Morning Discharges and Patient Length of Stay in Inpatient General Internal Medicine

Abirami Kirubarajan, MD, MSc[1,2], Saeha Shin, MPH[3], Michael Fralick, MD, PhD[4,5], Janice Kwan, MD, MPH[4,5], Lauren Lapointe-Shaw, MD, PhD[4,6,7], Jessica Liu, MD, MSc[4,5,6], Terence Tang, MD, FRCPC[4,8], Adina Weinerman, MD, MSc[4,9], Fahad Razak, MD, MSc[2,3,4**], Amol Verma, MD, MPhil[2,3,4*,**]

[1]*Faculty of Medicine, University of Toronto, Toronto, Ontario, Canada;* [2]*Institute of Health Policy, Management and Evaluation, University of Toronto, Toronto, Ontario, Canada;* [3]*Li Ka Shing Knowledge Institute, St Michael's Hospital, Toronto, Ontario, Canada;* [4]*Department of Medicine, University of Toronto, Toronto, Ontario, Canada;* [5]*Department of Medicine, Mount Sinai Hospital, Toronto, Ontario, Canada;* [6]*Division of General Internal Medicine, University Health Network, Toronto, Canada;* [7]*Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada;* [8]*Institute for Better Health, Trillium Health Partners, Toronto, Ontario, Canada;* [9]*Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada.*

BACKGROUND: Many initiatives seek to increase the number of morning hospital discharges to improve patient flow, but little evidence supports this practice.

OBJECTIVE: To determine the association between the number of morning discharges and emergency department (ED) length of stay (LOS) and hospital LOS in general internal medicine (GIM).

DESIGN, SETTING, AND PARTICIPANTS: Multicenter retrospective cohort study involving all GIM patients discharged between April 1, 2010, and October 31, 2017, at seven hospitals in Ontario, Canada.

MAIN MEASURES: The primary outcomes were ED LOS and hospital LOS, and secondary outcomes were 30-day readmission and in-hospital mortality. The number of morning GIM discharges (defined as the number of patients discharged alive between 8:00 AM and 12:00 PM) on the day of each hospital admission was the primary exposure. Multivariable regression models were fit to control for patient characteristics and situational factors, including GIM census.

RESULTS: The sample included 189,781 patient admissions. In total, 36,043 (19.0%) discharges occurred between 8:00 AM and 12:00 PM. The average daily number of morning discharges and total discharges per hospital was 1.7 (SD, 1.4) and 8.4 (SD, 4.6), respectively. The median ED LOS was 14.5 hours (interquartile range [IQR], 10.0- 23.1), and the median hospital LOS was 4.6 days (IQR, 2.4-9.0). After multivariable adjustment, there was not a significant association between morning discharge and hospital LOS (adjusted rate ratio [aRR], 1.000; 95% CI, 0.996-1.000; *P* = .997), ED LOS (aRR, 0.999; 95% CI, 0.997-1.000; *P* = .307), 30-day readmission (aRR, 1.010; 95% CI, 0.991-1.020; *P* = .471), or in-hospital mortality (aRR, 0.967; 95% CI, 0.920-1.020; *P* = .183). The lack of association between morning discharge and LOS was generally consistent across all seven hospitals. At one hospital, morning discharge was associated with a 1.9% shorter ED LOS after multivariable adjustment (aRR, 0.981; 95% CI, 0.966-0.996; *P* = .013).

CONCLUSIONS: The number of morning discharges was not significantly associated with shorter ED LOS or hospital LOS in GIM. Our findings suggest that increasing the number of morning discharges alone is unlikely to substantially improve patient throughput in GIM, but further research is needed to determine the effectiveness of specific interventions. *Journal of Hospital Medicine* 2021;16:333-338. © 2021 Society of Hospital Medicine

There is substantial interest in improving patient flow and reducing hospital length of stay (LOS).[1-4] Impaired hospital flow may negatively impact both patient satisfaction and safety through, for example, emergency department (ED) overcrowding.[5,6] Impaired hospital flow is associated with downstream effects on patient care, hospital costs, and availability of beds.[7-9]

***Corresponding Author:** Amol Verma, MD, MPhil; Email: amol.verma@mail.utoronto.ca; Telephone: 416-864-5431; Twitter: @AmolAVerma

