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THE RELATIONSHIP BETWEEN INPATIENT DISCHARGE TIMING AND EMERGENCY DEPARTMENT BOARDING

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☐ **Abstract—Background: Patient crowding and boarding in Emergency Departments (EDs) impair the quality of care as well as patient safety and satisfaction. Improved timing of inpatient discharges could positively affect ED boarding, and this hypothesis can be tested with computer modeling. Study Objective: Modeling enables analysis of the impact of inpatient discharge timing on ED boarding. Three policies were tested: a sensitivity analysis on shifting the timing of current discharge practices earlier; discharging 75% of inpatients by 12:00 noon; and discharging all inpatients between 8:00 a.m. and 4:00 p.m. Methods: A cross-sectional computer modeling analysis was conducted of inpatient admissions and discharges on weekdays in September 2007. A model of patient flow streams into and out of inpatient beds with an output of ED admitted patient boarding hours was created to analyze the three policies. Results: A mean of 38.8 ED patients, 22.7 surgical patients, and 19.5 intensive care unit transfers were admitted to inpatient beds, and 81.1 inpatients were discharged daily on September 2007 weekdays: 70.5%, 85.6%, 82.8%, and 88.0%, respectively, occurred between noon and midnight. In the model base case, total daily admitted patient boarding hours were 77.0 per day; the sensitivity analysis showed that shifting the peak inpatient discharge time 4 h earlier eliminated ED boarding, and discharging 75% of inpatients by noon and discharging all inpatients between 8:00 a.m. and 4:00 p.m. both decreased boarding hours to 3.0. Conclusion: Timing of inpatient discharges had an impact on the need to board admitted patients. This model demonstrates the potential to reduce or eliminate ED boarding by improving inpatient discharge timing in anticipation of the daily surge in ED demand for inpatient beds.** © 2012 Elsevier Inc.

☐ **Keywords—boarding; crowding; operations; admitting patients; discharging patients**

INTRODUCTION

Emergency department (ED) crowding has been the subject of significant public and academic attention (1,2). ED boarding and crowding are detrimental to quality of care as well as patient safety and satisfaction goals (3–12). Reducing ED crowding and boarding would likely lead to improved patient satisfaction and potential cost-savings for the ED (13–15).

It has become increasingly apparent that activities outside the ED, such as elective surgical scheduling and

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inpatient bed management, impact ED crowding (16,17). In hospitals that are capacity constrained due to a high inpatient bed occupancy, operations management skills are critical to optimizing patient flow and resource utilization (18). The hospital's limited number of inpatient beds may be occupied by inpatients from several input sources, including the ED (18). When the hospital reaches high levels of occupancy, patients admitted through the ED are often the patients who "board" in the ED, awaiting an inpatient bed to become available (19).

Solutions to minimize boarding and crowding have been proposed, including altering the elective surgical schedule, moving ED boarding admitted patients to inpatient hallways, improving inpatient bed availability, and balancing inpatient discharges and admissions (20–26). Although it is clear that there is a relationship between activities in the inpatient hospital and boarding in the ED, it has not been demonstrated that the timing of inpatient discharges may impact ED boarding of admitted patients.

The goal of this investigation was to evaluate whether or not there is a relationship between the timing of inpatient discharge practices and ED boarding of admitted patients. We utilized two hospital operations datasets to develop a computer model of patient flow into and out of the inpatient hospital to examine the potential impact of three alternative inpatient discharge timing policies on total admitted patient boarding hours. The strategies included: a sensitivity analysis on incrementally shifting current inpatient discharge timing practices (the "discharge distribution curve") earlier in the day, uniformly discharging 75% of inpatients before noon, and discharging all inpatients between 8:00 a.m. and 4:00 p.m.

MATERIALS AND METHODS

Study Design

This was a cross-sectional time analysis of weekday admissions to inpatient beds in the hospital and weekday inpatient discharges during the month of September 2007. A computer model was used to identify relationships between inpatient bed demand from multiple sources and inpatient bed supply. The model then assessed the effects of incrementally shifting the discharge distribution curve to earlier in the day. The model assessed the effects of two proposed alternate inpatient discharge timing policies on ED admitted patient boarding hours secondary to lack of inpatient bed availability. The study received expedited approval from the Northwestern University Institutional Review Board.

Study Setting and Population

The study was conducted in an urban, academic, tertiary care hospital. The hospital has a total of 398 inpatient floor beds and an additional 92 intensive care unit (ICU) beds. The hospital has Level I trauma designation and the ED has an annual volume > 75,000. The ED consists of 23 main room beds, a seven-bed urgent care unit, and a 23-bed observation unit.

Hospital operations data were collected for all days in September 2007. There were a total of 20 weekdays and 10 weekend days (Saturdays and Sundays) in September 2007. This analysis included only weekdays, as there was significant variation in elective surgical scheduling between weekdays and weekend days. Patients were included if they were admitted to an inpatient floor bed via one of the three primary sources of inpatient bed demand: the ED, elective surgery, or transfer out of the ICU. Patients were excluded if they were admitted directly to an ICU bed, to an inpatient floor bed via other means, or if data were not available on time of admission or ED boarding hours (in the case of ED admitted patients). All patients discharged from inpatient floor beds were included if data were available on the time of discharge. A pre-existing hospital bed management and tracking database (Primes System, McKesson Series, 2000 [McKesson, San Francisco, CA] with a system developed internally with Microsoft Excel 2003 [Microsoft Corporation, Redmond, WA]), and a hospital discharge database (Primes System, McKesson Series, 2000) were utilized to collect this information. Data were entered into these two systems through linkage with the hospital's computer order entry system. For example, a patient is time-stamped with a "Discharge Time" in the Primes system once a discharge order is placed. Patient-specific demographic data were not collected for this analysis.

