was 4 (interquartile range: 2–8) days for non-prICULOS patients versus a median of 6 (interquartile range: 3–12) days for prICULOS patients ($P<0.001$). The total number of first-time rehospitalizations occurring within 30 days of discharge for the entire cohort was 1105, which equated to 12 602 inpatient days (10 707 days for non-prICULOS patients and 1895 for prICULOS patients) (Table 2). The average cost of a hospital readmission occurring within the first 30 days postdischarge from cardiac surgery was \$13 960 CDN (\$10 738 USD using exchange rate of \$1.3 CDN/USD) for the prICULOS patient cohort and \$10 100 CDN (\$7769 USD) for the non-prICULOS cohort. Using an average value of

\$12 000 CDN per rehospitalization for the entire cohort and 1105 rehospitalizations in the first 30 days, gives a total cost of over \$13 million dollars CDN (≈\$10 million USD) just for patients readmitted within the first 30 days postdischarge home.

Heart failure (ICD 9 code 428 and ICD 10 code I50) was the most common reason for rehospitalization in prICULOS patients for those rehospitalized within 30 days from discharge home, accounting for 20.5% of the “most responsible diagnosis” at time of readmission (Table 3). Conversely, “Complications of Procedures” (ICD 9 code 998 and ICD 10 code T81) was the most common reason for rehospitalization for non-prICULOS patients for rehospitalization within 30 days, accounting for 12.8% of the “most responsible diagnosis” at time of readmission. Further exploration into the “Complications of Procedures” diagnosis code revealed that postoperative infections were the most prevalent

Table 2. Total Inpatient Days for Patients Rehospitalized

Hospital Readmission	Total Number of First	Number of Inpatient Days		
		Non-prICULOS	PrICULOS	Total Inpatient
Date Occurring in	Rehospitalizations in Specific Time Period	Patients (N=2416)	Patients (N=272)	Days (N=2688)
0 to 30 days postdischarge home	1105	10 707	1895	12 602
31 to 90 days postdischarge home	513	7857	1822	9679
91 to 180 days postdischarge home	444	7630	1489	9119
181 to 270 days postdischarge home	359	7216	1273	8489
271 to 365 days postdischarge home	267	6330	1174	7504
Totals	2688	39 740	7653	47 393

PrICULOS indicates prolonged intensive care unit length of stay.

Table 3. Top 4 “Most Responsible” Diagnosis for Rehospitalization for Various Time Periods (With Frequency of the Diagnosis)

Entire Population (N=1105)	Non-PrICULOS Cohort (N=996)	PrICULOS Cohort (N=109)
(a) Within 30 Days of Discharge Home		
Complications of procedures*—12.2%	Complications of procedures*—12.8%	Heart failure—20.5%
Heart failure—10.8%	Heart failure—9.7%	Convalescence—6.1%
Pleural effusion—6.7%	Pleural effusion—7.0%	Complications of procedures†—6.1%
Atrial fibrillation—5.7%	Atrial fibrillation—6.0%	†
(b) Within 365 Days of Discharge Home		
Heart failure—9.8%	Heart failure—8.7%	Heart failure—17.6%
Complications of procedures*—5.6%	Complications of procedures*—5.9%	Complications of procedures*—3.9%
Atrial fibrillation—4.0%	Atrial fibrillation—4.2%	Convalescence—3.8%
Pleural effusion—3.2%	Pleural effusion—3.4%	Chronic ischemic heart disease—2.7%

ICD 9/10 Codes for Various Diagnosis: Heart Failure: ICD 9 code 428 and ICD 10 code I50, Atrial fibrillation: ICD 9 code 427 and ICD 10 code I48, Pleural Effusion: ICD 9 code 511 and ICD 10 code J90; Complications of Procedures: ICD 9 code 998 and ICD 10 code T81; Convalescence: ICD 9 code V66 and ICD 10 code Z54; Chronic Ischemic Heart Disease: ICD 9 code 414 and ICD 10 code I25. PrICULOS indicates prolonged intensive care unit length of stay.

*Most commonly postoperative infection.