****Drs Razak and Verma are co–senior authors.

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A number of quality-improvement interventions aim to improve patient flow, including efforts to increase the number of discharges that occur before noon.[10,11] Morning discharges have been hypothesized to free hospital beds earlier, thus reducing ED wait times for incoming patients and increasing beds for elective surgeries.[11] Morning discharges may also be more predictable for staff and patients. However, it is unclear whether efforts to increase the number of morning discharges have a negative impact on inpatient LOS by incentivizing physicians to keep patients in the hospital for an extra night to facilitate discharge in the early morning rather than the late afternoon. Morning discharges have been associated with both increased[12] and decreased LOS.[10,11,13-15]

The purpose of this study was to examine the associations between morning discharges and ED LOS and hospital LOS in general internal medicine (GIM) at seven hospitals. GIM patients represent nearly 40% of ED admissions to a hospital,[16] and thus are an important determinant of patient flow through the ED and hospital. We hypothesized that patients who were admitted to GIM on days with more morning discharges would have shorter ED LOS and hospital LOS.

METHODS

Design, Setting, and Participants

This was a retrospective cohort study conducted using the General Medicine Inpatient Initiative (GEMINI) clinical dataset.[16] The dataset includes all GIM admissions at seven large hospital sites in Toronto and Mississauga, Ontario, Canada. These include five academic hospitals and two community-based teaching hospitals. Each hospital is publicly funded and provides tertiary and/or quaternary care to diverse multiethnic populations. Research ethics board approval was obtained from all participating sites.

GIM care is delivered by several interdisciplinary clinical teams functioning in parallel. Attending physicians are predominantly internists who practice as hospitalists in discrete service blocks, typically lasting 2 weeks at a time. Although GIM patients are preferentially admitted to GIM wards, participating hospitals did not have strict policies regarding cohorting GIM patients to specific wards (ie, holding patients in ED until a specific bed becomes available) that would confound the association between morning discharge and ED wait times. Approximately 75% of GIM patients are cared for on dedicated GIM wards at participating hospitals, with the remainder cared for on other medical or surgical wards.

We included all hospitalized patients who were admitted to hospital and discharged from GIM between April 1, 2010, and October 31, 2017, from the seven GEMINI hospitals. We included only patients admitted through the ED. As such, we did not include elective admissions or interfacility transfers who would not experience ED wait times. We excluded patients who were discharged without a provincial health insurance number (N = 2,169; 1.1% of total sample) because they could not be linked across visits to measure readmissions.

Data Source

The GEMINI dataset has been rigorously validated and previously described in detail.[16] GEMINI collects both administrative health data reported to the Canadian Institute for Health Information (including data about patient demographics, comorbidities, and discharge destination) as well as electronic clinical data extracted from hospital computer systems (including attending physicians, in-hospital patient room transfers, and laboratory test results). Data are collected for each individual hospital encounter, and the provincial health insurance number is used to link patients across encounters.

Exposures and Outcomes

The primary exposure was the number of GIM patients discharged alive between 8:00 AM and 12:00 PM (ie, morning GIM discharges) on the day of admission for each hospital encounter. This time window to define morning discharges was selected based on previous literature.[10-13] To report admission characteristics and unadjusted outcomes, hospital days were categorized into quartiles within each hospital based on the number of morning GIM discharges. Hospital days with the lowest number of morning discharges were classified into Q1 and the highest number of morning discharges into Q4, and quartiles were pooled across hospitals.

The two primary outcomes were ED LOS and hospital LOS. ED LOS was calculated as the difference between the time from triage by nursing staff to a patient's exit from the ED, measured in hours. We also examined 30-day readmission to GIM at any participating hospital as a balancing measure against premature discharges and inpatient mortality because it could modify hospital LOS.

Patient Characteristics

Baseline patient characteristics were measured, including age, sex, Charlson Comorbidity Index score,[17] day of admission (categorized as weekend/holiday or weekday), time of admission to hospital (categorized as daytime, 8:00 AM to 4:59 PM, or nighttime, 5:00 PM to 07:59 AM), study month, hospital site, and whether patients had been admitted to GIM in the prior 30 days. We used laboratory data to calculate the baseline Laboratory-based Acute Physiology Score (LAPS), which is a validated predictor of inpatient mortality when combined with age and Charlson Comorbidity Index score.[18,19] GIM census on day of admission was calculated in order to include overall patient volumes as an important adjustment variable that could confound the association between morning discharges and patient flow.