Study Protocol

Data collection. The two hospital operations datasets were merged and cleaned by removal of records with empty or inconsistent values. One dataset included data on inpatient bed demand and the other included data on inpatient bed availability at the start of each day as well as the inpatient beds made available through inpatient discharges. A record was considered inconsistent if the time values were not chronological or if the record contained non-numerical content.

All inpatient bed demand records in the final analysis included four consistent chronological time stamps: "Ready to Move," "Assigned," "Cleaned," and "Occupied." The "Ready to Move" time stamp indicated completion of all emergency care and the time an inpatient bed was requested, "Assigned" indicated the time that an inpatient bed was assigned, "Cleaned" indicated the time that the assigned bed was clean and ready for the admitted patient, and "Occupied" indicated the time that the admitted patient was placed in the room. Each inpatient bed admission was categorized as "ED Admission," "Elective Surgical Admission," or "ICU Transfer Admission." "Ready to Move" was used to determine the time of bed request for ED admissions and elective surgical admissions. For ED admissions, the difference between "Ready to Move" and "Occupied" indicated the time that the patient spent in the ED awaiting inpatient bed placement (ED admitted patient boarding hours). This time period included time for bed assignment, time spent in transport, and also time for the nursing report. "Assigned" was used to estimate the time of bed request and placement for patients transferred out of the ICU to an inpatient floor bed. These patients were already receiving inpatient care in the ICU and therefore did not board, and received beds after the ED and elective surgical admissions.

All inpatient discharge records in the final analysis included the variable "Discharge Time." According to internal hospital operations data, approximately 2 h was required to clean and prepare the room for the next patient; therefore, the bed was made available 2 h after the discharge order was placed. The time at which the inpatient bed was ready for the next patient was reflected in this analysis as the time of inpatient discharge.

Building the model. The inpatient bed demand and inpatient discharge records were used as inputs into a static model to recalculate daily ED admitted patient boarding in the model. We calculated average hourly mean values for the four inpatient flow streams relevant to our model: ED admissions, elective surgical admissions, ICU transfer admissions, and inpatient discharges. A computer spreadsheet model of an average weekday in September 2007 was created from these flow streams to recalculate total daily ED boarding hours secondary to lack of inpatient bed availability (the "Base Case"). A snapshot of the spreadsheet model is presented in Figure 1.

In this model, the capacity of the inpatient hospital was defined as 398 inpatient beds. Inpatients arrived in the model through one of three patient flow streams: ED admission, elective surgical admission, or transfer from the ICU to an inpatient bed. All inpatient beds were made available in the hospital system through inpatient discharges. All patient flow streams were entered into the model as hourly mean values. The total daily inpatient discharge capacity was defined as the mean number of inpatients discharged per day, and the discharge capacity curve was made up of the mean number of inpatients discharged per hour over the course of the day.

Assumptions of the model. The following assumptions were made in the model:

1. The inpatient hospital bed capacity at 8:00 a.m. was 100%.
2. All inpatient beds occupied by new admissions were made available by inpatient discharges.
3. There was no bed specialization (i.e., all units were capable of taking care of any type of admission).
4. Elective surgery patients were preferentially assigned beds over patients admitted through the ED.
5. Patients admitted through the ED and elective surgery had priority over patients currently in the hospital who were transferred from the ICU to an inpatient floor bed.

Calculating admitted patient boarding in the model. In the model, an ED admitted patient boarded for an hour if there were more than 398 inpatient beds required during the hour that he was made "Ready to Move." For example, if there were 396 inpatients occupying the 398 inpatient beds during the 9:00 a.m. hour and an additional 4 ED patients were admitted to the inpatient floor during that hour, 2 ED admitted patients would board. The total admitted patients boarding each hour was then summed over the 24-h day to generate the primary outcome measure: total daily admitted patient boarding hours.

Discharge timing policies: creation and implementation. Based on the initial analysis of the four patient flow streams, a sensitivity analysis and two alternate inpatient discharge timing policies were created.

Sensitivity analysis. The hospital's actual discharge distribution curve remained the same but each hourly discharge capacity was shifted 1, 2, 3, and 4 h earlier to evaluate the sensitivity of admitted patient boarding hours to the discharge distribution curve.

"Discharge by Noon". Seventy-five percent of the inpatients were to be discharged in a day, uniformly between 8:00 a.m. and 12:00 noon, and the remaining 25% uniformly between 12:00 noon and 8:00 p.m. Similar policies have been implemented in several hospitals across the country (22,26,27).

"Dayshift Uniform Discharge". Inpatients were to be discharged uniformly throughout the day between 8:00 a.m. and 4:00 p.m. This policy covers the hours of a typical inpatient physician team workday.

