The Epidemiology of Intensive Care Unit Readmissions in the United States

Sydney E. S. Brown¹, Sarah J. Ratcliffe¹, Jeremy M. Kahn², and Scott D. Halpern^{1,3,4}

¹Center for Clinical Epidemiology and Biostatistics, ³Division of Pulmonary, Allergy, and Critical Care Medicine, and ⁴Leonard Davis Institute of Health Economics, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania; and ²Department of Critical Care Medicine, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania

Rationale: The incidence of intensive care unit (ICU) readmissions across the United States is unknown.

Objectives: To determine incidence of ICU readmissions in United States hospitals, and describe the distribution of time between ICU discharges and readmissions.

Methods: This retrospective cohort study used 196,202 patients in 156 medical and surgical ICUs in 106 community and academic hospitals participating in Project IMPACT from April 1, 2001, to December 31, 2007. We used mixed-effects logistic regression, adjusting for patient and hospital characteristics, to describe how ICU readmission rates differed across patient types, ICU models, and hospital types.

Measurements and Main Results: Measurements consisted of 48- and 120-hour ICU readmission rates and time to readmission. A total of 3,905 patients (2%) were readmitted to the ICU within 48 hours, and 7,171 (3.7%) within 120 hours. In adjusted analysis, there was no difference in ICU readmissions across patient types or ICU models. Among medical patients, those in academic hospitals had higher odds of 48- and 120-hour readmission than patients in community hospitals without residents (1.51 [95% confidence interval, 1.12–2.02] and 1.63 [95% confidence interval, 1.24–2.16]). Median time to ICU readmission was 3.07 days (interquartile range, 1.27–6.58). Closed ICUs had the longest times to readmission (3.55 d [interquartile range, 1.42–7.50]).

Conclusions: Approximately 2% and 4% of ICU patients discharged to the ward are readmitted within 48 and 120 hours, within a median time of 3 days. Medical patients in academic hospitals are more likely to be readmitted than patients in community hospitals without residents. ICU readmission rates could be useful for policy makers and investigations into their causes and consequences.

Keywords: ICU readmissions; quality indicators; hospital trends

Intensive care unit (ICU) readmissions are associated with mortality, cost, and length of stay (1–9). They may also capture a component of hospital efficiency through optimal patient flow

AT A GLANCE COMMENTARY

Scientific Knowledge on the Subject

There is interest in using intensive care unit (ICU) readmissions as an ICU quality indicator, yet little is known about the incidence, timing, and risk factors for readmission.

What This Study Adds to the Field

This study provides risk-adjusted rates of ICU readmissions across different patient, ICU, and hospital types in the United States. It also describes the timing of ICU readmissions, and patient, ICU, and hospital risk factors associated with readmission.

management (2, 5, 10), and have been proposed as an appropriate measure of the quality of ICU care (11). However, little is known regarding the epidemiology of ICU readmissions in the United States: how commonly they occur, when, and where they occur, or whether rates have changed over time. Past studies in small numbers of ICUs (2, 5, 8, 10, 12–21) using heterogeneous definitions of ICU readmission have estimated rates from 4.6–13.4%, and a recent larger study in Australia examined patient risk factors for ICU readmission (22). Thus, although ICU readmission rate is a promising measure for assessing patient triage decisions and ICU performance, its use as a quality metric depends on a better understanding of their incidence and the hospital-level factors associated with their occurrence.

In the present study we used a large and diverse sample of United States ICUs to assess differences in ICU readmission incidence rates among different ICU and hospital types; the distribution of time between ICU discharges and readmissions; and patient, ICU, and hospital variables associated with readmission. We hypothesized that after adjusting for patient, ICU, and hospital characteristics, patients hospitalized in ICUs located in academic hospitals and in closed ICUs would have comparable predicted rates of ICU readmission compared with those hospitalized in community hospitals and open ICUs not requiring intensivists consultation. Some of these results have been previously reported in the form of an abstract (23).

METHODS

Data Source

We performed a retrospective cohort study using the Project IMPACT database (Cerner Corporation, Kansas City, MO). Project IMPACT is a nationally representative, voluntary, fee-based ICU clinical information system used for benchmarking and research (24–34). Each ICU uses a trained data collector and a standardized web-based instrument to collect data regarding individual patients, care processes, and ICU structural characteristics (27).

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Correspondence and requests for reprints should be addressed to Sydney E. S. Brown, B.A., University of Pennsylvania School of Medicine, 108 Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104-6021. E-mail: sydney2@mail.med.upenn.edu

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TABLE 1. ADJUSTED PATIENT CHARACTERISTICS ASSOCIATED WITH ICU READMISSION