Statistical Analysis

The study population and physician characteristics were summarized with descriptive statistics. The balance of baseline patient characteristics across morning discharge quartiles was assessed using standardized differences. A standardized difference of less than 0.1 reflects good balance.[20]

Unadjusted estimates of patient outcomes were reported across morning discharge quartiles. To model the overall association between morning discharge and outcomes, the number of morning GIM discharges on the day of admission was subtracted from the mean number of morning discharges at each hospital and considered as a continuous exposure. We used generalized linear mixed models to estimate the effect of morning discharges on patient outcomes. We fit negative binomial regression models with log link to examine the association between the number of morning discharges (centered by subtracting the hospital mean) and the two main outcomes, ED LOS and hospital LOS. Given the overdispersion of the study population due to the unequal mean and variance, a negative binomial model was preferred over a Poisson regression, as the mean and variance were not equal.[21] For our secondary outcomes of binary measures (30-day readmission and morality), we fit logistic regression models. Adjustment for multiple comparisons was not performed.

Multivariable analysis was conducted to adjust for the baseline characteristics described above as well as the total number of

TABLE 1. **Admission Characteristics**

		Quartiles[a]				
Variable	**Total cohort**	**Q1 (lowest)**	**Q2**	**Q3**	**Q4 (highest)**	**SMD[b]**
No. of admissions	189,781	42,623	47,555	48,656	50,947	N/A
No. of unique patients[c]	115,630	35,162	38,958	39,452	41,250	N/A
No. of morning discharges per day, mean (SD)	1.74 (1.35)	0.29 (0.46)	1.09 (0.48)	1.94 (0.50)	3.33 (1.19)	3.376
Age, median (IQR), y	73 (57-84)	74 (57-84)	73 (56-84)	73 (57-84)	72 (56-84)	0.034
No. (%) of women	95,482 (50.3)	21,563 (50.6)	23,955 (50.4)	24,455 (50.3)	25,509 (50.1)	0.010
Charlson Comorbidity Index 2+, No. (%)	83,085 (43.8)	18,670 (43.8)	20,751 (43.6)	21,429 (44.0)	22,235 (43.6)	0.029
Day of admission: weekday, No. (%)	140,554 (74.1)	22,968 (53.9)	32,824 (69.0)	39,335 (80.8)	45,427 (89.2)	0.849
Time of admission: daytime, No. (%)	42,655 (22.5)	9,667 (22.7)	10,749 (22.6)	10,969 (22.5)	11,270 (22.1)	0.013
Previous hospitalization within 30 days, No. (%)[d]	21,109 (11.1)	4,600 (10.8)	5,341 (11.2)	5,500 (11.3)	5,668 (11.1)	0.016
LAPS, mean (SD)[e]	19.92 (17.04)	20.12 (17.38)	20.13 (17.21)	20.00 (17.03)	19.47 (16.59)	0.038
GIM census, median (IQR)	93 (79-109)	92 (77-109)	94 (79-110)	93 (79-108)	94 (80-110)	0.120

[a] Hospital days were categorized into quartiles within each hospital based on the number of morning discharges on each day. Hospital days with the lowest number of morning discharges were classified into Q1 and those with the highest number of morning discharges into Q4.

[b] Standardized mean difference was calculated using the methodology followed by Austin.[19] We computed all possible pairwise standardized mean differences and reported the maximum of all standardized differences of four groups in this table.

[c] A patient may have been admitted more than once and on days in different quartiles.

[d] To a GIM ward in a participating hospital.

[e] LAPS is a validated score to predict inpatient mortality, which ranges from 0 to 256 points, with higher scores indicating a higher risk of mortality.

Abbreviations: GIM, general internal medicine; IQR, interquartile range; LAPS, Laboratory-based Acute Physiology Score; N/A, not applicable; SMD, standardized mean difference.