The sensitivity analysis and the two proposed inpatient discharge timing policies were then applied to the model in place of the base case discharge capacity curve. As mentioned in the assumptions, surgical patient boarding was relieved preferentially before ED admitted patient boarding. The mean total daily admitted patient boarding hours were calculated for each policy and compared to

Hour of the Day	ED Admissions	Elective Surgical Admissions	ICU Transfer Admissions	Total Inpatient Admissions	Inpatient Discharges	Inpatient Beds Required	ED Admitted Patients Boarding
1:00	1.6	0.0	0.0	1.6	0.5	393	0.0
2:00	1.5	0.0	0.0	1.5	0.1	394	0.0
3:00	1.3	0.0	0.0	1.3	0.2	395	0.0
4:00	0.9	0.0	0.0	0.9	0.0	395	0.0
5:00	1.3	0.0	0.1	1.4	0.0	397	0.0
6:00	0.4	0.0	0.1	0.5	0.2	397	0.0
7:00	0.7	0.1	0.0	0.8	0.2	398	0.0
8:00	0.7	0.2	0.1	0.9	0.2	399	0.8
9:00	0.7	0.1	0.5	1.2	0.4	400	1.8
10:00	0.7	0.2	0.6	1.4	1.2	401	3.1
11:00	0.9	1.1	0.7	2.6	2.3	403	5.3
12:00	1.1	1.8	1.4	4.3	5.3	406	8.5
13:00	1.2	2.1	1.6	4.9	5.6	409	11.1
14:00	1.7	2.7	1.3	5.6	7.6	409	11.5
15:00	2.4	2.2	2.4	7.0	11.0	411	12.9
16:00	2.1	2.9	1.5	6.4	10.3	410	11.7
17:00	2.2	2.5	1.7	6.4	8.4	405	7.1
18:00	2.5	2.2	1.9	6.6	8.5	401	3.4
19:00	1.8	1.5	1.1	4.4	8.3	397	0.0
20:00	2.5	1.3	1.4	5.2	6.4	394	0.0
21:00	3.8	1.3	1.6	6.7	4.2	393	0.0
22:00	2.9	0.5	1.3	4.7	0.4	391	0.0
23:00	2.4	0.2	0.3	2.9	0.4	390	0.0
0:00	2.0	0.0	0.2	2.2	0.3	391	0.0
Totals	**38.8**	**22.7**	**19.5**	**81.0**	**81.1**		**77.0**

Figure 1. Snapshot of the computer model. The model is a spreadsheet model: columns two through four represent inflow into, and the sixth column represents outflow from the inpatient beds. The seventh column is the number of beds required to accommodate all inpatients during that hour. Any number of inpatients over 398 (inpatient bed capacity) represents admitted patients boarding during that hour, and this is totaled in column eight. The 8:00 a.m. hour is highlighted as starting the hour at 100% capacity. During that hour, a net of 1 patient is admitted to the hospital and therefore the number of beds required during the 8:00 a.m. hour is 399.

base case admitted boarding hours. Boarding calculated in the model reflected ED admitted patient boarding secondary to lack of inpatient bed availability.

Key Outcome Measure

The primary outcome for this study was total daily admitted patient boarding hours.

Data Analysis

We calculated daily mean and median values for the four inpatient flow streams relevant to our model: ED admissions, elective surgical admissions, ICU transfer admissions, and inpatient discharges. In addition, we calculated descriptive statistics for actual ED boarding: mean daily boarding hours, mean and median boarding hours per patient, and mean number of patients boarding per hour. We calculated mean admitted patient boarding hours in the model and after application of each of the discharge timing policies to the model. Boarding that resulted after application of the proposed timing policy included only ED admitted patients because surgical patients were preferentially given inpatient beds over ED admitted patients.

We used Microsoft Excel 2003 to collect and store the data. We used Microsoft Excel 2007 to analyze and model the data.

RESULTS

A total of 5277 patient records for the month of September 2007 were included. There were 501 records excluded for incomplete data, and therefore, 90.5% were available for analysis. The records with incomplete data were evenly distributed over both weekend days and weekdays, as well as over the time of day. There were 1927 weekday inpatient admissions available for analysis and 1622 weekday inpatient discharges. Included in the analysis were: 776 ED admissions, 432 elective surgical admissions, 389 ICU transfers to inpatient beds, and 1622 inpatient discharges (Figure 2).

Operations Dataset Results

Descriptive statistics from the hospital operations datasets are presented in Table 1. The daily demand for inpatient beds in relation to the daily supply of inpatient beds through inpatient discharges is reflected in Figure 3. Mean daily and hourly values are reported as

Figure 2. Inclusion and exclusion. Patient flow streams included in the analysis and the model are in bold. RTM = ready to move; ED = emergency department; ICU = intensive care unit.

primary statistics as they serve as the input into the model.

Patient inflows included ED admissions, elective surgical admissions, and ICU transfer admissions to the inpatient floors. The mean daily ED census during September 2007 was 234 patients. The mean number of ED patients admitted to the hospital per weekday was 38.8 (95% confidence interval [CI] 36.1–41.5) and 70.5% occurred between noon and midnight. The mean number of elective surgical patients admitted per day was 22.7 (95% CI 20.7–24.8) and 85.6% occurred between noon and midnight. There was variability in the mean number of daily elective surgical admissions based on day of the week: 26.0 patients on Mondays and 20.0 patients on Tuesdays–Fridays. The mean number of patients transferred from the ICU to inpatient beds per day was 19.5 (95% CI 17.3–21.6), and 82.8% occurred between noon and midnight.