†Not reportable as count <6.

complication within this code, occurring in ≈80% of cases. Atrial fibrillation and pleural effusion were also common reasons for rehospitalization in the non-prICULOS cohort, occurring 6% to 8% of the time (Table 3).

One-Year Outcomes of Patients Post Rehospitalization

Patients who were rehospitalized within 30 days from discharge had increased mortality within 1 year of readmission compared to patients who were not rehospitalized for both non-prICULOS patients as well as prICULOS patients. However, the mortality rate in rehospitalized prICULOS patients (15.6%) was double the mortality rate of rehospitalized non-prICULOS patients (7.6%) (Figure 3). Most patients in both groups who died did so while in the hospital (59% in non-prICULOS and prICULOS cohorts) and the most common primary causes of death were chronic ischemic heart disease,

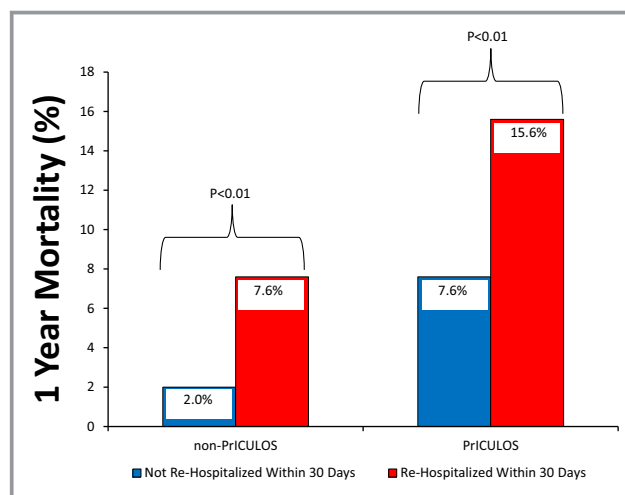


Figure 3. Rehospitalization within 30 days of discharge home was associated with an increased risk of mortality within 1 year of rehospitalization. PrICULOS indicates prolonged intensive care unit length of stay.

ST elevation and non-ST elevation myocardial infarction as well as stroke. In addition, for those discharged post rehospitalization, 9/8614 (0.1%) of non-prICULOS patients and 10/596 (1.7%) of prICULOS patients were discharged to a personal care home ($P<0.01$) after their rehospitalization in the first year after discharge from the index cardiac surgery hospitalization.

To examine whether rehospitalization was an independent factor associated with poor functional survival (dead or institutionalized), a multivariate logistic regression analysis was performed, and this confirmed that rehospitalization within 30 days of discharge was indeed independently associated (odds ratio [OR] 2.29, $P<0.001$) with poor functional survival at 1 year (Table 4).

Curiously, when looking at all patients discharged home regardless of ICULOS or rehospitalization (Table 4), no physician visits was also associated with poor functional survival at 1 year (OR 4.69; $P<0.0001$); and for just prICULOS patients, preoperative need for social assistance (OR 11.2, $P<0.0001$) and no physician visits was also associated with poor functional survival (OR 5.15; $P<0.0001$) at 1 year. Interestingly, prICULOS as an independent variable was not associated with poor functional survival (OR=0.70, 95% CI: 0.42–1.15, $P=0.16$) likely because of other variables being highly correlated with having prICULOS and already being present in the model.

Predictors of Early Rehospitalization

Examining the entire cohort of patients regardless of ICULOS showed 16 different variables to be associated with increased risk of rehospitalization (Table 5). PrICULOS was not

Table 4. Multivariable Logistic Regression Model for Factors Associated With Poor Functional Survival (Dead or Institutionalized) at 1 Year for All Patients After Discharge From Hospital After Cardiac Surgery (N=9210)