Patient Characteristics at the Time of First ICU Admission	Bivariable Models, 48-h Readmissions			Multivariable Models			
	% Not Readmitted 191,308	% Readmitted 3,894	P Value	48-h Readmissions		120-h Readmissions	
Number of patients, n				OR (95% CI)	P Value	OR (95% CI)	P Value
Age							
<65	98.2	1.8	—	Reference		Reference	
65–74	97.8	2.3	<0.001	1.07 (0.96–1.20)	0.438	1.07 (0.99–1.16)	0.332
75–84	97.6	2.4	<0.001	1.14 (1.01–1.29)	0.088	1.07 (0.98–1.17)	0.258
≥85	98.0	2.0	0.004	1.02 (0.86–1.21)	0.791	0.95 (0.84–1.08)	0.459
Race/ethnicity, %							
Black	98.2	1.8	—	Reference		Reference	
White	97.9	2.1	0.003	1.13 (1.02–1.27)	0.052	1.18 (1.08–1.28)	<0.001
Other or missing	98.3	1.7	0.155	0.96 (0.81–1.13)	0.584	0.95 (0.84–1.07)	0.411
Sex				Not included in multivariable models			
Females	98.1	1.9	—				
Males	97.9	2.1	0.036				
Functional status							
Independent	98.1	1.9	—	Reference		Reference	
Partially dependent	97.6	2.4	<0.001	1.14 (1.04–1.25)	0.006	1.22 (1.14–1.31)	<0.001
Fully dependent	97.3	2.7	<0.001	1.32 (1.14–1.52)	<0.001	1.48 (1.34–1.65)	<0.001
Insurance							
Private	98.3	1.8	—	Reference		Reference	
Medicare	97.8	2.3	<0.001	1.06 (0.96–1.18)	0.534	1.06 (0.98–1.14)	0.349
Medicaid	98.0	2.1	0.034	1.16 (1.01–1.33)	0.120	1.14 (1.03–1.26)	0.036
Self-pay	98.6	1.4	0.001	0.85 (0.73–1.00)	0.140	0.83 (0.74–0.93)	0.008
Other	97.9	2.1	0.522	1.05 (0.84–1.31)	0.660	0.92 (0.77–1.10)	0.349
Avg. MPM0-III admission score	10.9 (11.9)	13.1 (12.7)	<0.001*				
Probability death >0.2				1.01 (0.98–1.04)	0.551	1.00 (0.98–1.02)	0.966
Probability death 0.05–0.2				0.99 (0.97–1.00)	0.051	0.99 (0.98–0.99)	0.004
Probability death <0.05				0.97 (0.95–0.98)	<0.001	0.97 (0.95–0.98)	<0.001
Patient had critical care consult				1.27 (1.15–1.40)	<0.001	1.27 (1.17–1.37)	<0.001
No	98.4	1.6					
Yes	97.7	2.3	<0.001				
Required pressor use				Not included in multivariable models			
No	98.2	1.9	—				
Yes	97.2	2.8	<0.001				
Required mechanical ventilation				0.81 (0.69–0.95)	0.010	0.85 (0.76–0.97)	0.007
No	98.2	1.8	—				
Yes	97.5	2.5	<0.001				
Avg. duration days between extubation and ICU discharge	2.1 (1.6)	2.3 (2.2)	<0.001†	1.17 (1.04–1.30)	0.006	1.09 (1.00–1.18)	0.038
Avg. # days mechanical ventilation	4.1 (6.3)	4.9 (7.1)	<0.001†	1.12 (1.02–1.23)	0.013	1.05 (0.98–1.12)	0.131
Avg. # comorbidities	0.41 (0.73)	0.52 (0.82)	<0.001	Not included in multivariable models			
Chronic gastrointestinal disease	97.7	2.3	0.027	Not included in multivariable models			
Chronic cardiovascular disease	97.8	2.2	<0.001				
Chronic respiratory disease	97.1	2.9	<0.001	1.29 (1.14–1.47)	<0.001	1.31 (1.19–1.44)	<0.001
Chronic hemo/peritoneal dialysis	97.4	2.7	<0.001	1.25 (1.07–1.45)	0.005	1.24 (1.10–1.39)	<0.001
Chronic immunosuppression	96.8	3.2	<0.001	1.50 (1.20–1.87)	<0.001	1.35 (1.14–1.61)	<0.001
Chronic HIV	97.4	2.6	0.125	Not included in multivariable models			
Cancer with proved metastasis	97.8	2.2	0.325				
Baseline serum creatinine >2 mg/dl	97.3	2.7	<0.001				
Hematogenous cancer	96.9	3.1	0.028				
Lymphoma	98.0	2.0	0.843				
Solid organ tumor	97.6	2.4	0.015	1.15 (1.02–1.30)	0.028	1.17 (1.07–1.29)	<0.001
Avg. length of ICU stay	3.41 (4.84)	4.28 (6.06)	<0.001†	1.00 (0.91–1.09)	0.993	1.17 (1.10–1.25)	<0.001
Source of ICU admission							
Emergency department	98.2	1.8	—	Reference		Reference	
Direct admission	97.7	2.3	0.001	1.15 (0.99–1.32)	0.319	1.20 (1.07–1.33)	0.006
General care floor	97.2	2.8	<0.001	1.37 (1.23–1.52)	<0.001	1.42 (1.31–1.54)	<0.001
Step-down unit	97.6	2.4	0.008	1.09 (0.89–1.33)	1.000	1.24 (1.07–1.43)	0.018
Procedure	98.2	1.8	0.501	1.06 (0.92–1.23)	1.000	1.10 (0.99–1.22)	0.156
SNF, rehab, LTAC	97.5	2.5	0.050	1.16 (0.77–1.75)	0.948	1.35 (1.01–1.80)	0.121
Other	97.3	2.7	<0.001	0.91 (0.68–1.22)	0.526	0.95 (0.76–1.18)	0.615
ICU destination							
Floor	98.3	1.7	—	Reference		Reference	
Step-down unit	97.5	2.5	<0.001	1.42 (1.33–1.53)	<0.001	1.37 (1.29–1.44)	<0.001
Patient type							
Elective surgery	98.3	1.7	—	Reference		Reference	
Emergency surgery	97.7	2.3	<0.001	1.07 (0.94–1.22)	0.620	1.10 (1.00–1.21)	0.096
Medical	97.9	2.1	<0.001	1.02 (0.88–1.19)	0.760	0.97 (0.87–1.09)	0.636