The mean hospital bed occupancy rate at 8:00 a.m. was 95%. The mean number of inpatients discharged per day was 81.1 (95% CI 75.1–87.1), and 88.0% of inpatient discharges occurred between noon and midnight.

The mean total ED admitted patient boarding hours for an average day were 81.0, and a mean and median of 2.6 h and 1.6 h per ED admitted patient, respectively (range = 0.2–67.4 h; 95% CI 2.4–2.8; 25% and 75% interquartile range = 1.1 and 2.7 h, respectively), and a mean of 4.0 ED admitted patients boarding per hour.

Model Results

Under the base case discharge timing policy in the model, the total daily admitted patient boarding time was 77.0 h with a mean of 2.0 h per patient, and a mean of 4.2 patients boarding per hour. Of the total boarding hours, 56.3 h were attributed to ED admitted patient boarding and 20.7 h were attributed to surgical patient boarding. Surgical patient boarding occurred primarily between the hours of 10:00 a.m. and 6:00 p.m. when the surgical recovery room was open (Figure 4).

The application of the sensitivity analysis to the model is pictured in Figure 5A. Shifting the discharge distribution curve 1 h earlier in the day eliminated the 20.7 h of surgical boarding and decreased total ED admitted boarding hours secondary to lack of inpatient bed availability to 34.4 h per day; shifting it 2 h earlier decreased ED boarding to 8.3 h; shifting it to 3 h earlier decreased ED boarding to 1.2 h; and shifting it to 4 h earlier eliminated ED boarding (Figure 5B).

The application of the two proposed inpatient discharge timing policies to the available inpatient discharge capacity of 81.0 inpatients per day is pictured in Figure 6A. “Discharge by noon” eliminated surgical patient boarding and decreased total ED admitted patient boarding to 3.0 h per day. “Dayshift uniform discharge” also resulted in elimination of surgical patient boarding and decreased total ED admitted patient boarding to

Table 1. Descriptive Statistics for Daily Patient Flow Variables

Patient Flow Variable	Mean (95% CI)	Median (25% and 75% IQR)	Range	% between Noon and Midnight	% of Total Weekday Inpatient Admissions
ED admissions	38.8 (36.1–41.5)	39.5 (35.0 and 42.3)	26.0–50.0	70.5%	40.3%
Elective surgical admissions	22.7 (20.7–24.8)	22.0 (20.5 and 26.5)	14.0–31.0	85.6%	22.4%
ICU transfer admissions	19.5 (17.3–21.6)	19.5 (17.3 and 22.3)	10.0–30.0	82.8%	20.2%
Inpatient discharges	81.1 (75.1–87.1)	83.0 (72.5 and 87.0)	59.0–105.0	88.0%	N/A

CI = confidence interval; IQR = interquartile range; ED = emergency department; ICU = intensive care unit.

