Association Between Intensive Care Unit Occupancy at Discharge, Afterhours Discharges, & Clinical Outcomes: An Historical Cohort Study

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Research

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Abstract

Background: There is a paucity of contemporary, patient-level data evaluating the association between discharge occupancy in the intensive care unit (ICU) and clinical outcomes such as readmission and mortality. Additionally, it is unknown whether increased occupancy at discharge may modify the timing of discharge (i.e. increased afterhours discharge) and further provoke negative clinical consequences. The objective of this single-center historical cohort study was to explore the association between ICU occupancy on the day of discharge and afterhours discharges, 72-hour readmission and 30-day mortality.

Methods: This was a historical cohort study of a single large quaternary ICU in Canada. Discharge occupancy was defined as the number of hours of patient care delivered on the day of discharge divided by the total amount of hours of care available for that day (number of funded beds x 24 hours). Afterhours discharge was defined as a discharge between 22:00 and 6:59. Logistic regression models controlling for important covariates were constructed. Adjusted restricted cubic spline models were also created to control for non-linear relationships.

Results: A total of 8,862 ICU discharges, representing 7,288 individual patients, between April 1, 2010 and August 10, 2017 were included in this analysis. A total of 1180 (13.3%) afterhours discharges, 408 (4.6%) 72-hour readmissions, and 574 (6.5%) 30-day post discharge deaths occurred. In the adjusted analysis, greater discharge occupancy was associated with afterhours discharges (per 10% increase; adjusted odds ratio (aOR) 1.12, 95% CI 1.03-1.20, $p = 0.005$). Discharge occupancy was not associated with 72-hour readmission (per 10% increase; aOR 0.97, 95% CI 0.87-1.09, $p = 0.624$) or 30-day mortality (per 10% increase; aOR 1.05, 95% CI 0.95-1.16, $p = 0.323$). Afterhours discharge was not associated with neither 72-hour readmission (aOR 1.15, 95% CI 0.86-1.54, $p = 0.341$) nor 30-day mortality (aOR 1.05, 95% CI 0.82-1.36, $p = 0.691$).

Conclusions: Greater ICU occupancy on the day of discharge was associated with a significant increase in afterhours discharges. However, neither discharge occupancy nor afterhours discharge were associated with 72-hr readmission or 30-day mortality.

Keywords: Intensive care unit; occupancy; capacity strain; process-of-care; afterhours discharge; readmission; mortality

Background

Over the last decade, average intensive care unit (ICU) occupancy at larger tertiary and quaternary centers has steadily increased with many sites routinely operating near or over capacity (1,2). As a result, there is growing interest and acknowledgment that capacity strain in the ICU may significantly impact patient processing, decision making, and clinical outcomes(3–7)

In the ICU, capacity strain has been defined as the discrepancy between available resources (beds, staff, equipment, etc.) and the current demand to admit patients in need of intensive care (3,7). Two commonly

utilized metrics of capacity strain in the ICU are occupancy and afterhours discharge (3). Afterhours discharge is an important metric of strain as these discharges are ideally avoided due to the association with increased mortality and ICU readmission (4,5,8–11). Occupancy is a higher-level indicator of strain and reflects the current environment in the ICU on a given day. Yet, while many analyses have focused on the impact of high occupancy at the time of admission (7,12–15), few have assessed the impact of occupancy at ICU discharge (6). It is unknown whether higher occupancy at discharge increases the risk of afterhours discharges or leads to worse clinical outcomes.

There is a paucity of contemporary, patient-level data evaluating the association between high occupancy at ICU discharge and clinical outcomes such as readmission and subsequent mortality. Many tertiary and quaternary centers have developed new strategies to deal with increasing admission demand and it is unlikely that previous studies that used aggregate data from mostly small centers with fixed ICU capacities and open models of care are applicable (6). Additionally, it is unknown whether increased occupancy at discharge may modify the timing of discharge (i.e. increased afterhours discharge) or provoke negative clinical consequences. The objective of this single-center historical cohort study was to explore the association between ICU occupancy on the day of discharge and afterhours discharges, subsequent 72-hour readmission and 30-day mortality.