(Continued)

TABLE 1. (CONTINUED)

Patient Characteristics at the Time of First ICU Admission	Bivariable Models, 48-h Readmissions			Multivariable Models			
	% Not Readmitted 191,308	% Readmitted 3,894	P Value	48-h Readmissions		120-h Readmissions	
Number of patients, n				OR (95% CI)	P Value	OR (95% CI)	P Value
DNR status at ICU discharge							
Full code	98.5	1.5	—	Reference		Reference	
No cardiopulmonary resuscitation	98.0	2.0	<0.001	1.82 (1.53–2.17)	<0.001	1.99 (1.73–2.28)	<0.001
Discharge time							
Morning (6 A.M.–12 P.M.)	98.4	1.6	—	Reference		Reference	
Afternoon (12 P.M.–6 P.M.)	98.0	2.0	0.003	1.17 (1.03–1.32)	0.015	1.12 (1.02–1.23)	0.016
Night (6 P.M.–6 A.M.)	97.8	2.2	<0.001	1.20 (1.05–1.37)	0.012	1.13 (1.03–1.25)	0.022
ICU occupancy within 2 h of discharge							
>1 bed available	98.1	1.9	—	Reference		Reference	
≤1 bed available	97.9	2.1	0.920	0.98 (0.90–1.08)	0.739	1.01 (0.95–1.09)	0.648

Definition of abbreviations: CI = confidence interval; DNR = do-not-resuscitate; ICU = intensive care unit; LTAC = long-term acute care hospital; MPM0-III = Mortality Prediction Model III; OR = odds ratio; SNF = skilled nursing facility.

P values are from mixed-effects regression models with ICU-specific random intercepts.

Variables in bivariable analysis that were not also in multivariable analysis either did not meet criteria for inclusion in the multivariable model, or did alter model fit and were not important confounders.

All P values reflect Holm adjustment for multiple comparisons.

Month of initial ICU admission and hospital region are also included in the model.

*Modeled as piecewise linear polynomial.

†Natural log transformed.

Patients and Variables

Eligible patients were admitted to ICUs from April 1, 2001, to December 31, 2007. We compared patients discharged alive to a hospital ward from the ICU later readmitted at least once with those never readmitted, adjusting for patient characteristics at the time of first ICU admission. Patients dying during the initial ICU stay were excluded. Our primary definition of ICU readmission excluded patients discharged from one ICU and subsequently readmitted to a different ICU because readmissions to other ICUs are more likely to be elective rather than related to care in the initial ICU. To enhance comparability of our results to several prior studies (2, 5, 8, 10, 12–22) we included readmissions to other ICUs in secondary analyses.

To preserve independence between observations, we examined only first ICU readmissions. We excluded patients who were (1) ineligible to receive an Mortality Prediction Model III (MPM0-III) severity of illness score (30), (2) less than 18 years of age, (3) admitted to ICUs with less than 10 patients in a given year or that provided data for less than 12 consecutive months, (4) discharged from the ICU with documented limitations on life support beyond simple do-not-resuscitate orders, (5) discharged in a “moribund” condition, or (6) died after ICU discharge before they could be readmitted to an ICU within either 48 or 120 hours of ICU discharge. We also excluded patients admitted to government hospitals because of limited sample sizes.

Statistical Analyses

We evaluated ICU readmission within 48 and 120 hours (3). We chose 48 hours because proximate readmissions may be most likely attributable to ICU care or triage decisions (11, 35). By contrast, readmissions after 120 hours may be more likely elective or caused by events occurring on the floor after discharge. Patient and ICU characteristics were described using means or percentages, and compared across outcome groups using mixed-effects logistic regression models with ICU-specific random intercepts. Covariates were included in final models based on prespecified scientific plausibility (8, 10, 12–14, 36–39), or associations with the outcomes with an odds ratio (OR) of more than 1.2 or less than 0.8 accompanied by a P value of less than 0.0001 chosen because of large sample size. Backward elimination techniques were used to create a parsimonious final model. Patient variables included age (<65, 65–74, 75–84, ≥85); race (black, white, other); discharge time (6 AM–12 PM, 12 PM–6 PM, 6 PM–6 AM); ICU occupancy within 2 hours of ICU discharge (less than or equal to one open bed versus more than one open bed); and length of ICU stay. We used a piecewise linear polynomial to model associations with patient severity of illness, using the MPM0-III (30).

Four sets of analyses were conducted. First, diagnoses were examined among readmitted patients on index ICU admission and first

readmission to estimate the proportion of patients who were readmitted for new versus unresolved problems. For this purpose, approximately 50 primary diagnoses were grouped into nine categories (see Table E1 in the online supplement). Second, to test whether ICU readmission rates differed across patient, hospital, and ICU types, we examined the relationship between 48- and 120-hour ICU readmission rates and these variables. Patient type (elective surgical, emergency surgical, or medical) was the primary exposure. ICU model was closed, mandatory intensivist consult, optional intensivist consult, or no consult available. The last two categories were combined because of small sample size in the latter category (40, 41). Hospital types included academic, community with residents during the day, or community without residents.