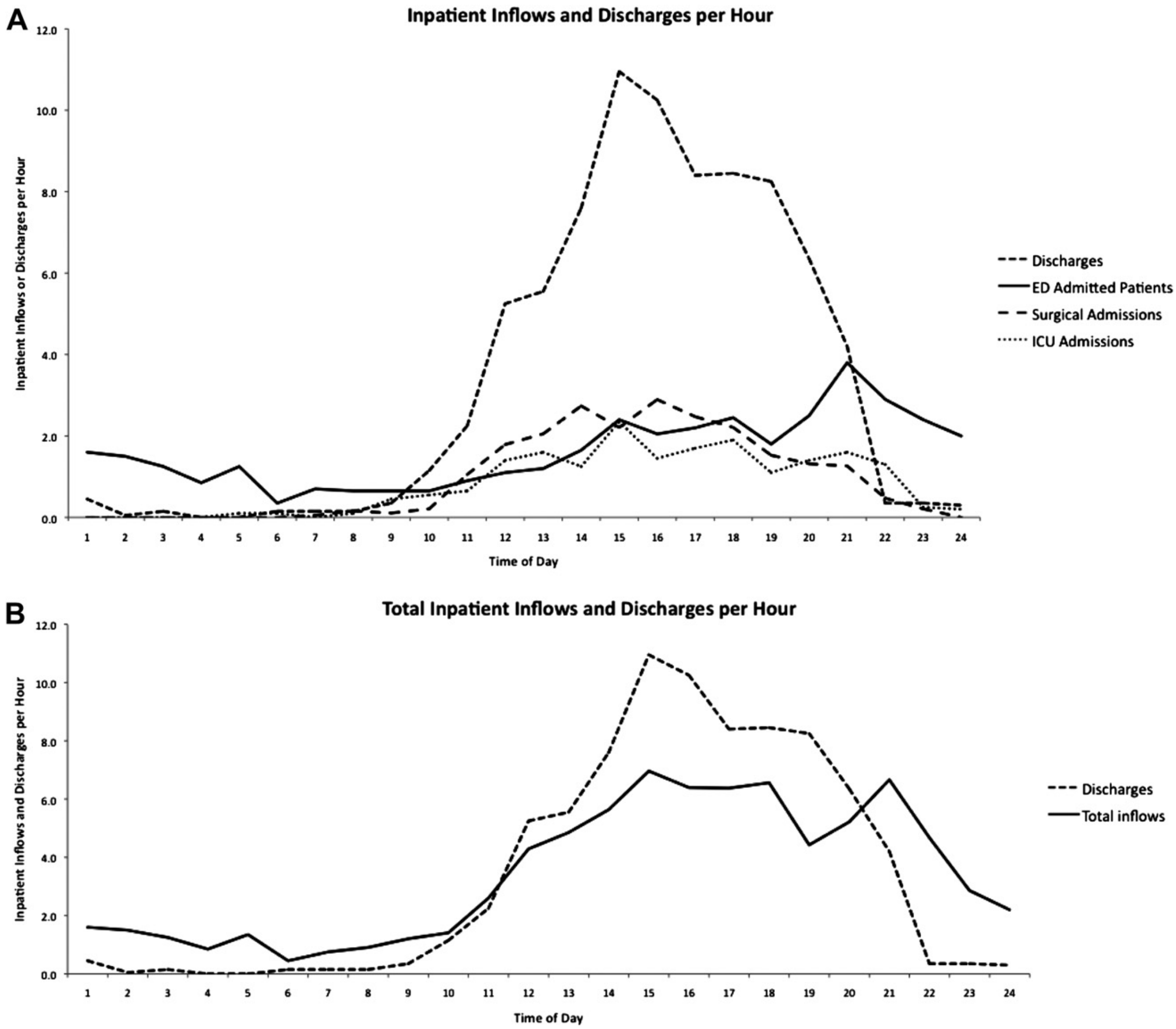

Figure 3. (A) Inpatient discharges and three inpatient admission flow streams: emergency department (ED) admissions, elective surgical admissions, and intensive care unit transfer admissions. (B) Total flow of inpatient admissions and inpatient discharges into and out of inpatient beds.

3.0 hours per day. These results are presented graphically in Figure 6B.

DISCUSSION

This analysis reveals the association and high impact of the timing of inpatient discharges on ED boarding of admitted patients secondary to lack of inpatient bed availability. The model examined the relationship between the supply of inpatient beds and the demand for this limited supply from three primary sources: ED admissions, elective surgical admissions, and transfers from the ICU to inpatient floor beds. Our results highlight a discrepancy between the timing of daily demand for inpatient beds from the ED and the supply of inpatient beds made available through daily inpatient discharges in this capacity-constrained hospital. The primary outcome used to measure this discrepancy in our model was ED admitted patient boarding hours.

Our results corroborate the work of Forster et al., who found a correlation between rising hospital occupancy and increasing ED length of stay (19). Work at this institution has also concluded that the key bottleneck in this ED is the rate at which admitted patients leave the ED for inpatient beds, and improving this rate would have a more significant impact on ED length of stay than adding additional ED beds (28). Our present study examines potential operational strategies directed at

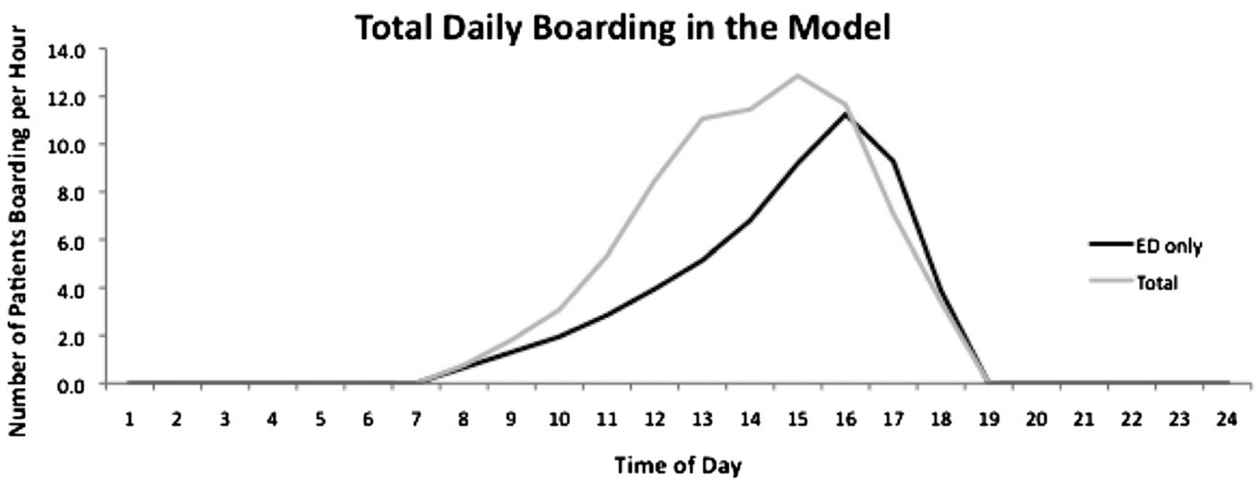

Figure 4. Number of emergency department (ED) admitted patients boarding as an output of the model.

overcoming this ED bottleneck to decrease ED length of stay and boarding by recognizing the impact of inpatient hospital operations on ED operations.