GIM discharges on the day of admission and GIM census on the day of admission. Hospital and study month (to account for secular time trends) were included as fixed effects, and patients and admitting physicians were included as crossed random effects to account for the nested structure of admissions within patients and admissions within physicians within hospitals.

A sensitivity analysis was performed to assess for nonlinear associations between morning discharges and the four outcomes (hospital LOS, ED LOS, in-hospital mortality, and readmission) by inputting the term as a restricted cubic spline, with up to five knots, in multivariable regression models. We compared the Akaike information criteria (AIC), computed using the log-likelihood, to determine the goodness-of-fit from the negative binomial models.[22] We replicated models for each individual hospital to examine whether any hospital-specific associations existed. Two additional sensitivity analyses were performed to examine heterogeneity in hospital-specific effects. Regression models were fit, including interaction terms between morning discharge and hospital, as well as interaction terms between hospital and the total number of GIM discharges and GIM census. The findings of these models (data not presented) were qualitatively similar to the overall results.

RESULTS

Study Population and Patient Characteristics

The study population consisted of 189,781 hospitalizations involving 115,630 unique patients. The median patient age was 73 years (interquartile range [IQR], 57-84), 50.3% were female, 43.8% had a high Charlson Comorbidity Index score, and 11.1% were admitted to GIM in the prior 30 days (Table 1). The median ED LOS was 14.5 hours (IQR, 10.0-23.1), and the mean was 18.1 hours (SD, 12.2). The median hospital LOS was 4.6 days (IQR, 2.4-9.0), and the mean was 8.6 days (SD, 18.7).

In total, 36,043 (19.0%) discharges occurred between 8:00 AM and 12:00 PM. The average number of total daily discharges per hospital was 8.4 (SD, 4.6), and the average number of morning discharges was 1.7 (SD, 1.4). Morning discharges varied across hospitals, ranging from 0.9 per day (SD, 1.1) to 2.1 (SD, 1.6) (Appendix Table 1). The average number of morning discharges in the lowest quartile (Q1) was 0.3 (SD, 0.5) and was 3.3 (SD, 1.2) in the highest quartile (Q4). Baseline patient characteristics were well balanced across the quartiles, with standardized differences less than 0.1 (Table 1), except day of admission and GIM census. Days with a greater number of morning discharges were more likely to be weekdays rather than weekends/holidays (89.2% weekday admissions in Q4 compared with 53.9% in Q1). The median GIM census was 93 patients (IQR, 79-109).

Outcomes

Unadjusted clinical outcomes by number of morning discharges are presented in Table 2. The median unadjusted ED LOS was 14.4 (SD, 14.1), 14.3 (SD, 13.2), 14.5 (SD, 13.0), and 14.8 (SD, 13.0) hours for the first to fourth quartiles (fewest to largest number of morning discharges), respectively. The median unadjusted hospital LOS was 4.6 (SD, 6.5), 4.6 (SD, 6.9), 4.7 (SD, 6.4), and 4.6 (SD, 6.4) days for the first to fourth quartiles, respectively.

TABLE 2. **Description of Unadjusted Clinical Outcomes by Number of Morning Discharges**

		No. of morning discharges on the day of admission			
		Quartiles[a]			
Variable	**Total cohort**	**Q1**	**Q2**	**Q3**	**Q4**
No. of admissions	189,781	42,623	47,555	48,656	50,947
No. of unique patients[b]	115,630	35,162	38,958	39,452	41,250
Hospital LOS, median (SD), d	4.6 (6.5)	4.6 (6.9)	4.6 (6.5)	4.7 (6.4)	4.6 (6.4)
ED LOS, median (SD), h	18.1 (13.1)	14.4 (14.1)	14.3 (13.2)	14.5 (13.0)	14.8 (13.0)
Readmission within 30 days, No. (%)[c]	22,131 (11.6)	4,843 (11.3)	5,622 (11.8)	5,754 (11.8)	5,912 (11.6)
Inpatient mortality, No. (%)	10,515 (5.5)	2,586 (6.1)	2,597 (5.5)	2,658 (5.5)	2,674 (5.2)

[a] Hospital days were categorized into quartiles within each hospital based on the number of morning discharges on each day. Hospital days with the lowest number of morning discharges were classified into Q1 and those with the highest number of morning discharges into Q4.
[b] A patient may have been admitted more than once and on days in different quartiles.
[c] To a GIM ward in a participating hospital.
Abbreviations: ED, emergency department; GIM, general internal medicine; LOS, length of stay.