Variable	Odds Ratio	95% CI	P Value
Age ≥80 years old	1.89	1.35 to 2.64	<0.01*
Chronic obstructive pulmonary disease	1.47	1.05 to 2.05	0.03*
Arrhythmia	1.52	1.14 to 2.02	<0.01*
Diabetes mellitus	1.61	1.24 to 2.07	<0.01*
Peripheral vascular disease	1.66	1.28 to 2.16	<0.01*
Preoperative renal insufficiency (creatinine >1.8 mg/dL)	1.80	1.27 to 2.55	<0.01*
Preoperative renal failure (dialysis)	3.29	1.82 to 5.94	<0.0001*
Single non-CABG vs isolated CABG	1.55	1.11 to 2.16	0.01*
Two procedures vs isolated CABG	2.16	1.61 to 2.89	<0.0001*
Three procedures vs isolated CABG	1.72	0.92 to 3.21	0.09
Other respiratory problems postoperatively	3.14	1.31 to 7.51	0.01*
Pericardial tamponade postoperatively	2.42	1.11 to 5.31	0.03*
Ejection fraction grade out of 4 (per increase of 1 grade)	1.44	1.25 to 1.67	<0.0001*
Total days on mechanical ventilation (per day)	1.07	1.02 to 1.14	0.01*
Total hospital length of stay (per day)	1.02	1.01 to 1.02	<0.0001*
Rehospitalization within 30 days	2.29*	1.76 to 2.99*	<0.001*
No physician visits vs 1 to 4 physician visits in 30 days postdischarge	4.69*	3.53 to 6.23*	<0.0001*
5+ physician visits vs 1 to 4 physician visits in 30 days postdischarge	1.26	0.91 to 1.75	0.17

Area under receiver operating characteristic curve=0.848 (0.827–0.869); Hosmer-Lemeshow P value=0.30.
 CABG indicates coronary artery bypass graft.
 *Statistically significant.

independently associated with rehospitalization (OR=1.00, 95% CI: 0.77–1.28, P=0.97), because of other variables being highly correlated with having prICULOS and already being present in the model. Some of the 16 variables were nonmodifiable (eg, age, sex), others were comorbidities that

Table 5. Multivariable Logistic Regression Model for Factors Associated With Rehospitalization Within 30 Days of Discharge for All Patients After Discharge From Hospital After Cardiac Surgery (N=9210)

Variable	Odds Ratio	95% CI	P Value
Age (per year of age)	1.01	1.00 to 1.02	<0.01*
Female	1.13	1.05 to 1.21	<0.01*
Cerebrovascular disease	1.31	1.07 to 1.59	0.01*
Chronic obstructive pulmonary disease	1.41	1.15 to 1.74	<0.01*
Hypertension	1.18	1.10 to 1.27	0.03*
Arrhythmia	1.55	1.31 to 1.83	<0.0001*
Diabetes mellitus	1.26	1.09 to 1.46	<0.01*
Preoperative renal insufficiency (creatinine >1.8 mg/dL)	1.75	1.40 to 2.20	<0.0001*
Preoperative renal failure (dialysis)	2.22	1.48 to 3.33	<0.01*
Any preoperative mental health condition	1.24	1.05 to 1.46	0.01*
Social assistance requirement before surgery	1.48	1.09 to 2.03	0.01*
Income quintile 2 vs 1	0.94	0.78 to 1.15	0.56
Income quintile 3 vs 1	0.84	0.68 to 1.03	0.09
Income quintile 4 vs 1	0.81	0.66 to 0.98	0.03*
Income quintile 5 vs 1	0.62	0.50 to 0.78	<0.0001*
Income quintile not found vs 1	0.71	0.50 to 1.00	0.05*
Urban residence vs rural residence	0.59	0.52 to 0.68	<0.0001*
Cardiopulmonary bypass time (per min)	1.00	1.00 to 1.00	0.02*
Red blood cell transfusion (per unit)	1.06	1.03 to 1.08	<0.0001*
No physician visits vs 1 to 4 physician visits in 30 days postdischarge	1.91	1.56 to 2.33	<0.0001*
5+ physician visits vs 1 to 4 physician visits in 30 days postdischarge	1.49	1.25 to 1.78	<0.0001*

Area under receiver operating characteristic curve=0.670 (0.653–0.686); Hosmer-Lemeshow P value=0.19.
 *Statistically significant.

could possibly be modified (such as chronic obstructive pulmonary disease, and diabetes); however, there were a number of modifiable psychosocial variables as well such as preoperative mental health status, social assistance need, household income status, and access to physician services within 30 days of discharge. Examining just the prICULOS

cohort (Table 6) again demonstrated preoperative anxiety disorders and no physician visits as modifiable risk factors.