When examining current inpatient discharge practices in this hospital, we found that by keeping the current hourly discharge capacity the same but shifting the discharge distribution curve to earlier in the day, according to this model we would be able to decrease and ultimately eliminate boarding in a non-linear fashion. Even by shifting current discharge practices just 1 h earlier in the day, to have a peak discharge time of 2:00 p.m. instead of 3:00 p.m., we demonstrate the ability to

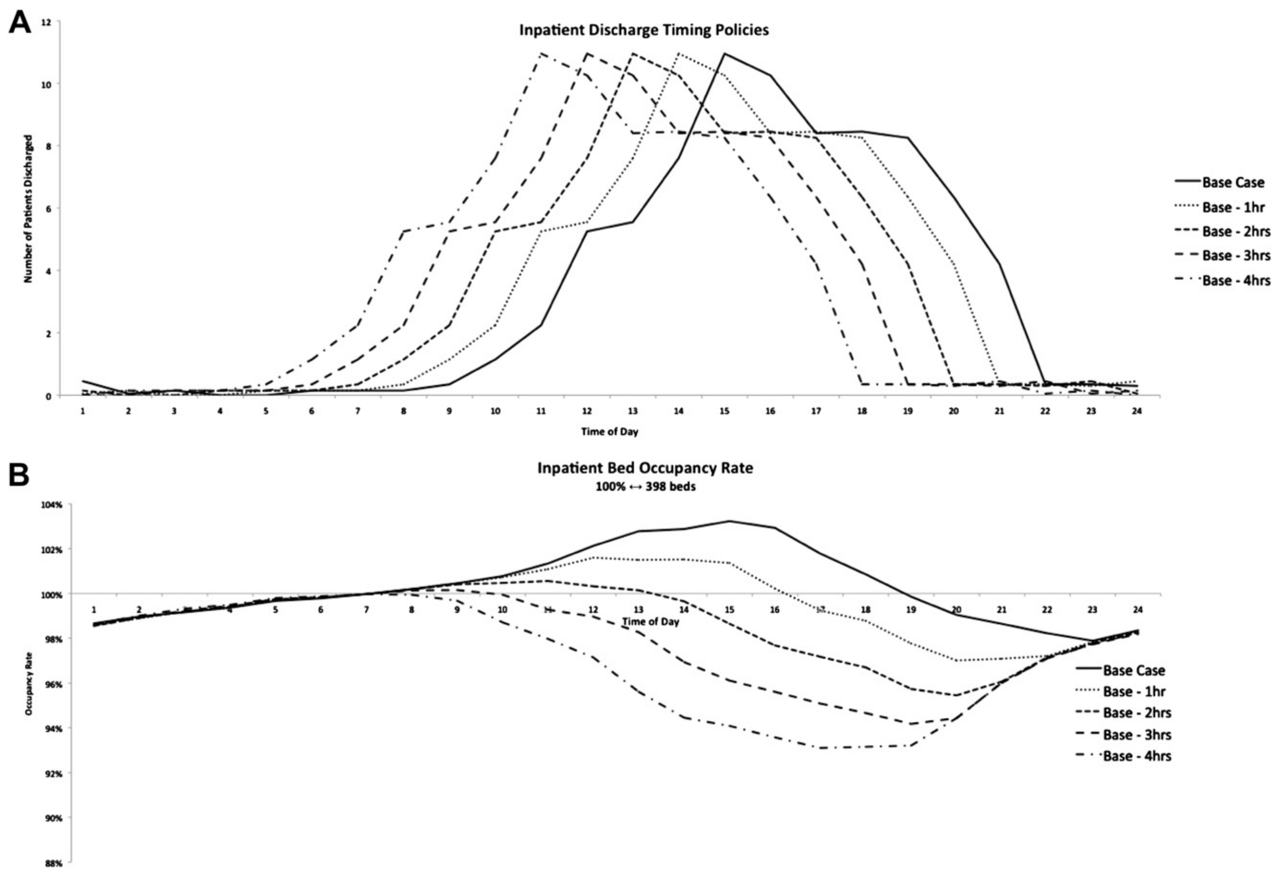

Figure 5. (A) Sensitivity analysis on the timing of current inpatient discharge practices. The current inpatient discharge distribution curve is shifted to earlier in the day in 1-, 2-, 3-, and 4-h increments. (B) Inpatient beds to be occupied as a result of each of the incremental shifts in the discharge distribution curve in the model. Any movement of a line above the x-axis indicates admitted patient boarding. Any movement of a line below the x-axis indicates excess inpatient bed capacity.