To examine the independent effects of ICU model, hospital type, and patient type on ICU readmission rates, we examined the distribution of the rates of 48- and 120-hour readmission across different types of patients, hospitals, and ICU models, while adjusting for patient, ICU, and hospital characteristics. Multivariable mixed-effects logistic regression models with ICU-specific random-intercepts were used (42) for all models. Hospital type and ICU model were modeled as interaction terms with patient type. We used postestimation to obtain expected probabilities of ICU readmission for each patient type within each ICU model or hospital type (43); Wald tests to compare ICU readmission odds across patient, ICU, and hospital types; and a Holm correction to adjust for multiple comparisons.

The third analysis compared the distribution of time between ICU discharge and readmission using a histogram among different patient, hospital, and ICU types using Wilcoxon rank sum tests, adjusting for multiple comparisons using the Holm test.

The fourth analysis examined hospital, ICU, and patient characteristics associated with readmission, and changes in ICU readmission rates April 1, 2001, to December 31, 2007, compared with the reference year of 2007, and presents P values following Holm adjustments for multiple comparisons. This model included ICU and hospital variables not included in other analyses because of failure to meet selection criteria described previously. We tested model discrimination using the C statistic, or area under the receiver operating characteristic curve (44).

All analyses were performed using STATA 11.2 (StataCorp, College Station, TX).

RESULTS

Description of Participating ICUs and Patients

The dataset initially contained 365,968 admissions in 192 ICUs. The exclusions are shown in Figure E1. Because MPM0-III has not been validated in coronary (n = 16,388), cardiac surgery (n = 22,920),

TABLE 2. ADJUSTED HOSPITAL AND ICU CHARACTERISTICS ASSOCIATED WITH ICU READMISSION

Hospital and ICU Characteristics at the Time of First ICU Admission	% Not Readmitted (n = 191,308)	% Readmitted (n = 3,894)	P Value	48-h Readmissions		120-h Readmissions	
				OR (95% CI)	P Value	OR (95% CI)	P Value
Year							
2001	98.5	1.6	0.068	0.96 (0.80–1.15)	0.669	1.03 (0.90–1.19)	1.000
2002	98.1	1.9	0.703	1.13 (0.97–1.31)	0.493	1.13 (1.01–1.27)	0.144
2003	98.0	2.0	0.435	1.16 (1.01–1.34)	0.226	1.14 (1.02–1.27)	0.094
2004	97.9	2.1	0.477	1.13 (0.99–1.30)	0.331	1.14 (1.03–1.26)	0.068
2005	97.9	2.1	0.319	1.10 (0.96–1.26)	0.490	1.09 (0.99–1.21)	0.268
2006	97.9	2.1	0.470	1.08 (0.95–1.24)	0.486	1.02 (0.92–1.12)	0.763
2007	98.0	2.0	—	Reference		Reference	
Fellowship programs							
No program	98.3	1.8	—	Reference		Reference	
Primary fellowship site	97.5	2.5	0.002	1.36 (1.00–1.84)	0.049	1.34 (1.01–1.78)	0.044
Residency programs				Not included in multivariable models			
No residents	98.3	1.7	—				
Residents	97.8	2.2	0.038				
Hospital location							
Urban	98.0	2.0	—	Reference		Reference	
Suburban	98.1	1.9	0.629	0.95 (0.78–1.15)	0.594	0.98 (0.81–1.17)	0.802
Rural	97.7	2.3	0.138	1.32 (1.02–1.70)	0.071	1.20 (0.95–1.53)	0.268
ICU night coverage							
Critical care attending	98.1	1.9	—	Reference		Reference	
Other attending	98.1	1.9	0.282	1.21 (1.00–1.46)	0.198	1.17 (0.99–1.37)	0.248
Fellow	97.1	2.9	0.032	1.34 (0.96–1.87)	0.266	1.25 (0.92–1.69)	0.300
Resident	98.0	2.0	0.154	1.22 (0.96–1.53)	0.195	1.13 (0.92–1.39)	0.237
Other	98.3	1.7	0.642	0.77 (0.54–1.08)	0.132	0.77 (0.57–1.04)	0.272
# ICU beds							
4–12	98.4	1.6	—	Reference		Reference	
13–15	98.0	2.0	0.393	1.20 (0.95–1.51)	0.265	1.17 (0.95–1.44)	0.395
16–18	97.8	2.3	0.015	1.18 (0.97–1.44)	0.315	1.13 (0.94–1.35)	0.386
19–24	97.9	2.1	0.001	1.27 (1.03–1.56)	0.010	1.35 (1.12–1.62)	0.006
25–66	97.8	2.2	0.606	1.03 (0.79–1.36)	0.807	1.04 (0.81–1.34)	0.761
# hospital beds							
70–341	98.1	1.9	—	Reference		Reference	
346–426	98.0	2.0	0.246	0.86 (0.67–1.11)	0.261	0.82 (0.64–1.04)	0.096
450–462	97.8	2.2	0.216	0.72 (0.53–0.97)	0.059	0.61 (0.46–0.81)	0.002
563–795	98.3	1.7	0.049	0.62 (0.47–0.82)	0.003	0.57 (0.44–0.75)	<0.001
838–1,389	97.8	2.2	0.46	0.66 (0.48–0.93)	0.051	0.64 (0.46–0.88)	0.012
ICU model							
Optional consult or no consult	98.2	1.8	—	Reference		Reference	
Mandatory intensivist consult	97.7	2.4	0.032	0.93 (0.76–1.13)	0.434	0.98 (0.83–1.15)	0.7796
Closed	97.6	2.4	0.074	0.79 (0.54–1.15)	0.448	0.85 (0.61–1.19)	0.704
Hospital organization							
Community, no residents	98.4	1.6	—	Reference		Reference	
Community, with residents	98.0	2.0	0.148	1.21 (0.96–1.54)	0.111	1.25 (1.00–1.57)	0.048
Academic	97.6	2.4	0.008	1.31 (0.94–1.82)	0.220	1.46 (1.07–2.00)	0.035

Definition of abbreviations: CI = confidence interval; ICU = intensive care unit; OR = odds ratio.