Discussion

In this analysis, we sought to understand the impact of rehospitalization in a vulnerable group of patients, namely, those who required prICULOS following cardiac surgery. PrICULOS was defined as ≥ 5 days in our study, as that would allow one to study the “sick” cardiac surgery ICU patient (as opposed to the patient just requiring 48 hours of inotrope/vasopressor for low cardiac output or vasoplegia) but still allow enough sample size to perform meaningful statistical analysis. PrICULOS patients had high rehospitalization rates, with almost 20% of rehospitalizations occurring within 30 days and almost 50% of rehospitalizations occurring within 1 year of discharge. It is possible that prICULOS patients had increased rehospitalization rates compared to non-prICULOS patients because the prICULOS patients developed complications that would increase the probability of readmission such as heart failure, renal dysfunction, and infection. We also found that rehospitalization was costly, with the total number of rehospitalizations within the first 30 days postdischarge costing over \$13 million CDN (\approx \$10 million USD) in a population of just 1 million people. Acknowledging the inherent flaws of simple extrapolation, this would translate to direct healthcare costs of \$3.9 billion over the study period

Table 6. Multivariable Logistic Regression Model for Factors Associated With Rehospitalization Within 30 Days of Discharge From Hospital for Cardiac Surgery Patients Who Had PrICULOS (N=596)

Variable	Odds Ratio	95% CI	P Value
Preoperative renal insufficiency (creatinine >1.8 mg/dL)	2.02	1.15 to 3.55	0.01*
Any preoperative anxiety diagnosis	2.20	1.21 to 3.98	0.01*
Red blood cell transfusion (per unit)	1.04	1.01 to 1.07	0.02*
No physician visits vs 1 to 4 physician visits in 30 days postdischarge	2.11	1.17 to 3.83	0.01*
5+ physician visits vs 1 to 4 physician visits in 30 days postdischarge	1.50	0.90 to 2.50	0.12

Area under receiver operating characteristic curve=0.645 (0.586–0.705); Hosmer-Lemeshow P value=0.83. PrICULOS indicates prolonged intensive care unit length of stay.

*Statistically significant.

in the United States, assuming an average population of 303 million in the United States. We also found that rehospitalization within 30 days of discharge from the hospital was associated with a doubling risk of poor functional survival (dead or institutionalized) within 1 year of rehospitalization for prICULOS patients. Importantly, that was associated with almost a quadrupling of risk in non-prICULOS patients, the etiology of which needs further investigation. Furthermore, at present, about 10% of patients need prICULOS after cardiac surgery but this number is over 50% higher than a decade ago.^{1,2} With high rehospitalization rates and an expected increasing number of cardiac surgery patients expected to have prICULOS over the next decades, it is likely that there will be significant economic implications for policy makers, healthcare systems, and society. To our knowledge, this is the first report enumerating the current clinical and financial impact of treatment related to this specific group of patients.

The high rehospitalization rate could point to quality of care issues at our institution. Firstly, looking at our entire population shows rehospitalization rates similar to those published in the literature. Our 30-day rehospitalization rate for a mixture of cardiac surgery operations for the entire patient population (not just prICULOS patients) postdischarge was 11.7%. This is in keeping with the published literature, which generally consists of large studies (thousands of patients) from multiple hospitals in the United States where 30-day rehospitalization rates (mostly post CABG) average about 5% to 12% with the range being 0% to 80%.^{10,19–21,23,24,29} Our 90-day rehospitalization rate of 17.2% (Figure 1) is also comparable to the published results from Iribarne et al,¹⁹ who reported 65-day rehospitalization rates (from index operation) among 10 centers with 5158 adult cardiac surgical patients at 18.7%. Our observed 30-day rehospitalization rates based on procedure type for the entire cohort were 11.0% for CABG, 13.1% for isolated valve, and 16.7% for CABG+Valve. This is comparable to a previous report published by Iribarne et al,¹⁹ where rehospitalization rates were 14.9% for isolated CABG, 18.3% for isolated valve, and 25% for CABG+Valve. Hence, our rehospitalization rates overall are similar to the published literature.