Unadjusted inpatient mortality was 6.1%, 5.5%, 5.5%, and 5.2% across the first to fourth quartiles, respectively. Unadjusted 30-day readmission to GIM was 12.2%, 12.6%, 12.6%, and 12.5% across the first to fourth quartiles, respectively.

After multivariable adjustment, there was no significant association between morning discharge and hospital LOS (aRR, 1.000; 95% CI, 0.996-1.000; *P* = .997), ED LOS (aRR, 0.999; 95% CI, 0.997-1.000; *P* = .307), in-hospital mortality (aRR, 0.967; 95% CI, 0.920-1.020; *P* =.183), or 30-day readmission (aRR, 1.010; 95% CI, 0.991-1.020; *P* = .471) (Table 3, Appendix Table 2, Appendix Table 3, Appendix Table 4, Appendix Table 5). When examining each hospital separately, we found that morning discharge was significantly associated with hospital LOS at only one hospital (Hospital D; aRR, 0.981; 95% CI, 0.966-0.996; *P* = .013). Morning discharge was statistically significantly associated with ED LOS at three hospitals (A, B, and C), but the aRR was at least 0.99 in all three cases (Table 4).

In sensitivity analyses, we found no improvements in model fit when adding spline terms to the model, suggesting no significant nonlinear associations between morning discharges and the outcomes of interest.

DISCUSSION

This large multicenter cohort study found no significant overall association between the number of morning discharges and ED or hospital LOS in GIM. At one hospital, there was a 1.9% reduction in adjusted ED LOS for every additional morning discharge, but no difference in hospital LOS. We also did not observe differences in readmission or inpatient mortality associated with the number of morning discharges. Our observational findings suggest that there is unlikely to be a strong association between morning discharge and patient throughput in GIM. Given that there may be other downstream benefits of morning discharge, such as freeing beds for daytime surgeries,[23] further research is needed to determine the effectiveness of specific interventions.

Several studies have posited morning discharge as a method of improving both patient care and hospital flow metrics.[10,11,13-15,23] Quality improvement initiatives targeting morning discharges have included stakeholder meetings, incentives programs, discharge-centered breakfast programs, and creating deadlines for discharge orders.[24-29] Although these initiatives have gained support, critics have suggested that their supporting evidence is not robust. Werthemier et al[10] found a 9.0% reduction of observed to expected LOS associated with increasing the number of early discharges. However, a response article suggested that their findings were confounded by other hospital initiatives, such as allocation of medical and social services to weekends.[30] Other observational studies have concluded that hospital LOS is not affected by the number of morning discharges, but this research has been limited by single-center analysis and relatively smaller sample sizes.[12] Our study further calls into question the association between morning discharge and patient throughput.

An additional reason for the controversy is that physicians may actively work to discharge patients late in the day to avoid an additional night in hospital. A qualitative study by Minichiello et al[31] evaluated staff perceptions regarding afternoon discharges. Physicians and medical students believed that afternoon discharges were a result of waiting for test results and procedures, with staff aiming to discharge patients immediately after obtaining results or finishing necessary procedures. As such, there are concerns that incentivizing morning discharge may lead physicians in the opposite direction, to consciously or unconsciously keep patients overnight in order to facilitate an early morning discharge.[30]

Our study's greatest strength was the large sample size over 7 years at seven hospitals in two cities, including both academic and community hospitals with different models of care. To our knowledge, this is the first cohort study that has analyzed the association between early discharge and LOS using multiple centers. To avoid the confounding and reverse causality that

TABLE 3. **Association Between Morning Discharges and Clinical Outcomes, Before and After Multivariable Adjustment**

	Unadjusted			Multivariable adjustment[a]		
Outcome	**RR**	**95% CI**	***P* value**	**aRR**	**95% CI**	***P* value**
Hospital LOS	0.990	0.986-0.993	<.001	1.000	0.996-1.000	.997
ED LOS	0.985	0.983-0.987	<.001	0.999	1.000	.307
In-hospital mortality	0.975	0.960-0.990	.001	0.967	0.920-1.020	.183
Readmission	1.000	0.993-1.010	.448	1.010	1.020	.471