Methods

Study Design & Setting

We conducted an historical cohort study of all patients discharged from the ICU at Vancouver General Hospital between April 1st, 2010 and August 10th, 2017. Results are reported in accordance with the Strengthening the Reporting of Observational Epidemiology (STROBE) statement (16). The ICU is a closed, 32-bed mixed medical surgical unit affiliated with the University of British Columbia. It operates on an approximately 1:1.2 nurse to patient ratio. When all ICU beds are filled, additional patients admitted to the ICU are attended to by the ICU care team in off-service beds (e.g. post-anesthetic care unit, emergency department). During the study period in April 2014, the size of the ICU increased from 27 to 31 physical beds and then from 31 to 32 beds in April 2016. There is also a 12-bed High-Acuity Unit (HAU) that services patients in need of a higher level of care, but not requiring advanced life sustaining therapies. The HAU opened in September 2015 and admits patients who require vasoactive medications or non-invasive ventilation. Additionally, the HAU can function as a step-down unit for the ICU. Patients admitted solely to the HAU were excluded in this analysis. Patients in the ICU and HAU are cared for by one of three physician teams, each consisting of an attending intensive care physician, resident physicians (variety of subspecialty residents, including critical care medicine fellows) and other clinical staff (nurses, respiratory therapists, pharmacists, dieticians, physical and occupational therapists). Discharge readiness is assessed by the attending physician.

Data

Data were obtained from the British Columbia (BC) Critical Care Database which records patient specific data for all patients admitted to the ICU. Patient specific data included baseline demographics (age, sex), primary diagnosis, and illness acuity. Illness acuity was characterized by the Sequential Organ Function Assessment (SOFA) which is a commonly utilized mortality prediction score based on the level of dysfunction present in six organ systems (17). Scores can range from 0–24 and greater scores are associated with greater risk of mortality and readmission to the ICU (9–11). SOFA score was determined at the time of ICU admission. This database also included daily processual factors such as the number of patients discharged, hours of patient care performed, and number of available beds. There were no missing data to report.

Exposure

By linking each ICU discharge to daily ICU characteristics, we were able to identify several indicators of capacity strain for each individual ICU discharge. Our principal exposure included ICU occupancy at discharge. Occupancy was defined as the number of hours of ICU patient care delivered in a day divided by the total amount of hours of care available for that day (number of funded beds x 24 hours). This method is considered to be a better representation of ICU capacity strain compared to other methods of determining occupancy, such as a simple patient census (18,19). The occupancy on the day of ICU discharge was calculated for each discharge. Additional exposures of ICU capacity strain included the total number of admissions in the 24 hours preceding that specific discharge. For example, if a patient was discharged at 15:00, all ICU admissions from that instance to 15:00 the day prior were totalled. Delayed discharge was defined as a delay of 6 or more hours between the time a patient was labelled appropriate for discharge and when patient physically left the ICU. This definition of delayed discharge has been utilized in a previous analysis(20) while other studies have used either 4 or 8 hours (21). Temporal factors were also included such as weekend discharge (Saturday-Sunday) and season of discharge (Winter [December to February], Spring [March to May], Summer [June to August], Fall [September to November]). The number of funded beds by era were also included (n = 27 [April 2010 to March 2014], n = 31 [April 2014 to March 2016], n = 32 [April 2016 to August 2017]) along with a binary variable of pre- and post-HAU creation (September 2015).

Outcomes

Outcomes of interest included afterhours discharge, 72-hour readmission, and 30-day mortality. Afterhours discharge was defined as any discharge from the ICU between 22:00 and 06:59. This definition is a commonly used standard in Canadian and U.K. practice and has been used in more contemporary analyses of larger tertiary and quaternary centers (4,22). Seventy-two-hour readmission was defined as any patient who was discharged and admitted back to the ICU within 72 hours. We chose 72 hours as our readmission time frame as it is commonly used metric to indicate readmissions that are thought to be avoidable, and it represents the median time to ICU readmission from previous large epidemiological studies (23,24). Seven-day mortality was defined as any death (regardless of location) that occurred within 7 days of being discharged from the ICU. A period of 7 days was chosen as it represents a reasonable timeframe to assume that mortality may be related to ICU discharge. Deaths

occurring after 7 days post discharge are very unlikely to be related to any strain factor that occurred at discharge.

Statistical Methods

The base unit of analysis was ICU discharge and data were treated as longitudinal, controlling for repeatedly discharged patients. Sample size was one of convenience, acknowledging that over a seven-year period we would have an adequate number of events to build a robust multivariable model. Descriptive statistics were presented for the overall cohort and for each ascending quintile of discharge occupancy. All continuous variables were presented as mean (standard deviation; SD) and categorical variables were presented as total number (%) unless otherwise stated.