Secondly, the probability that the high rehospitalization rate was secondary to early discharge from the hospital was low. From our previous analysis,¹ our hospital length of stay after the index operation was a median of 24.0 days, with 14.3% needing transfer to a community hospital requiring an additional 21.5 days median stay for prICULOS patients. The equivalent numbers for non-prICULOS patients was 8.0 days median hospital LOS, where 4.2% of them were transferred for further care of 12.0 days (median). In addition, the median time to first rehospitalization was 51 to 52 days for non-prICULOS and prICULOS patients, respectively, and only \approx 40% of patients were rehospitalized within the first 30 days

postdischarge—both of which suggest early discharge was likely not the reason for the high rate of rehospitalization. Our times to rehospitalization and percentage of patients rehospitalized for the entire cohort of patients are consistent with the published literature, where 60% to 80% of cardiac surgery patients are rehospitalized within 30 days of discharge with the median time to rehospitalization varying between 5 and 20 days.^{10,19,20,23} This again supports the fact that the high rehospitalization rates of prICULOS patients were not attributable to early discharge of these patients.

Lastly, we examined whether there was something unique about the “most responsible reason” for rehospitalization in the prICULOS patients to see if this explained the high rate of rehospitalization. In the literature, the top 3 reasons for rehospitalization post cardiac surgery (not specifically related to ICULOS) are heart failure (13–25% of cases), infection (10–25% of cases), and arrhythmias (13–25% of cases).^{*} Our results were similar, with heart failure being the cause ≈20% of the time and the main reason for rehospitalization in prICULOS survivors; whereas complications of procedures (mostly postoperative infection) were the cause ≈12% of the time and the main reason for rehospitalization in the non-prICULOS cohort early after discharge. Our rate of readmission for atrial fibrillation (which is only in the non-prICULOS cohort) occurred only 4% to 6% of the time, which is lower than what has been previously reported.[†] However, the prICULOS patients did have convalescence (which is a specific ICD 9/10 diagnostic code) as the most responsible reason for rehospitalization 4% to 6% of the time within the first 30 days of discharge. Though it is possible that rehospitalization with a most responsible diagnosis of convalescence may be interpreted as being discharged from the hospital too early, this is unlikely to be the case the majority of the time (though we do recognize that there is the possibility that occasional patients may have been discharged too early). We have comprehensive biweekly multidisciplinary meetings involving clinicians, physiotherapists, occupational therapists, social work, and home care personnel who review each patient on the ward to plan an appropriate and safe discharge. The fact that convalescence is an important reason for rehospitalization and psychological/outpatient physician access factors are significant in our multivariable model may suggest a link between the 2. Because of privacy restrictions on being able to report data for any sample size <6 per category, we were unable to report on secondary diagnosis for the convalescence diagnosis as these were all counts <6 per category to better determine the reason for need for convalescence.