[a] The absolute number of morning discharges was modeled as a continuous variable in multivariable negative binomial regression models, adjusting for patient baseline characteristics, the total number of GIM discharges on the day of admission, GIM census on the day of admission, hospital, study month, patient, and admitting physician. Likelihood ratio tests were conducted by comparing fully adjusted multivariate and null (intercept-only) models via analysis of variance (ANOVA) to test the overall significance for a regression model, all of which were statistically significant ($P < .001$).

Abbreviations: aRR, adjusted rate ratio; ED, emergency department; GIM, general internal medicine; LOS, length of stay; RR, relative risk.

TABLE 4. **Hospital-Specific Associations Between Morning Discharges and Clinical Outcomes**

	Hospital LOS			ED LOS		
Hospital[a]	**aRR**	**95% CI**	***P* value**	**aRR**	**95% CI**	***P* value**
A	0.996	0.980-1.010	.598	0.990	0.982-0.997	.006
B	1.000	0.989-1.020	.740	0.990	0.983-0.997	.005
C	1.000	0.990-1.010	.924	0.993	0.987-0.999	.017
D	0.981	0.966-0.996	.013	0.994	0.985-1.000	.238
E	1.000	0.995-1.010	.501	0.995	0.989-1.000	.088
F	0.998	0.990-1.010	.542	0.998	0.993-1.000	.314
G	0.998	0.990-1.010	.644	1.000	0.998-1.010	.369

[a] The absolute number of morning discharges was modeled as a continuous variable in multivariable negative binomial regression models. The results are specific for each of the seven hospitals.

Abbreviations: aRR, adjusted rate ratio; ED, emergency department; LOS, length of stay.

may exist when examining the relationship between LOS and morning discharge at the patient level (eg, patients who stay in hospital longer may have more "planned" discharges and leave in the morning), we examined the association based on variation across different days within the GIM service of each hospital. Further, we included robust risk adjustment using clinical and laboratory data. Finally, since our study included a diverse patient population served by participating centers in a system with universal insurance for hospital care, our findings are likely generalizable to other urban and suburban hospitals.

There are several important limitations of our analysis. First, we could only include GIM patients, who represent nearly 40% of ED admissions to hospital at participating centers. A more holistic analysis across all hospital services could be justified; however, given that many quality improvement initiatives occur at the level of a single hospital service, we felt our approach would be informative for future research and improvement efforts. Approximately 75% of GIM patients at participating hospitals were cared for on a GIM ward, with 25% cared for on off-service units. We were unable to include the total hospital census in our models, and this could affect LOS and waiting times for GIM patients, particularly those admitted to off-service units. GIM census is likely highly correlated with hospital census, and we were able to adjust for this. Nevertheless, this remains an important potential source of unmeasured confounding. Second, we did not model the effects of morning discharges from GIM on patient-flow measures for non-GIM patients. Given the lack of effects for GIM patients, who would be more likely to be directly affected, it is unlikely that large effects would be seen for other hospital patients, but we did not measure effects on surgical delays or cancellations, for example.[23] Third, we report 30-day readmission to GIM at participating hospitals only, rather than all readmissions. However, prior research in our region demonstrated that 82% of hospital readmissions occur to the same site.[32] Thus, our measure, which includes admission to any participating hospital, likely captures more than 80% of all readmissions, and this was a secondary outcome in our analysis. Finally, qualitative metrics, such as patient or provider satisfaction, were not measured in our study. Earlier discharge may impact patient care in other ways by being more predictable for staff, improving bed allocation for daytime procedures, making medication pick-ups easier to arrange, or making consultations with allied health services more convenient.[11,28,33] Conversely, if pressured to discharge before noon, providers may feel rushed to complete tasks and may face disruptions to typical workflow.[24] As such, future research is needed to provide a more complete understanding of the impact of early-morning discharge beyond hospital flow. Given the lack of a strong association observed between morning discharge and patient throughput in our study, further research should also consider the opportunity costs of interventions designed to improve morning discharge.