P values are from mixed-effects regression models with ICU-specific random intercepts.

Variables in bivariable analysis that were not also in multivariable analysis either did not meet criteria for inclusion in the multivariable model, or did alter model fit and were not important confounders.

All P values reflect Holm adjustment for multiple comparisons.

Month of initial ICU admission and hospital region are also included in the model.

and burn patients (n = 385), they were excluded from the analysis, as were patients missing variables needed to compute an MPM0-III score (n = 1,625). A total of 196,250 eligible patients were discharged from study ICUs. The final analytic datasets included 195,202 patients eligible for readmission within 48 hours, and 194,028 patients eligible for readmission within 120 hours. These patients derived from 156 ICUs in 106 hospitals.

Overall Readmission Rates

Among 196,250 eligible patients, 3,905 (2%) were readmitted within 48 hours; 7,171 (3.7%) within 120 hours; and 10,608 (5.4%) within 21 days of discharge. A total of 389 patients readmitted within 48 hours (10%) were readmitted more than once. The median 48- and 120-hour readmission rates were 1.8% (interquartile range [IQR], 1.1–2.4%, max 5.4%) and 3.2%

(IQR, 2.2–4.4%, max 9.8%), respectively. Among patients admitted to an ICU, 8.6% died during their initial ICU stay; 5% died in the hospital subsequent to initial ICU discharge; and 86.4% survived hospitalization. Comparing never-readmitted patients with those readmitted within 48 hours, 3.7% versus 20.7% died in the hospital after ICU discharge, 64.4% versus 36.6% were discharged home, and median hospital length of stay was 8 versus 15 days, respectively (all P values < 0.001).

During the index ICU admission, patients who were readmitted within 48 hours had higher index admission MPM scores (13.1 vs. 10.9; P < 0.001) (Table 1). Patients requiring mechanical ventilation were more likely to be readmitted than those not requiring it (1.8% vs. 2.5%; P < 0.001), as were patients with comorbidities, such as chronic cardiovascular disease (2% vs. 2.2%; P < 0.001), chronic respiratory disease (1.9% vs. 2.8%; P < 0.001), and baseline serum creatinine greater than 2 mg/dl (1.9% vs. 2.7%; P < 0.001). Patients

TABLE 3. INDEX ADMISSION AND READMISSION DIAGNOSES

Never Readmitted		48-h Readmissions				120-h Readmissions			
Index Readmission Diagnosis	%	Index Readmission Diagnosis	%	Readmission Diagnosis	%	Index Readmission Diagnosis	%	Readmission Diagnosis	%
Respiratory arrest or failure	20.5	Respiratory arrest or failure	23.5	Respiratory arrest or failure	69.3	Respiratory arrest or failure	23.1	Respiratory arrest or failure	65.2
				Cardiac arrest or failure	15.7			Cardiac arrest or failure	16.1
				Sepsis	5.9			Sepsis	7.1
				Surgical emergency	0.5			Surgical emergency	1.4
				Postoperative observation	0.4			Postoperative observation	1.1
				Hemorrhage	3.1			Hemorrhage	3.9
				Neuro/neurosurgery	3.6			Neuro/neurosurgery	3.6
				Metabolic	1.0			Metabolic	1.2
Cardiac arrest or failure	16.1	Cardiac arrest or failure	15.2	Other	0.6	Cardiac arrest or failure	14.9	Other	0.5
				Respiratory arrest or failure	25.5			Respiratory arrest or failure	25.1
				Cardiac arrest or failure	56.6			Cardiac arrest or failure	52.4
				Sepsis	5.1			Sepsis	6.7
				Surgical emergency	0.8			Surgical emergency	1.2
				Postoperative observation	2.3			Postoperative observation	4.2
				Hemorrhage	3.8			Hemorrhage	3.7
				Neuro/neurosurgery	4.1			Neuro/neurosurgery	4.5
Sepsis	6.7	Sepsis	9.6	Metabolic	1.3	Sepsis	9.6	Metabolic	1.7
				Other	0.7			Other	0.6
				Respiratory arrest or failure	37.5			Respiratory arrest or failure	34.8
				Cardiac arrest or failure	21.6			Cardiac arrest or failure	19.4
				Sepsis	26.7			Sepsis	30.6
				Surgical emergency	1.8			Surgical emergency	2.1
				Postoperative observation	1.0			Postoperative observation	1.3
				Hemorrhage	5.9			Hemorrhage	6.3
Surgical emergency	6.4	Surgical emergency	7.2	Neuro/neurosurgery	2.3	Surgical emergency	7.9	Neuro/neurosurgery	3.4
				Metabolic	1.5			Metabolic	1.3
				Other	1.5			Other	0.8
				Respiratory arrest or failure	45.2			Respiratory arrest or failure	41.0
				Cardiac arrest or failure	23.5			Cardiac arrest or failure	19.3
				Sepsis	7.6			Sepsis	12.0
				Surgical emergency	7.9			Surgical emergency	11.3
				Postoperative observation	1.0			Postoperative observation	1.5
Postoperative observation	10.7	Postoperative observation	10.0	Hemorrhage	3.8	Postoperative observation	9.9	Hemorrhage	4.1
				Neuro/neurosurgery	3.8			Neuro/neurosurgery	3.6
				Metabolic	2.4			Metabolic	2.6
				Other	4.8			Other	4.6
				Respiratory arrest or failure	46.4			Respiratory arrest or failure	43.7
				Cardiac arrest or failure	30.8			Cardiac arrest or failure	26.0
				Sepsis	4.1			Sepsis	7.2
				Surgical emergency	0.2			Surgical emergency	1.7
Hemorrhage	7.4	Hemorrhage	8.7	Postoperative observation	4.8	Hemorrhage	8	Postoperative observation	7.2
				Hemorrhage	2.4			Hemorrhage	4.3
				Neuro/neurosurgery	6.3			Neuro/neurosurgery	5.4
				Metabolic	3.1			Metabolic	2.3
				Other	1.9			Other	2.3
				Respiratory arrest or failure	16.8			Respiratory arrest or failure	17.9
				Cardiac arrest or failure	12.8			Cardiac arrest or failure	13.5
				Sepsis	4.0			Sepsis	7.3
Neuro/neurosurgery	18.3	Neuro/neurosurgery	14.2	Surgical emergency	3.7	Neuro/neurosurgery	15.7	Surgical emergency	4.7
				Postoperative observation	2.3			Postoperative observation	3.7
				Hemorrhage	50.4			Hemorrhage	43.4
				Neuro/neurosurgery	6.6			Neuro/neurosurgery	5.1
				Metabolic	1.4			Metabolic	1.2
				Other	2			Other	3.2
				Respiratory arrest or failure	28.1			Respiratory arrest or failure	27.2
				Cardiac arrest or failure	15.5			Cardiac arrest or failure	12.9
				Sepsis	2.6			Sepsis	2.8
				Surgical emergency	0.9			Surgical emergency	1.0
				Postoperative observation	0.5			Postoperative observation	1.0
				Hemorrhage	0.9			Hemorrhage	1.6
				Neuro/neurosurgery	50.4			Neuro/neurosurgery	52.2
				Metabolic	0.7			Metabolic	1.0
				Other	0.4			Other	0.5