Examining our models that predict rehospitalization for the entire cohort (Table 5) shows a number of risk factors relating to comorbidity, which would generally be considered to be nonmodifiable such as age, sex, and established comorbidities such as cerebrovascular disease and preoperative renal failure. In addition, some potentially modifiable variables such as hypertension, diabetes mellitus, chronic obstructive pulmonary disease, and arrhythmias, which may have the capacity for optimization prior to surgery, also were significant in the model. Finally, psychosocial variables such as mental health issues, access to physician services early postdischarge, and socioeconomic factors were also associated with early rehospitalization. These may represent potentially underrecognized modifiable, nonmedical risk factors when it comes to rehospitalization. Even though the prICULOS cohort (Table 6) has a reduced sample size resulting in a smaller number of covariates being selected in the final model, it is particularly interesting that preoperative anxiety disorder and access to physician services within 30 days of discharge are significant in the model. Once again, potentially modifiable risk factors for rehospitalization outside of “classical comorbid medical conditions” seem to be present in this specific cohort. With minimal access to physician services, it stands to reason that ongoing management of manageable comorbidities would degrade, resulting in rehospitalization. Our findings are corroborated by others who have also found that patients with lower education levels, lower income, and increased distance from the hospital/rural location had a higher risk of rehospitalization, though the patient population studied was different from ours.^{9,21,25,29,31,43} These hypothesis-generating findings need corroboration with prospective study to determine whether manipulating these variables affects outcomes. If indeed psychosocial and physician access postdischarge are major obstacles for patients and the only viable option for the patient becomes repeated inpatient treatment, then perhaps this would need to be accounted for before hospitals (in the United States) are financially penalized for rehospitalization. Of note, the specific dichotomous variable, prICULOS, did not come out independently associated with either poor functional survival or rehospitalization. This is likely explained by the fact that other variables, which are correlated with prICULOS (eg, age, certain comorbidities, days on mechanical ventilation), were already in the model.

There have been a number of studies done to try to prevent rehospitalization in medical and surgical patients. As heart failure is a very common reason for rehospitalization, attempts have been made to try to detect when a patient is decompensating (with remote electronic monitoring technologies) and institute outpatient therapy (eg, increase diuretics or afterload reduction) before they get severe enough to need rehospitalization. The results have been variable and not all institutions have access to these advanced technologies.^{44,45}

^{*}References 7, 9, 12, 19–21, 24, 27, 29, 30

[†]References 7, 9, 12, 19–21, 24, 27, 29, 30

There have also been studies done (mostly in noncardiac surgery patients and none in cardiac surgery patients with prICULOS) trying to address the psychosocial and healthcare access issues patients have to see if this can decrease rehospitalization, but again the results have been variable.^{26,33–36} One of the problems has been the cost and logistics to instituting the interventions, and thus better processes of care need to be established.^{34,46}

Another very important finding identified in this analysis was that rehospitalization was independently associated with poor 1-year functional survival (dead or institutionalized), being 15.6% in the prICULOS cohort and 7.6% in the non-prICULOS cohort. In both cohorts, this risk of death or institutionalization was over 2-fold higher compared to nonrehospitalized patients (Figure 3 and Table 4). While similar to previous findings in general cardiac surgery and other patient groups that looked at death rates post rehospitalization, length of time from discharge to rehospitalization and death, and rehospitalization hospital type and outcome,^{15–17} this reporting with respect to rehospitalization in prICULOS patients is rather novel and emphasizes the importance of identifying reasons for rehospitalization to prevent its occurrence.

Analysis of the potential reasons for poor functional survival at 1 year post discharge from initial cardiac surgery (Table 4) reveals that the patients were older with multiple comorbidities including cerebrovascular disease, peripheral vascular disease, chronic obstructive pulmonary disease, and most importantly renal dysfunction. The primary causes of death were most commonly chronic ischemic heart disease, new myocardial infarction, and stroke. Note: We only collected the primary cause of death recorded and not all the causes (which may have included renal failure, chronic obstructive pulmonary disease, and such diagnoses). It is logical that patients with more comorbidities were more likely to be readmitted and suffer worse long-term outcomes, often succumbing to cardiovascular diseases. Nonetheless, readmission itself was independently predictive of poor functional survival and possibly overlooked psychosocial and medical access issues were predictive of the need for readmission. Intervention with medical and other community supports to reduce hospital readmission after cardiac surgery, particularly in prICULOS patients, presents a potential opportunity to improve postdischarge care and reduce the tremendous cost of rehospitalization.