We constructed three logistic regression models to evaluate the association between ICU discharge occupancy (per 10% increase) and afterhours discharge, 72-hour readmission, and 30-day mortality. Since patients could have more than one ICU discharge, we accounted for within-patient correlation using mixed-effects logistic regression model with the random-effect specified at the patient level (STATA command xtreg). In each model we controlled for important baseline covariates such as age, sex, discharge SOFA score, year of discharge, primary diagnosis category (e.g. Shock), season of discharge (e.g. Winter) and discharge location (e.g. Medical Ward). Other possible metrics of capacity strain such as the total number of ICU admissions in the 24 hours prior to discharge, delayed discharges (Yes/No), and weekend discharge (Sat/Sun) were included. For the 72-hr readmission model we included afterhours discharge as a predictor variable. Additionally, for the 30-day mortality model we included both afterhours discharge and 72-hr readmission as predictor variables. Results of the logistic regression models were displayed as odd ratios (OR) with 95% confidence intervals (CI).

To adjust for non-linear relationships, we generated restricted cubic spline models (STATA commands mkspline & xbrcspline) to visually characterize the relationship between discharge occupancy and the odds of afterhours discharges, 72-hour readmission, and 30-day mortality. These models consisted of four knots and adjusted for important baseline covariates (same as logistic regression models). Discharge occupancy was rounded to the nearest 5% and corresponding adjusted odds ratios with 95% confidence intervals were determined for afterhours discharges, 72-hour readmission, and 30-day mortality. A reference value of 70% was chosen as it corresponded with the lowest occupancy value.

Several sensitivity analyses were conducted to ensure the robustness of our results. We assessed whether altering the definition of afterhours discharge from 22:00–6:59 to 19:00–6:59 would alter any study results. This more liberal definition is sometimes used in previous literature (3). We also modeled our results using only patient for which SOFA scores at discharge were known. This applied only to patients with an ICU length of stay less than seven days as SOFA is only calculated daily for the first week. We also wanted to evaluate whether weekend discharge modified any associations between discharge occupancy, afterhours discharge and clinical outcomes. We also evaluated whether afterhours discharge modified the effect of discharge occupancy on 72-hour readmission and 30-day mortality. Lastly, multicollinearity between the number of admissions in the 24 hours prior to discharge and

discharge occupancy was evaluated. All analyses were performed using STATA (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

Results

Descriptive Statistics

A total of 8,862 discharges, representing 7,288 individual patients, from the ICU occurred between April 1, 2010 and August 10, 2017. All discharges during this period were included in this analysis. A total of 1180 (13.3%) afterhours discharges, 408 (4.6%) 72-hour readmissions, and 574 (6.5%) 30-day post discharge deaths occurred. Complete descriptive statistics for the overall cohort and by discharge occupancy quintile are presented in Table 1. The range of discharge occupancy values associated with each quintile are 68–90% (Quintile 1), 91–94% (Quintile 2), 95–99% (Quintile 3), 100–106% (Quintile 4), and 106–137% (Quintile 5).