CONCLUSION

The number of morning discharges was not significantly associated with shorter ED LOS or hospital LOS for GIM patients. Our observational findings suggest that increasing morning discharges alone may not substantially improve patient flow in GIM. Further research is needed to evaluate specific morning discharge interventions and assess hospital-wide effects.

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References

1. Trzeciak S, Rivers EP. Emergency department overcrowding in the United States: an emerging threat to patient safety and public health. *Emerg Med J.* 2003;20(5):402-405. https://doi.org/10.1136/emj.20.5.402
2. McKenna P, Heslin SM, Viccellio P, Mallon WK, Hernandez C, Morley EJ. Emergency department and hospital crowding: causes, consequences, and cures. *Clin Exp Emerg Med.* 2019;6(3):189-195. https://doi.org/10.15441/ceem.18.022
3. Bernstein SL, Aronsky D, Duseja R, et al. The effect of emergency department crowding on clinically oriented outcomes. *Acad Emerg Med.* 2009;16(1):1-10. https://doi.org/10.1111/j.1553-2712.2008.00295.x
4. Derlet RW, Richards JR. Overcrowding in the nation's emergency departments: complex causes and disturbing effects. *Ann Emerg Med.* 2000;35(1):63-68. https://doi.org/10.1016/s0196-0644(00)70105-3
5. Pines JM, Iyer S, Disbot M, Hollander JE, Shofer FS, Datner EM. The effect of emergency department crowding on patient satisfaction for admitted patients. *Acad Emerg Med.* 2008;15(9):825-831. https://doi.org/10.1111/j.1553-2712.2008.00200.x
6. Carter EJ, Pouch SM, Larson EL. The relationship between emergency department crowding and patient outcomes: a systematic review. *J Nurs Scholarsh.* 2014;46(2):106-115. https://doi.org/10.1111/jnu.1205
7. Bueno H, Ross JS, Wang Y, et al. Trends in length of stay and short-term outcomes among Medicare patients hospitalized for heart failure, 1993-2006. *JAMA.* 2010;303(21):2141-2147. https://doi.org/10.1001/jama.2010.748
8. Rotter T, Kinsman L, James E, et al. Clinical pathways: effects on professional practice, patient outcomes, length of stay and hospital costs. *Cochrane Database Syst Rev.* 2010;(3):Cd006632. https://doi.org/ 10.1002/14651858.CD006632.pub2
9. Zodda D, Underwood J. Improving emergency department throughput: evidence-based strategies aimed at reducing boarding and overcrowding. *Phys Leadership J.* 2019;6(3):70-73.
10. Wertheimer B, Jacobs REA, Bailey M, et al. Discharge before noon: an achievable hospital goal. *J Hosp Med.* 2014;9(4):210-214. https://doi.org/10.1002/jhm.2154
11. Kane M, Weinacker A, Arthofer R, et al. A multidisciplinary initiative to increase inpatient discharges before noon. *J Nurs Adm.* 2016;46(12):630-635. https://doi.org/10.1097/NNA.0000000000000418
12. Rajkomar A, Valencia V, Novelero M, Mourad M, Auerbach A. The association between discharge before noon and length of stay in medical and surgical patients. *J Hosp Med.* 2016;11(12):859-861. https://doi.org/10.1002/jhm.2529
13. Patel H, Morduchowicz S, Mourad M. Using a systematic framework of interventions to improve early discharges. *Jt Comm J Qual Patient Saf.* 2017;43(4):189-196. https://doi.org/10.1016/j.jcjq.2016.12.003
14. El-Eid GR, Kaddoum R, Tamim H, Hitti EA. Improving hospital discharge time: a successful implementation of Six Sigma methodology. *Medicine (Baltimore).* 2015;94(12):e633. https://doi.org/10.1097/MD.0000000000000633
15. Mathews KS, Corso P, Bacon S, Jenq GY. Using the red/yellow/green discharge tool to improve the timeliness of hospital discharges. *Jt Comm J Qual Patient Saf.* 2014;40(6):243-252. https://doi.org/10.1016/s1553-7250(14)40033-3