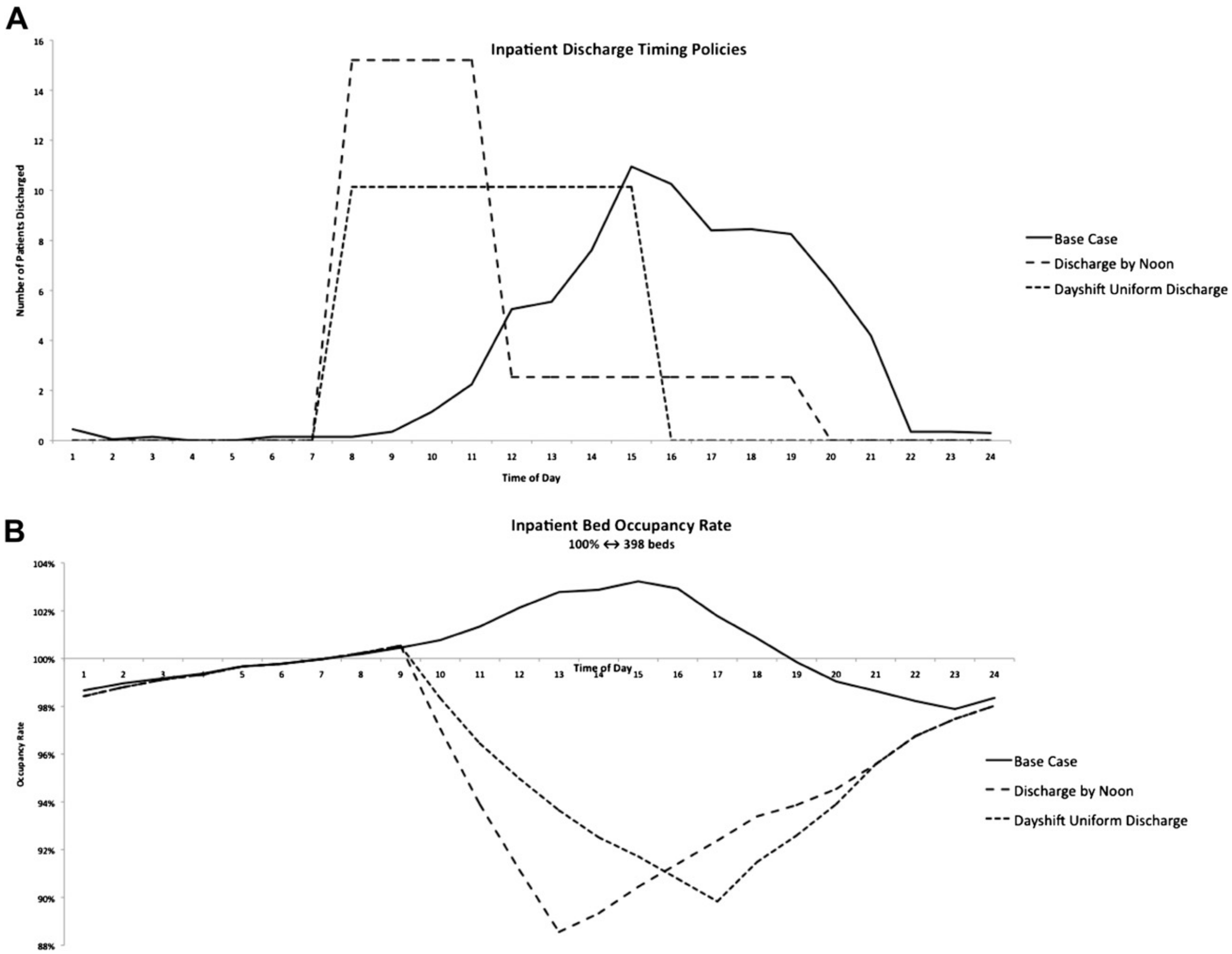

Figure 6. (A) Application of the current inpatient discharge capacity per day to the two proposed inpatient discharge timing policies. (B) Inpatient beds to be occupied as a result of each of the two proposed inpatient discharge timing policies in the model. Any movement of a line above the x-axis indicates admitted patient boarding. Any movement of a line below the x-axis indicates excess inpatient bed capacity.

decrease overall boarding hours of admitted patients by over 50%, from 77.0 h per day to 34.4 h per day, and to decrease boarding hours of ED admitted patients from 56.3 h per day to 34.4 h per day. Shifting the peak discharge time to 4 h earlier, 11:00 a.m., eliminates all boarding. Arguably, this policy likely could be implemented without the addition of staff or further resources, but with alterations in staff shift scheduling.

This study also finds that the two proposed alternate inpatient discharge timing policies have the theoretical potential to eliminate nearly all ED admitted patient boarding hours relative to present discharge timing practices. The inclusion of these policies in the model allows us to extend the operational concepts and potential for improvement past this hospital's particular discharge capacity curve. Future work in other sites could extend these results and focus on determining the optimal inpatient discharge timing policies under different hospital-specific constraints as well as consider specific factors such as physician and nurse staffing.

The primary driver of the positive effects on total and ED boarding in this study is the increased availability of inpatient beds earlier in the day, during times that have higher ED census and thus ED admissions. Although we demonstrate a magnitude of benefit for this hospital, we recognize that with different admission and discharge numbers, the numerical results of the inpatient discharge policies would be mathematically different, but the policies would likely still decrease ED boarding. As demand for inpatient beds increases in the future, the "discharge by noon" policy would likely outperform the other policies as it provides more inpatient beds earlier in the day. This better serves the timing and variability of ED admissions and could ultimately decrease ED boarding that is secondary to the lack of inpatient bed availability. Our model supports the assertion that if the model is successfully executed, the hospital would have the potential to accommodate nearly every ED admitted patient without any significant boarding and without the addition of any inpatient or ED beds (Figures 5B, 6B).

Although the overarching concept of improving inpatient outflow to decrease boarding seems obvious, it continues to be a challenge in many hospitals, and work such as this highlights its importance. The medical community is only beginning to understand and appreciate the inter-relationships and inter-dependencies between departments in a hospital system. The relationship between inpatient discharge timing and the ED have not been fully explored or reported widely in the medical literature. We need studies like this to prioritize informed action steps to ameliorate the issue of crowding in our nation's EDs.