(Continued)

TABLE 3. (CONTINUED)

Never Readmitted		48-h Readmissions				120-h Readmissions			
Index Admission Diagnosis	%	Index Admission Diagnosis	%	Readmission Diagnosis	%	Index Admission Diagnosis	%	Readmission Diagnosis	%
Metabolic	7.6	Metabolic	3.8	Respiratory arrest or failure	38.2	Metabolic	3.5	Respiratory arrest or failure	34.5
				Cardiac arrest or failure	19.1			Cardiac arrest or failure	18.0
				Sepsis	6.6			Sepsis	9.4
				Surgical emergency	2.6			Surgical emergency	3.1
				Postoperative observation	1.3			Postoperative observation	2.0
				Hemorrhage	5.3			Hemorrhage	5.5
				Neuro/neurosurgery	5.9			Neuro/neurosurgery	7.5
				Metabolic	20.4			Metabolic	19.2
				Other	0.7			Other	0.8
Other	6.3	Other	7.6	Respiratory arrest or failure	48.1	Other	7.4	Respiratory arrest or failure	45.6
				Cardiac arrest or failure	15.9			Cardiac arrest or failure	14.8
				Sepsis	5.2			Sepsis	4.6
				Surgical emergency	9.1			Surgical emergency	11.1
				Postoperative observation	0.3			Postoperative observation	0.6
				Hemorrhage	2.0			Hemorrhage	3.3
				Neuro/neurosurgery	6.2			Neuro/neurosurgery	7.5
				Metabolic	0.7			Metabolic	1.5
				Other	12.7			Other	11.1

hospitalized in academic hospitals (Table 2) (academic, 2.4% vs. community without residents, 1.6%; $P = 0.008$) were more likely to be readmitted, as were patients discharged during the afternoon or night (morning, 1.6% vs. afternoon, 2% [$P = 0.003$], vs. night, 2.2% [$P < 0.001$]). Readmitted patients had longer ICU lengths of stay (4.3 vs. 3.4 d) during their first ICU admission than patients never readmitted.

Patient Diagnoses: Index versus First Readmission

Never readmitted patients had similar index admission diagnoses as those eventually readmitted to the ICU. Readmission diagnoses in relation to index admission diagnoses are shown in Table 3. The most common readmission diagnoses were respiratory (42.3%), and cardiac arrest or failure (24.4%). Among readmitted patients, 42% and 41% were readmitted for a similar diagnosis as their index admission at 48 and 120 hours, respectively, suggesting a perpetuation or recurrence of the original problem, rather than a new problem. The proportion readmitted for an old problem was highest among patients originally admitted for respiratory (69.3%) or cardiac arrest or failure (56.6%).

ICU Readmission Rates Across Patient Types, ICU Models, and Hospital Types

In adjusted models with no interaction terms, there was no difference in 48-hour ICU readmission rates between elective surgery (1.5% [1.3–1.7%]); emergency surgery (2% [1.7–2.2%]); and medical patients (1.9% [1.7–2%]). ICU readmission rates within 120 hours were 2.8% (2.5–3%) for elective surgery; 3.9% (3.5–4.3%) for emergency surgery; and 3.3% (3.1–3.6%) for medical patients.