16. Verma AA, Pasricha SV, Jung HY, et al. Assessing the quality of clinical and administrative data extracted from hospitals: the General Medicine Inpatient Initiative (GEMINI) experience. *J Am Med Inform Assoc.* 2021; 28(3):578-587. doi: 10.1093/jamia/ocaa225.
17. Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *Am J Epidemiol.* 2011;173(60:676-682. https://doi.org/10.1093/aje/kwq433
18. Escobar GJ, Greene JD, Scheirer P, Gardner MN, Draper D, Kipnis P. Risk-adjusting hospital inpatient mortality using automated inpatient, outpatient, and laboratory databases. *Med Care.* 2008;46(3):232-239. https://doi.org/10.1097/MLR.0b013e3181589bb6
19. Austin PC. Using the standardized difference to compare the prevalence of a binary variable between two groups in observational research. *Commun Stat Simul Comput.* 2009;38(60:1228-1234. https://doi.org/10.1080/03610910902859574
20. van Walraven C, Escobar GJ, Greene JD, Forster AJ. The Kaiser Permanente inpatient risk adjustment methodology was valid in an external patient population. J Clin Epidemiol. 2010;63(7):798-803. https://doi.org/10.1016/j.jclinepi.2009.08.020
21. Hilbe JM. Negative binomial regression. In: *Modeling Count Data.* Cambridge University Press. 2014:126-160.
22. Harrell FE Jr. *Regression Modeling Strategies: With Applications to Linear Models, Logistic and Ordinal Regression, and Survival Analysis.* 2nd ed. Springer; 2015.
23. Durvasula R, Kayihan A, Del Bene S, et al. A multidisciplinary care pathway significantly increases the number of early morning discharges in a large academic medical center. *Qual Manag Health Care.* 2015;24(1):45-51. https://doi.org/10.1097/QMH.0000000000000049
24. Goolsarran N, Olowo G, Ling Y, Abbasi S, Taub E, Teressa G. Outcomes of a resident-led early hospital discharge intervention. *J Gen Intern Med.* 2020;35(2):437-443. https://doi.org/10.1007/s11606-019-05563-w
25. Beck MJ, Okerblom D, Kumar A, Bandyopadhyay S, Scalzi LV. Lean intervention improves patient discharge times, improves emergency department throughput and reduces congestion. *Hosp Pract (1995).* 2016;44(5):252-259. https://doi.org/10.1080/21548331.2016.1254559
26. Karling A, Tang KW. Discharge before noon: a study in a medical emergency ward. 2015. Accessed February 11, 2021. http://publications.lib.chalmers.se/records/fulltext/231873/231873.pdf
27. Mathews K, Corso P, Bacon S, Jenq GY. Using the red/yellow/green discharge tool to improve the timeliness of hospital discharges. *Jt Comm J Qual Patient Saf.* 2014;40(6):243-252. https://doi.org/10.1016/s1553-7250(14)40033-3
28. Goodson AS, DeGuzman, PB, Honeycutt A, Summy C, Manly F. Total joint replacement discharge brunch: meeting patient education needs and a hospital initiative of discharge by noon. *Orthop Nurs.* 2014;33(3):159-162. https://doi.org/10.1097/NOR.0000000000000048
29. Kravet SJ, Levine RB, Rubin HR, Wright SM. Discharging patients earlier in the day: a concept worth evaluating. *Health Care Manag (Frederick).* 2007;26(2):142-146. https://doi.org/10.1097/01.HCM.0000268617.33491.60
30. Shine D. Discharge before noon: an urban legend. *Am J Med.* 2015;128(5):445-446. https://doi.org/10.1016/j.amjmed.2014.12.011
31. Minichiello TM, Auerbach AD, Wachter RM. Caregiver perceptions of the reasons for delayed hospital discharge. *Eff Clin Pract.* 2001;4(6):250-255.
32. Staples JA, Thiruchelvam D, Redelmeier DA. Site of hospital readmission and mortality: a population-based retrospective cohort study. *CMAJ Open.* 2014;2:E77-E85. https://doi.org/10.9778/cmajo.20130053
33. Bowles KH, Foust JB, Naylor MD. Hospital discharge referral decision making: a multidisciplinary perspective. *Appl Nurs Res.* 2003;16(3):134-143. https://doi.org/10.1016/s0897-1897(03)00048-x