Table 1
Demographics

ICU Discharge Occupancy Quintile							
	Total	Quintile 1 (68– 90%) ^c	Quintile 2 (91– 94%) ^c	Quintile 3 (95– 99%) ^c	Quintile 4 (100– 106%) ^c	Quintile 5 (106– 137%) ^c	p- value ^a
No. of Discharges	8,862	1,736	1,790	1,797	1,769	1,770	
No. of Unique Patients	7,288 (82.2%)	1,460 (84.1%)	1,467 (82.0%)	1,484 (82.6%)	1,448 (81.9%)	1,429 (80.7%)	0.12
Age	57.2 (17.4)	57.1 (17.1)	57.3 (17.4)	57.1 (17.6)	57.1 (17.3)	57.5 (17.4)	0.94
Female	3,175 (35.8%)	606 (34.9%)	662 (37.0%)	668 (37.2%)	626 (35.4%)	613 (34.6%)	0.36
SOFA at Discharge	4.3 (3.2)	4.1 (3.2)	4.2 (3.1)	4.4 (3.2)	4.3 (3.2)	4.3 (3.3)	0.026
Afterhours Discharges (22:00–6:69)	1,180 (13.3%)	162 (9.3%)	236 (13.2%)	257 (14.3%)	259 (14.6%)	266 (15.0%)	< 0.001
Weekend Discharge	2,554 (28.8%)	542 (31.2%)	503 (28.1%)	497 (27.7%)	526 (29.7%)	486 (27.5%)	0.065
No. of ICU Admissions in 24 h Prior to Discharge ^b	4 (3–5)	4 (3–5)	4 (3–5)	4 (3–5)	5 (4–6)	5 (4–6)	< 0.001
Delayed Discharge (≥ 6 hours)	2,670 (30.1%)	557 (32.1%)	581 (32.5%)	536 (29.8%)	530 (30.0%)	466 (26.3%)	< 0.001
Primary Diagnosis							
Shock	1,260 (14.2%)	222 (12.8%)	236 (13.2%)	270 (15.0%)	262 (14.8%)	270 (15.3%)	0.22
MSK / Dermatological	112 (1.3%)	20 (1.2%)	20 (1.1%)	30 (1.7%)	19 (1.1%)	23 (1.3%)	
Metabolic / Toxicity	394 (4.4%)	98 (5.6%)	76 (4.2%)	75 (4.2%)	65 (3.7%)	80 (4.5%)	
GI / Urologic	1,362 (15.4%)	278 (16.0%)	284 (15.9%)	267 (14.9%)	259 (14.6%)	274 (15.5%)	
Hematologic	659 (7.4%)	120 (6.9%)	138 (7.7%)	139 (7.7%)	132 (7.5%)	130 (7.3%)	
Neurologic	2,359 (26.6%)	467 (26.9%)	481 (26.9%)	464 (25.8%)	454 (25.7%)	493 (27.9%)	

ICU Discharge Occupancy Quintile							
Pulmonary/Pneumonia	2,716 (30.6%)	531 (30.6%)	555 (31.0%)	552 (30.7%)	578 (32.7%)	500 (28.2%)	
Source of Discharge							
Home	85 (1.0%)	39 (2.2%)	19 (1.1%)	5 (0.3%)	14 (0.8%)	8 (0.5%)	< 0.001
Ward	5,043 (56.9%)	1,054 (60.7%)	1,056 (59.0%)	1,029 (57.3%)	966 (54.6%)	938 (53.0%)	
ICU Transfer	309 (3.5%)	41 (2.4%)	44 (2.5%)	56 (3.1%)	63 (3.6%)	105 (5.9%)	
High Acuity Unit	321 (3.6%)	53 (3.1%)	47 (2.6%)	46 (2.6%)	106 (6.0%)	69 (3.9%)	
Special Care Unit	3,104 (35.0%)	549 (31.6%)	624 (34.9%)	661 (36.8%)	620 (35.0%)	650 (36.7%)	
Season							
Winter	2,092 (23.6%)	221 (12.7%)	347 (19.4%)	503 (28.0%)	554 (31.3%)	467 (26.4%)	< 0.001
Spring	2,352 (26.5%)	392 (22.6%)	502 (28.0%)	570 (31.7%)	461 (26.1%)	427 (24.1%)	
Summer	2,361 (26.6%)	720 (41.5%)	539 (30.1%)	375 (20.9%)	326 (18.4%)	401 (22.7%)	
Fall	2,057 (23.2%)	403 (23.2%)	402 (22.5%)	349 (19.4%)	428 (24.2%)	475 (26.8%)	
No. Funded Beds							
27 (Apr 2010 – Mar 2014)	4,626 (52.2%)	847 (48.8%)	914 (51.1%)	959 (53.4%)	755 (42.7%)	1,151 (65%)	< 0.001
31 (Apr 2014 – Mar 2015)	2,539 (28.7%)	408 (23.5%)	582 (32.5%)	562 (31.3%)	586 (33.1%)	401 (22.7%)	
32 (Apr 2016 – Aug 2017)	1,697 (19.1%)	481 (27.7%)	294 (16.4%)	276 (15.4%)	428 (24.2%)	218 (12.3%)	
Post-HAU Creation (Sep 2015)	2,444 (27.6%)	562 (32.4%)	407 (22.7%)	383 (21.3%)	668 (37.8%)	424 (24.0%)	< 0.001

ICU Discharge Occupancy Quintile

SOFA = Sequential Organ Function Assessment, ICU = Intensive Care Unit, MSK = Musculoskeletal GI = Gastrointestinal, HAU = High Acuity Unit
Data are presented as mean (SD) or median (IQR) for continuous measures, and n (%) for categorical measures.