In adjusted models with interaction terms between patient-type and hospital-type ICU model, rates of 48-hour readmission did not differ across hospital type or ICU model (Figures 1 and 2). Among medical patients, academic hospitals had nonsignificantly higher 48-hour ICU readmission rates than community hospitals with residents (OR, 1.23 [0.97–1.55]; $p_{\text{Holm}} = 0.092$), and significantly higher readmission rates than community hospitals without residents (OR, 1.51 [1.12–2.02]; $p_{\text{Holm}} = 0.018$). The odds of 120-hour readmission for medical patients in academic hospitals were higher than in community hospitals with residents (OR, 1.31 [1.05–1.64]; $p_{\text{Holm}} = 0.031$) and without residents (OR, 1.63 [1.24–2.16]; $p_{\text{Holm}} = 0.001$). The odds of 120-hour readmission in community hospitals with residents were nonsignificantly higher than

in community hospitals without residents (OR, 1.25 [1.00–1.55]; $p_{\text{Holm}} = 0.051$). There were no differences in adjusted 48- or 120-hour readmission rates between ICU models.

Time to Readmission

Figure 3 illustrates the distribution of time between ICU discharge and first readmission. Ninety-nine percent occurred within 30 days of discharge. The median time to ICU readmission was 3.07 days (IQR, 1.27–6.58). Roughly 20% of readmissions occurred within 24 hours of ICU discharge; 90% occurred within 12 days.

In closed ICUs, the median time to ICU readmission (3.55 d; IQR, 1.42–7.50) was longer than in ICUs requiring an intensivist consult (3.15 d; IQR, 1.31–6.65; $p_{\text{Holm}} = 0.006$) or in ICUs with optional consults (2.95 d; IQR, 1.21–6.29; $p_{\text{Holm}} = 0.0001$). Mandatory-consult ICUs displayed longer times to readmission than optional ($p_{\text{Holm}} = 0.008$). ICUs in academic centers had longer times to readmission (3.24 d; IQR, 1.39–6.73) than community hospitals with residents (2.95 d; IQR, 1.20–6.41; $p_{\text{Holm}} = 0.0002$), but not community hospitals without residents (3.06 d; IQR, 1.28–6.70; $p_{\text{Holm}} = 0.455$). Elective (3.26 d; IQR, 1.36–6.72) and emergency surgical patients (3.37 d; IQR, 1.49–6.83) had longer times to ICU readmission than medical patients (2.94 d; IQR, 1.20–6.44) (emergency, $p_{\text{Holm}} = 0.0001$; elective, $p_{\text{Holm}} = 0.0007$).

Adjusted Hospital and Temporal Variables Associated with ICU Readmission

Several patient variables remained associated with increased odds ICU readmission in multivariable analysis (Tables 1 and 2) including severity of illness, functional status, admission from a general care floor, duration of mechanical ventilation, chronic respiratory or renal disease, chronic immunosuppression, and solid organ tumor. Length of ICU stay was no longer associated with 48-hour readmission, but was with 120-hour readmission. Patients admitted to ICUs with critical care fellows had higher readmission odds; hospitals with more beds had lower readmission odds. Compared with patients discharged from the ICU in the morning, those discharged in the afternoon or at night were more commonly readmitted. There was no association between ICU occupancy at discharge and readmission odds. ICU readmission odds did not change 2001–2007.

Model Fit

The C statistics for the models estimating 48- and 120-hour ICU readmission rates over time were 0.64 (95% confidence interval,

Figure 1. Adjusted rates of readmission by hospital organization. Percent readmitted after 48 and 120 hours. Rates represent predicted probabilities of intensive care unit readmission after adjusting for patient, intensive care unit, and hospital characteristics. CI = confidence interval.

0.63–0.65) and 0.65 (95% confidence interval, 0.64–0.66), respectively, indicating moderate discrimination, but with important unexplained variability remaining. Models including interaction terms and nested models for 48-hour readmissions with hospital and ICU level random intercepts had comparable discrimination.

Secondary Analysis

Including patients readmitted to other ICUs as readmissions increased the 48- and 120-hour readmission rates from 2–2.3% and 3.7–4%, respectively. Including these readmissions, there were still no differences in readmission rates among ICUs using different staffing models. Because hospitals naturally vary in the numbers and types of ICUs they have, and the possibility of being readmitted to a different ICU depends on the availability of another ICU within the same hospital, differences among hospital types were not assessed using this secondary definition of ICU readmission.

DISCUSSION

This national study across a diverse sample of ICUs shows that roughly 2% of critically ill patients are readmitted to the same ICU within 48 hours of ICU discharge; 4% are readmitted within 120 hours. Neither 48- nor 120-hour readmission rates varied across patient or ICU type. ICU readmission rates did not change 2001–2007. Among medical patients, those in academic hospitals were more likely to be readmitted after 48 hours than those in community hospitals without residents, and more likely to be readmitted after 120 hours than patients in community hospitals with or without residents. We did not evaluate readmissions after 120 hours because they are more likely to be determined by disease trajectories and care on the floor than ICU decisions. Further, the data suggest that fewer than 35% of readmissions occur beyond 120 hours, and modest C statistics suggest that even during

these short windows, unmeasured risk factors may lead to ICU readmission. Future research should explore how patients' severity of illness at ICU discharge (rather than at ICU admission), and how floor-based rather than ICU-based organizational structures, contribute to ICU readmission risk. Future research should also explore whether decision making by residents influences ICU readmission rates.