Limitations

Limitations to our study include those typical of a retrospective, administrative database study including biases and incorrect data collection; however, these databases have

been validated and used in many previously published studies.^{1,4,38} Secondly, we do not have access in the databases to information about quality of life, cognitive impairment, or frailty, which would be valuable. However, we feel that using functional survival (which takes into account institutionalization) is a reasonable surrogate for these missing variables, which we are endeavoring to incorporate in the future. Thirdly, we did not collect all the causes (if multiple) for each rehospitalization or death but just collected what was recorded as the primary cause. It is possible that we may have missed important information by this method. Lastly, the area under the receiver operating characteristic curve for our rehospitalization models were not very high, being in the 0.65 to 0.67 range (Tables 5 and 6). This, however, is consistent with the literature where various models to predict rehospitalization in various populations give c-statistic ranges between 0.56 and 0.83, with the majority being in the 0.55 to 0.65 range.⁴⁷ One of the reasons the c-stat is so low in many studies is because models generally do not include variables that are likely important in determining rehospitalization such as social support/quality of life/activities of daily independence, ethnicity, and similar factors. Future studies should try to include these variables.

Conclusions and Future Studies

Patients with prICULOS post cardiac surgery have high rates of rehospitalization, which is costly and associated with significantly worse functional survival at 1 year. Three potentially modifiable psychosocial risk factors to prevent rehospitalization in this cohort include provision of access to physicians, and mental health and social services. Development and evolution of dedicated discharge clinics for prICULOS patients using multidisciplinary teams to facilitate access to comprehensive health and other services may represent the next logical step in the quest to improve patient outcomes and minimize the associated extreme costs.

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SUPPLEMENTAL MATERIAL

Data S1:

Specific definitions used in this study which have been validated and used in other studies^{1,2} include: cerebrovascular disease which includes any previous cerebrovascular accident, transient ischemic attack or carotid endarterectomy/bypass; peripheral vascular disease which includes any type of peripheral vascular diseases, any vascular grafts, arterial insufficiency, aortic aneurysm - treated or not treated, amputations, gangrene due to arterial insufficiency or history of claudication; renal insufficiency means a creatinine ≥ 1.8 mg/dL and renal failure means needing dialysis; any mental health condition, any previous mood condition and any previous anxiety condition are detailed below. For operative procedures, “other” included all procedures that were not isolated CABG, CABG + Valve, or aortic cases and included procedures such as ventricular septal defect repair, resection of infarcted myocardium, pericardectomy, and infected graft resection.

Any mental health condition (ICD 9 & 10 codes) includes:

291 – Alcoholic psychoses

294 – Other organic psychotic conditions

296 – Episodic mood disorders

303 – Alcohol dependence

304 – Drug dependence

305 – Nondependent abuse of drugs

307.4 – Specific disorders of sleep

964 - Poisoning by agents primarily affecting blood constituents

F01 – Vascular dementia

F03 – Unspecified dementia

F05 – Delirium due to known physiological condition

F06 – Other mental disorders due to known physiological conditions

F07 – Personality and behavioral disorders due to known physiological conditions

F09 – Unspecified mental disorder due to known physiological condition

F10 – Alcohol related disorders

F11 – Opioid related disorders

F12 –Cannabis related disorders

F13 – Sedative, hypnotic, or anxiolytic related disorders

F17 – Nicotine dependence

F19 – Other psychoactive substance related disorders

F51 – Sleep disorders not due to a substance or known physiological condition

F52 – Sexual dysfunction not due to a substance or known physiological condition

F54 – Psychological and behavioral factors associated with disorders or disease classified elsewhere

F59 – Unspecified behavioral syndromes associated with physiological disturbances and physical factors

Any previous mood condition (ICD 9 & 10 codes) includes:

311 – Depressive Disorder

F30 – Manic Episode

F31 – Bipolar Affective Disorder

F32 – Depressive Episode

F33 – Recurrent Depressive Disorder

F34 – Persistent Mood Disorder

F38 – Other Mood Disorders

F39 – Unspecified Mood Disorder

Any previous anxiety condition (ICD 9 & 10 codes) includes:

300 – Neurotic Disorders

308 – Acute reaction to stress

309 – Adjustment reaction

F41 – Other anxiety disorders

F43 – Reaction to severe stress, and adjustment disorders

Supplemental References:

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