^a Significance tests were analysis of variance, Pearson's Chi squared, and Kruskal-Wallis when appropriate.

^b Results presented as median and interquartile range.

^cRange of occupancy within each respective quintile.

Afterhours discharges

In the crude analysis, each 10% increase in discharge occupancy was associated with an 19% increase in the odds of afterhours discharge (OR 1.19, 95% CI 1.11–1.27, p-value < 0.001, per 10% increase). After adjusting for covariates, increasing discharge occupancy remained significantly associated with afterhours discharge (Table 2). An adjusted restricted cubic spline model for the association between discharge occupancy and afterhours discharge are presented in both Figs. 1 & 2. Each additional admission to the ICU in the 24 hours prior to discharge resulted in a 12% increase in the odds of afterhours discharge (aOR 1.12, 95% CI 1.08–1.16, p-value < 0.001) (Table 2). The remaining results of the adjusted logistic regression model for afterhours discharge are presented in Table 2.

Table 2

Adjusted logistic regression models for afterhours discharge, 72-hour readmission, & 30-day mortality

	Afterhours Discharge			72-hour Readmission			30-day Mortality		
	OR	95% CI	p-value	OR	95% CI	p-value	OR	95% CI	p-value
Discharge Occupancy (per 10%)	1.12	1.03–1.20	0.005	0.97	0.87–1.09	0.624	1.05	0.95–1.16	0.323
Afterhours Discharge (22:00–6:59)	-	-	-	1.15	0.86–1.54	0.341	1.05	0.82–1.36	0.691
72-hour Readmission	-	-	-	-	-	-	1.51	1.07–2.14	0.018
No. of admissions in 24 hours before discharge	1.12	1.08–1.17	< 0.001	1.02	0.97–1.08	0.394	1.03	0.98–1.08	0.301
Weekend Discharge (Sat/Sun)	0.92	0.79–1.07	0.278	1.16	0.93–1.45	0.167	0.90	0.74–1.10	0.293
Delayed Discharge ($\geq$ 6 hours)	2.20	1.89–2.54	< 0.001	0.75	0.59–0.94	0.015	0.97	0.80–1.17	0.717
SOFA at Admission	1.01	0.99–1.03	0.147	1.03	1.00–1.06	0.026	1.08	1.06–1.11	< 0.001
Age	1.00	0.99–1.01	0.783	1.00	0.99–1.01	0.927	1.04	1.03–1.04	< 0.001
Female Sex	1.03	0.89–1.18	0.711	0.97	0.78–1.20	0.787	1.05	0.87–1.26	0.614
No. Funded Beds in ICU (Year)									
27 (2010 – 2014)	1.00	(ref)		1.00	(ref)		1.00	(ref)	
31 (2014–2015)	0.82	0.68–0.99	0.035	0.96	0.72–1.27	0.771	0.89	0.69–1.40	0.341
32 (2016–2017)	0.86	0.60–1.22	0.403	0.74	0.44–1.24	0.257	0.90	0.56–1.46	0.668
Post-HAU Creation (Sept 2015)	1.00	0.75–1.33	0.973	1.41	0.93–2.13	0.103	0.99	0.67–1.46	0.941
Source of Discharge									
Medical Ward	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Home	0.14	0.02–1.03	0.053	NE ^c	NE	NE	NE	NE	NE