Approximately 60% of readmitted patients were readmitted for different diagnoses than their original diagnosis, whereas the other 40% may have had perpetuation or recrudescence of their initial problem. Evidence-based discharge criteria for vulnerable patient groups, such as sepsis or mechanically ventilated patients, which could prevent adverse events after ICU discharge deserve further exploration. However, the challenge is to develop effective criteria across diverse institutions that limit unintended negative consequences.

Fifty percent of readmitted patients returned to the ICU within 3 days. Closed ICUs and academic hospitals had the longest median times to readmission, possibly because of differences in case-mix or discharge practices, or because increased bed scarcity in closed ICUs creates delays in or higher thresholds for readmission. Alternatively, if ICU readmissions after longer time periods on the floor imply that adverse events post-ICU discharge rather than ICU practices precipitate readmissions, these findings could be attributable to different post-ICU discharge practices or events.

Afternoon and evening discharge were important risk factors for ICU readmission in multivariable analyses. This finding is consistent with a prior study (22) and may be because such patients may be more likely discharged to create room for other patients, suggesting that they are less "ready" for initial ICU discharge. Alternatively, differences in ICU night staffing, discharge protocols, or handoff quality may account for these findings. Although no association was found between ICU occupancy at patient discharge and ICU readmission in this analysis, the idea that "early" discharge

Figure 2. Adjusted rates of readmission by intensive care unit (ICU) model. Percent readmitted after 48 and 120 hours. Rates represent predicted probabilities of ICU readmission after adjusting for patient, ICU, and hospital characteristics. CI = confidence interval.

because of ICU capacity strain could lead to adverse patient outcomes deserves further exploration (45).

ICU readmissions are considered a promising candidate for assessing ICU performance (12). This study addresses the epidemiology of ICU readmissions, and may guide sample selection for future studies that more directly assess the relevance of readmissions. This study does not settle the important questions of whether readmissions are preventable or causally related to poor outcomes. Too many readmissions could suggest the occurrence of preventable adverse events, but some readmissions may be inevitable, and others may even benefit patients. Similarly, too few readmissions could imply that hospitals retain patients in ICUs longer than necessary, exposing patients to unnecessary risks, causing denial of critical care to other patients, and increasing healthcare costs. Low ICU readmission rates could also be attributable to higher than expected mortality, or hasty hospital discharge. Therefore, any use of ICU readmissions as a quality metric must be accompanied

by mortality and length-of-stay metrics. Further research should explore the circumstances surrounding readmissions, and the attributable mortality caused by them.

Other studies have reported higher ICU readmission rates than found in this study. However, many of these studies have been small, and may have been undertaken by participating institutions out of concern that ICU readmissions were too frequent. Further, many included readmissions after longer time periods, to other ICUs, or were performed in academic centers (5, 10, 12–14, 16–18, 20), which have higher rates of unadjusted ICU readmission than community ICUs.

Our results could be biased toward finding lower readmission rates. ICUs pay to participate in Project IMPACT, and participating hospitals may be particularly invested in quality improvement, although previous studies have shown that ICUs in Project IMPACT are representative of ICUs in the United States (27). The results of this study may still be appropriate to use for benchmarking

Figure 3. Days to first intensive care unit (ICU) readmission. Unadjusted time to readmission across all ICU, hospital, and patient types, calculated from the time of discharge to the time of ICU readmission. Does not include readmissions to ICUs other than that from which the patient was initially discharged.

purposes, because benchmarks should be established from a sample of ICUs concerned about quality (8, 10, 12, 16–20, 46).

Additionally, our definition of ICU readmission was more restrictive than that used by other studies. Our definition was designed to describe unintended, potentially preventable ICU readmissions, rather than elective readmissions. Therefore, the sample was limited to first readmissions and excluded readmissions to different ICUs. We established, *a priori*, temporal cut-points expected to provide clinically useful information, and also examined the full distribution of readmissions to a full picture of the relationships between patient, hospital, and ICU type and readmission rates. In secondary analyses, we found that including ICU readmissions to other ICUs increased rates by 0.3% in absolute terms.

This study has additional limitations. Severity of illness at the time of ICU discharge and adverse events occurring post-ICU discharge were not available for analysis. However, we used other variables as proxies for severity of illness at ICU discharge, such as duration of mechanical ventilation, time between extubation and ICU discharge, ICU length of stay, and the use of a step-down unit. Because no prior study has used similar adjustments, our severity adjusted readmission rate, while imperfect, represents the best estimate currently available.

Burn, cardiac, or coronary patients were not included in the analysis because they lacked an MPM0-III score, preventing a valid severity of illness adjustment. These estimates should be applied with caution to ICUs that serve primarily these patients.

Finally, because the study focuses on ICUs in the United States, results may not be generalizable to ICUs in other countries where healthcare systems, ICU management including criteria for readmission, and patient characteristics may differ substantively.

In summary, no differences were found between ICU models and hospital types in the rates of 48-hour ICU readmission in the largest and most representative sample of ICUs in the United States studied to date. The observed differences in 120-hour readmission rates across hospital types likely were attributable to residual confounding by unmeasured phenomena occurring on the floors. Using a shorter timeframe to define ICU readmission may avoid mixing readmissions attributable to ICU decisions with those attributable to post-ICU discharge events. Future research describing the clinical course of a prototypical ICU readmission, and the attributable mortality caused by readmissions, will provide further guidance for whether or how to use ICU readmissions as a quality benchmark.

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