Limitations

There are limitations to this study that must be considered. We have used a simplified computer model to examine the complex relationship between inpatient discharge timing and ED boarding. We included the top three sources of inpatient bed demand in the analysis and made several exclusions to simplify the process and focus on the relationship to be evaluated. We did not include the patients transferred in or directly admitted to the hospital (6.4% of all weekday admissions) as they are given priority after ED admissions; or patients transferred from one inpatient floor bed to another inpatient floor bed (10.7% of all weekday admissions) as the net result of such a transfer on inpatient bed supply is zero. Information on inpatient beds made unavailable for reasons other than occupancy were not available for this retrospective analysis and therefore not included. We excluded admissions to the ICU as we wanted this work to focus on a specific operational relationship: inpatient discharge timing and boarding of admitted patients. We hypothesize that the addition of these processes would only add to congestion in the inpatient hospital part of the model and would only work to increase ED boarding hours and amplify our results.

We did not consider bed specialization in this analysis. In our institution, ED admitted patients awaiting inpatient bed assignment are frequently admitted to other units if the requested bed type is not available. This applies to all inpatient bed requests other than requests for telemetry beds. Given that only 24.1% of bed requests were for telemetry beds, the majority of bed requests were for beds subject to open assignment, and therefore we chose to remove bed specialization from the analysis. Had we included bed specialization, it would likely have worked to increase ED admitted patient boarding hours and further augment the effect of the proposed discharge timing policies.

Modeling requires rules and simplifications that give way to slight differences in results from the actual circumstance. In the model, we utilized a baseline bed occupancy rate of 100% at 8:00 a.m. although the actual average daily occupancy rate was 95% at 8:00 a.m., including critical care beds, based on aggregate hospital statistics. We were not able to retrospectively ascertain the number of inpatient floor beds available at the beginning of each day and therefore simplified the number in the model to 100% occupancy at 8:00 a.m. We assumed that there was a shortage of inpatient beds and that all new admissions were admitted to inpatient beds vacated by inpatient discharges during that 24-h period (29). This modest increase in the hospital occupancy rate also accounted for congestion factors not incorporated in our model, as mentioned above.

There was also a necessary difference in the method of calculation of total boarding hours between the operations datasets and the computer model. The operations dataset gave the actual time the patient boarded while waiting for an inpatient bed and included time spent for bed placement and patient transport, whereas the computer model generated a boarding hour when a patient was admitted to an inpatient bed during an hour of the day that the inpatient hospital was at capacity and all 398 inpatient beds occupied. Boarding in the model accounted for boarding secondary to lack of inpatient bed availability. Therefore, the total boarding hours under actual and modeled scenarios did not match exactly, and boarding reported in the model was less than that reported in the actual data. If we were to recalculate ED boarding from the actual data and exclude time spent on bed placement and transport (we conservatively hypothesized this to be approximately 30 min per patient who boards), the mean daily ED patient boarding hours would be approximately 65.1 h.

As this study was an observational analysis of two pre-existing hospital operations datasets, we did not have control over the original collection of data and therefore cannot personally attest to its validity. A recent study by Gordon and colleagues demonstrated that active time-stamp data derived from an ED tracking system such as the datasets utilized for this project may represent conservative estimates of time data (30). Therefore, the time estimates presented here likely represent a conservative interpretation of ED boarding hours. Additionally, only 501 of the 5277 records (9.5%) were excluded for incomplete data, and these records were evenly distributed over weekdays, weekend days, and time of day. The 90.5% inclusion rate reduces the likelihood that our data were prone to internal selection bias.

This study was based on data from one hospital system that functions under a capacity-constrained framework. Although this framework creates unique challenges, it has increasingly become the common model for United States hospitals (18). Other hospital systems may experience differences in constraints on the supply of inpatient beds and may not be able to generalize the magnitude of the proposed solutions to their institutions. However, the operations management concepts and the relationship between inpatient discharge timing and boarding presented here are likely to be broadly applicable.

CONCLUSIONS

Effective solutions to ED crowding and boarding require a system-wide approach. Timing of inpatient discharge from the hospital has a meaningful effect on ED boarding and crowding. This model demonstrates this relationship and the potential to reduce or eliminate total ED boarding hours secondary to lack of inpatient bed availability by shifting inpatient discharge timing to earlier in the day, ahead of the daily surge in ED demand. This study highlights an area for further investigation of direct interventions aimed at decreasing ED boarding and crowding in capacity-constrained health systems.

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ARTICLE SUMMARY

1. Why is this topic important?

Emergency department (ED) crowding and boarding impairs patient quality, safety, and satisfaction. This is no longer strictly a problem of the ED, but is now a concern of the entire hospital institution.

2. What does this study attempt to show?

This study uses computer modeling to demonstrate the relationship between inpatient discharge timing and the boarding of ED admitted patients by evaluating the impact of altering inpatient discharge timing on boarding.

3. What are the key findings?

Shifting current inpatient discharge timing practices to earlier in the day decreases boarding in an exponential fashion with each additional hour shift in the model. Discharging 75% of inpatients by 12:00 noon or all inpatients uniformly between 8:00 a.m. and 4:00 p.m. nearly eliminates boarding in the model.

4. How is patient care impacted?

This analysis reveals the association and high impact of the timing of inpatient discharges on ED boarding of admitted patients and the ability to nearly eliminate boarding with alterations in inpatient discharge timing.