	Afterhours Discharge			72-hour Readmission			30-day Mortality		
ICU Transfer	2.30	1.63– 3.23	< 0.001	0.13	0.03– 0.53	0.004	0.08	0.02– 0.32	0.001
High Acuity Unit	5.07	3.64– 7.05	< 0.001	1.65	1.01– 2.71	0.046	1.70	1.11– 2.62	0.015
Special Care Unit	1.61	1.36– 1.90	< 0.001	1.09	0.85– 1.39	0.516	0.73	0.58– 0.92	0.007
Primary Diagnosis Category									
Shock	1.00	(ref)		1.00	(ref)		1.00	(ref)	
MSK/ Dermatologic	0.66	0.32– 1.34	0.249	0.31	0.07– 1.29	0.108	0.30	0.07– 1.27	0.102
Metabolic / Toxicity	1.29	0.89– 1.87	0.172	0.16	0.05– 0.51	0.002	0.73	0.41– 1.30	0.287
Gastrointestinal / Urologic	1.16	0.90– 1.49	0.255	0.97	0.69– 1.37	0.883	0.71	0.52– 0.96	0.027
Hematologic	1.24	0.92– 1.67	0.152	1.36	0.93– 2.01	0.117	1.26	0.90– 1.77	0.184
Neurologic	1.11	0.88– 1.41	0.373	0.64	0.45– 0.91	0.014	1.09	0.81– 1.48	0.571
Pulmonary / Pneumonia	1.05	0.84– 1.31	0.662	0.81	0.59– 1.11	0.187	0.85	0.66– 1.11	0.240
Season of Discharge									
Winter	1.00	(ref)		1.00	(ref)		1.00	(ref)	
Spring	1.01	0.84– 1.22	0.913	1.33	1.00– 1.78	0.054	0.97	0.75– 1.25	0.787
Summer	0.99	0.81– 1.20	0.889	1.23	0.91– 1.66	0.185	1.12	0.87– 1.44	0.372
Fall	1.06	0.87– 1.28	0.583	1.12	0.82– 1.52	0.476	1.11	0.86– 1.44	0.405
<p>OR = Odds Ratio, CI = Confidence Interval, SOFA = Sequential Organ Function Assessment, ICU = Intensive Care Unit, HAU = High Acuity Unit, NE = Not estimable, MSK = Musculoskeletal, GI = Gastrointestinal</p> <p>Data are presented as mean (SD) or median (IQR) for continuous measures, and n (%) for categorical measures.</p> <p>^a Significance tests were analysis of variance, Pearson's Chi squared, and Kruskal-Wallis when appropriate.</p> <p>^b Results presented as median and interquartile range.</p> <p>^c Not estimable due to lack of events.</p>									

72-Hour Readmission

In the crude analysis, there was no association between discharge occupancy and 72-hour readmission to the ICU (OR 1.00, 95% CI 0.89–1.11, p-value = 0.969, per 10% increase). After adjustment, the lack of association between increasing discharge occupancy and the odds 72-hour readmission persisted (Table 2). An adjusted restricted cubic spline model for the association between discharge occupancy and 72-hour readmission is presented in Fig. 1. In the adjusted model, afterhours discharges from the ICU were not associated with any statistically significant difference in the odds of 72-hour readmission (aOR 1.15, 95% CI 0.86–1.54, p-value 0.341) (Table 2). The remaining results of the adjusted logistic regression model for 72-hour readmission are presented in Table 2.

30-Day Mortality

In the crude analysis, discharge occupancy was not associated with 30-day mortality (OR 1.04, 95% CI 0.96–1.14, p-value = 0.323, per 10% increase). In the adjusted model, the lack of association between discharge occupancy and 30-day mortality persisted (Table 2). An adjusted restricted cubic spline model for the association between discharge occupancy and 30-day mortality is presented in Fig. 2. In the adjusted model, afterhours discharge was not associated with any statistically significant difference in the odds of 30-day mortality (aOR 1.05, 95% CI 0.82–1.36, p-value 0.691) (Table 2). 72-hour readmission to the ICU was associated with a statistically significant increase in the odds of 30-day mortality (aOR 1.51, 95% CI 1.07–2.14, p-value 0.018) (Table 2). The remaining results of the adjusted logistic regression model for 30-day mortality are presented in Table 2.

Sensitivity Analyses

Altering the definition of afterhours discharge to any discharge between 19:00–6:59 (vs. 22:00–6:59) did not alter the study findings. Additionally, a subgroup analysis of patients with discharge SOFA scores available (ICU length of day 7 days or less) did not result in any deviations from study findings. Weekend discharge was not found to modify the effect between discharge occupancy, afterhours discharge and clinical outcomes (72-hour readmission & 30-day mortality). Further, afterhours discharge itself did not modify the effect of discharge occupancy on 72-hour readmission and 30-day mortality. Results were also modeled without the number of admissions in the prior 24 hours to check for multicollinearity between this variable and discharge occupancy.

Discussion

In our single-center historical study of 8,862 ICU discharges over a seven-year period, ICU occupancy on the day of discharge was associated with increased odds of afterhours discharge. Yet, neither discharge occupancy, nor afterhours discharge were associated with clinical outcomes such as 72-hour readmission and 30-day post-discharge mortality.

This study presents a novel analysis of the association between ICU discharge occupancy and the odds of afterhours discharge. Previous studies have focused solely on either afterhours discharge(4–6,9–

11,22,25) or discharge occupancy(6,26) separately when assessing their independent effects on patient outcomes. We specifically wanted to evaluate if greater strain, such as higher occupancy on the day of discharge, would modify the discharge process by pushing clinicians to discharge patients from the ICU at night. It is known that afterhours or night-time discharges are strongly avoided due to the strong association with increased readmission and mortality risk in previous studies (4,5,8–11). Our results demonstrate that higher discharge occupancy is associated with increased odds of afterhours discharge, but not in a linear fashion. Instead, there appears to be a steady climb in the odds of afterhours discharge as occupancy approaches near capacity (100%) which then plateaus once occupancy is over capacity (> 100%). This mirrors results from a large Scottish analysis that found that when ICU occupancy was > 80% there was a notable increase in early discharges from the ICU which plateaued once overcapacity (27). Furthermore, we included the number of ICU admissions in the 24 hours prior to discharge as an additional measure of capacity strain. We observed that for each additional admission to the ICU in the preceding 24 hours there was a statistically significant increase in the odds of afterhours discharge. These are important findings as it demonstrates that capacity strain, as indicated by both high discharge occupancy and the number of admissions in the 24 hours prior to discharge, can impact the timing, and more broadly, the process of discharge.

Our next objective was to assess whether high occupancy at discharge was associated with clinical outcomes such as 72-hour readmission and 30-day mortality. Few studies have evaluated the effects of high occupancy at discharge and subsequent clinical outcomes. One study using aggregate data from 155 ICUs in the US between 2001–2008 determined that a higher census on the day of discharge was associated with ICU readmissions but not subsequent mortality (6). Although a signal for increased readmissions was present, the authors stressed that the lack of mortality signal may indicate that clinicians are safely discharging ICU patients even in periods of increased strain. One drawback of this analysis is that occupancy was the census on the day of discharge standardized to the average annual census from the respective center. Although grossly indicative of capacity strain, total daily census is a less desirable measure of occupancy as it is summation of total patients rather than the quantity of patient care hours provided (18,19). For instance, if five patients are discharged from the ICU in the morning, all five of those patients are included in the daily census despite them not being present in the ICU. A more precise and accurate method of calculating occupancy, and the method used in this analysis, is to calculate the fraction total hours of patient care delivered in a day by the total funded hours available (19). A single center analysis of 8,693 discharges from between 1989 and 1996 demonstrated that lack of ICU bed vacancy at the time of discharge was associated with a statistically significant 56% increase in the odds of early death and readmission (26). However, lack of bed vacancy is a cruder, binary metric of occupancy that may be more reflective of the normality rather than increased strain in modern, large ICUs. As well, ICUs may ‘hold’ patients that are ready for discharge when there are no incoming patients. In this circumstance, lack of an available bed may not necessarily reflect increased capacity strain. In our adjusted analysis controlling for baseline covariates demonstrated that discharge occupancy was not associated with 72-hour readmission or 30-day mortality. It was originally hypothesized that higher occupancy at discharge may lead to increased pressure on the ICU team to

prematurely discharge, resulting in increased rates of 72-hour readmission and 30-day mortality. However, our findings do not suggest this. Although high occupancy may impact discharge decisions, such as discharging during afterhours, it did not impact clinical outcomes at our center.

Our final objective was to determine if afterhours discharge at our center was associated with 72-hour readmission and 30-day mortality. Afterhours discharge has been previously shown to increase the risk of readmission and subsequent mortality (4,5,8–11). A recent meta-analysis pooling data from 1,191,178 patients across 18 cohort studies demonstrated that afterhours discharges were associated with a statistically significant 42% increase in the odds of mortality (odds ratio (OR) 1.42, 95% confidence intervals (CI) 1.32–1.53 p-value < 0.0001) (4). Additionally, afterhours discharge was associated with a greater rate of readmission (6.3% vs. 5.1%, p-value < 0.0001). Interestingly, in our adjusted models we did not observe any effect of afterhours discharge itself on 72-hour readmission or 30-day mortality. This aligns with our findings that occupancy at discharge was not associated with subsequent clinical outcomes.

A variety of center-specific variables may explain why increased capacity strain did not result in clinical consequences. Similar to many larger ICUs in Canada, our ICU operates routinely near capacity and often, over-capacity. Our total beds available are not fixed and patients can be admitted to the ICU service despite not physically being present in an ICU bed, leading to occupancy values above 100%. In response to this increasing burden, our center introduced a Critical Care Outreach Team in 2008 that re-assesses all patients discharged from the ICU within 12 hours. Moreover, our center possesses a 12-bed High Acuity Unit (HAU) that can admit patients from the ICU, functioning as a step-down unit for patients who may not be ready for the hospital wards. A recent analysis demonstrated that implementation of a rapid response team, similar to our Critical Care Outreach Team, had marked benefits with respect to ICU workflow by reducing ICU admissions and occupancy (28). Perhaps, the combination of our flexible ICU capacity, Critical Care Outreach Team, and HAU services provides the structural support to mitigate the clinical consequences of capacity strain. It is well known and understandable that ICU physicians and staff experience increased stress during periods of increased capacity strain (29–31). Our study does validate that capacity strain, such as high occupancy, modifies the discharge process by increasing the amount of afterhours discharges. Yet, we demonstrate that despite increased capacity strain, clinicians at our center appear to be efficiently and safely discharging patients from the ICU.

Limitations of our analysis should be noted. Our study is a single center analysis of a large quaternary ICU center and our results may not be generalizable to other centers. Although we incorporated a more accurate and precise metric of determining occupancy on the day of discharge, this value is still ultimately aggregated over a calendar day and does not represent the instantaneous burden of occupancy at the exact time of discharge. An additional limitation of our analysis is the inability to determine whether a patient was discharged from the ICU with a 'do not readmit' status. This may occur if a patient is palliative and the level of care has been modified. In times of increased strain these patients may be discharged from the ICU but are ineligible to be readmitted to the ICU and may artificially increase post discharge mortality. Yet, these patients likely represent a very small fraction of our overall

population. Lastly, our study is historical and observational in nature and although we have attempted to adjust for important baseline covariates there is certainly unmeasured and residual confounding that could provide an alternate explanation to our findings.

Conclusion

In summary, we demonstrated that greater ICU occupancy on the day of discharge was associated with a significant increase in afterhours discharges. However, neither discharge occupancy nor afterhours discharge were associated with an increase in 72-hour readmission or 30-day mortality at our large quaternary center.

List Of Abbreviations

CI; Confidence Interval

HAU; High Acuity Unit

ICU; intensive care unit

SOFA; Sequential Organ Function Assessment

STROBE; Strengthening the Reporting of Observational Epidemiology

OR; Odds ratio

Declarations

Ethics approval and consent to participate

This project was approved by the University of British Columbia Clinical Research Ethics Board (Reference number H17-03588).

Consent for publication

Not applicable.

Availability of data and materials

The data to support this study were provided by the BC Critical Care Database and Vancouver Coastal Health. Data are available from the authors upon reasonable request and with permission of Vancouver Coastal Health.

Competing interests

The authors declare that they have no competing interests.

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Author's Contribution

NAF & DEG conceived and designed the overarching framework for the project. NAF performed data retrieval, cleaning, & statistical analyses with the assistance and guidance of SA & DEG. MSS, VKD, NA, DRC, ARM provided guidance & logistical feedback. All authors contributed to and critically reviewed the final version of this manuscript.

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Figures

Figure 1

Adjusted a restricted cubic splines for ICU occupancy at discharge versus odds of afterhours discharge & 72-hour readmission. a Restricted cubic spline models are adjusted for age, female sex, SOFA score at admission, afterhours discharges, weekend discharges, delayed discharge, no. of ICU admissions in 24h prior to discharge, primary diagnosis, source of discharge, season, no. of funded ICU beds, and post-HAU creation.

Figure 2

Adjusted a restricted cubic splines for ICU occupancy at discharge versus odds of afterhours discharge & 7- day mortality. a Restricted cubic spline models are adjusted age, female sex, SOFA score at admission, afterhours discharges, weekend discharges, delayed discharge, no. of ICU admissions in 24h prior to discharge, primary diagnosis, source of discharge, season, no. of funded ICU beds, and post-HAU creation.