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ORIGINAL RESEARCH

# Inpatient Discharge-By-Noon: Are Fewer Better than All?

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**Introduction:** To address boarding in hospital emergency departments, discharge-by-noon could free up inpatient beds earlier in the day. However, discharging all patients by noon can heavily burden inpatient units and may not be feasible. In this study, we determine the number of discharges after which the benefits of an additional discharge-by-noon diminish.

**Methods:** We conducted a simulation analysis to quantify how occupancy rate, mean daily number of discharges, and peak discharge time impact upstream boarding time in an inpatient neurology unit at Maine Medical Center. Using a day-of-discharge simulation model with one year of retrospective data, we assessed configurations approximating various inpatient units to increase the number of patients discharged by noon from 1 to all. Measured outcomes included the (1) average upstream boarding time across all patients and (2) average time of day for discharge completion.

**Results:** Units with a higher occupancy rate, later peak time of day for discharge, or more discharges may benefit more from discharge-by-noon initiatives. For any unit configuration studied, approximately 75% of the maximum expected reduction in boarding time (when all-by-noon is implemented) can be achieved by discharging half of the average daily discharges by noon.

**Discussion:** Studies have aimed to achieve all discharges before noon. Our study suggests that although discharging patients by noon reduces upstream boarding time, discharging all by noon does not eliminate upstream boarding. Hospitals may have better outcomes by implementing strategies based on the characteristics of specific units.

**Conclusions:** Although setting a discharge target can help an inpatient unit better achieve earlier discharges and reduce upstream patient boarding, discharge-by-noon does not need to be used in its original form of "all" by noon.

**Keywords:** simulation modeling, discharge planning, boarding time, quantitative

Delays and inefficiencies in inpatient discharge reduce the capacity of hospital inpatient units (IUs). When inpatient capacity is full, patients in the emergency department (ED) who need to be admitted will wait in the ED and block access for newly arriving patients. This event is called "boarding." Boarding reduces patient satisfaction and access, and it creates safety risks. Common policies for hospital discharge targets are currently leveraged in hospitals due to their simplicity, perceived ease of implementation, and potential to reduce ED boarding and improve hospital efficiency.[1]

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Complex policies for discharge targets have been proposed, such as length-of-stay prediction models[2] and staff-determined discharge time.[3] However, the most prominent policy is 'discharge before noon (DBN).' DBN policies encourage IUs to release all eligible patients by noon each day. This strategy has been purported to decrease peak arrival time,[4] shorten length of stay,[4] and reduce boarding time,[5, 6] all without negatively affecting patient satisfaction.[7]

Despite the known benefits of DBN, implementing the policy has raised several concerns about its aggressive nature, difficulty of implementation, and potential for unintended negative consequences.[8,9] Factors hindering the successful implementation and sustainability of DBN include lack of bed availability, waiting on physician availability to place the discharge order, and time conflicts with the patient's family given the initial discharge time.[10] Also, providers have difficulty focusing on discharges in the morning, which often involves rounding, caring for existing and recently admitted patients, and attending educational activities.[11] There is also the potential for perverse incentives arising from a push for early discharges that can lead to delaying discharges until the next morning in an attempt to meet the DBN metric.[8,12]

The objective of this study was to explore more tailored patient-discharge policies that achieve the benefits of DBN but are less likely to incur negative effects. To this end, we estimated the incremental benefit, measured in terms of reduced upstream boarding time, of adding 1 discharge-ready patient to the total number of patients to be discharged by noon for a given unit on a given day. We conducted this analysis using a previously published simulation model.[13,14] The benefits of incrementally increasing discharges were explored across a variety of IUs, each characterized by occupancy rate, peak time of discharge completion, and discharge workload.

## METHODS

Our study used hospital administrative data from a neurology IU at Maine Medical Center in Portland, ME. We selected this unit primarily due to the willingness of the unit director to collaborate with us and the availability of data. The hospital's Institutional Review Board approved the study.

### Setting

Maine Medical Center is an urban academic, tertiary care hospital. It is the largest hospital in the state of Maine, with 637 licensed beds and more than 9600 employees. During the study in 2015, the neurology IU had 26 beds and more than 2100 discharges.

### Data

Data was gathered retrospectively from the hospital's electronic data warehouse for patients discharged alive from this unit during 2015. The following variables from the discharging unit's perspective were considered: (1) number of discharges per day, (2) time of day the physicians placed discharge orders, (3) the amount of time it took to process discharges once the discharge order had been placed, and (4) time to clean the room after discharge. For upstream patients requiring care in the unit, the following variables were considered: (1) time of day the bed requests were placed, and (2) time to transport the patients to the unit when a bed was available.

### Simulation model

We extended a discrete-event simulation model that has been validated and previously published. The model was developed to characterize patient flow through this particular neurology IU.[14] Figure 1 provides a flow diagram for the simulation model, which simulates an average day in the IU, from midnight to midnight. See the Appendix for a detailed description of the model.

This model dictates behaviors for discharge preference using 2 variables $n$ and $T$, where $n$ refers to a number of discharges to be completed by a specified time $T$. We take an $n$ and $T$ combination and call it an $n$-by-$T$ policy.

For this study, we extended this validated model by first setting $T$ = 12 PM (to model DBN). To evaluate the marginal benefits, $n$ was incremented from 0 (0 DBNs) to the maximum value (reflecting all DBNs). For this unit, more than 98% of days in the study timeframe had 12 or fewer discharges, so we chose 12 as the maximum value of $n$.

Different IU configurations were extrapolated from the simulated neurology unit by varying occupancy rate, daily discharge workload, and peak discharge time. To model the bed occupancy rate in the IU, we included a variable $B$ that indicates the number of empty beds available at the start of the day; $B$ = 0 implies 100% occupancy. To model low, medium, and high discharge workload in the unit on a day-to-day basis, we included a variable $D$ that indicates the average number of discharges per day. Finally, to capture the discharge dynamics in different units, we included a variable $P$ to indicate the peak discharge time varied at 3 levels. Appropriate statistical distributions governing the uncertainty in $D$ and $P$ were also derived using collected data. For each combination of $B$, $D$, and $P$, the entire range of $n$ (0 to 12 in our case) was simulated. Each $n$ value was replicated 5000 times, such that each replication corresponded to one 24-hour day. This process was repeated 30 times, with each


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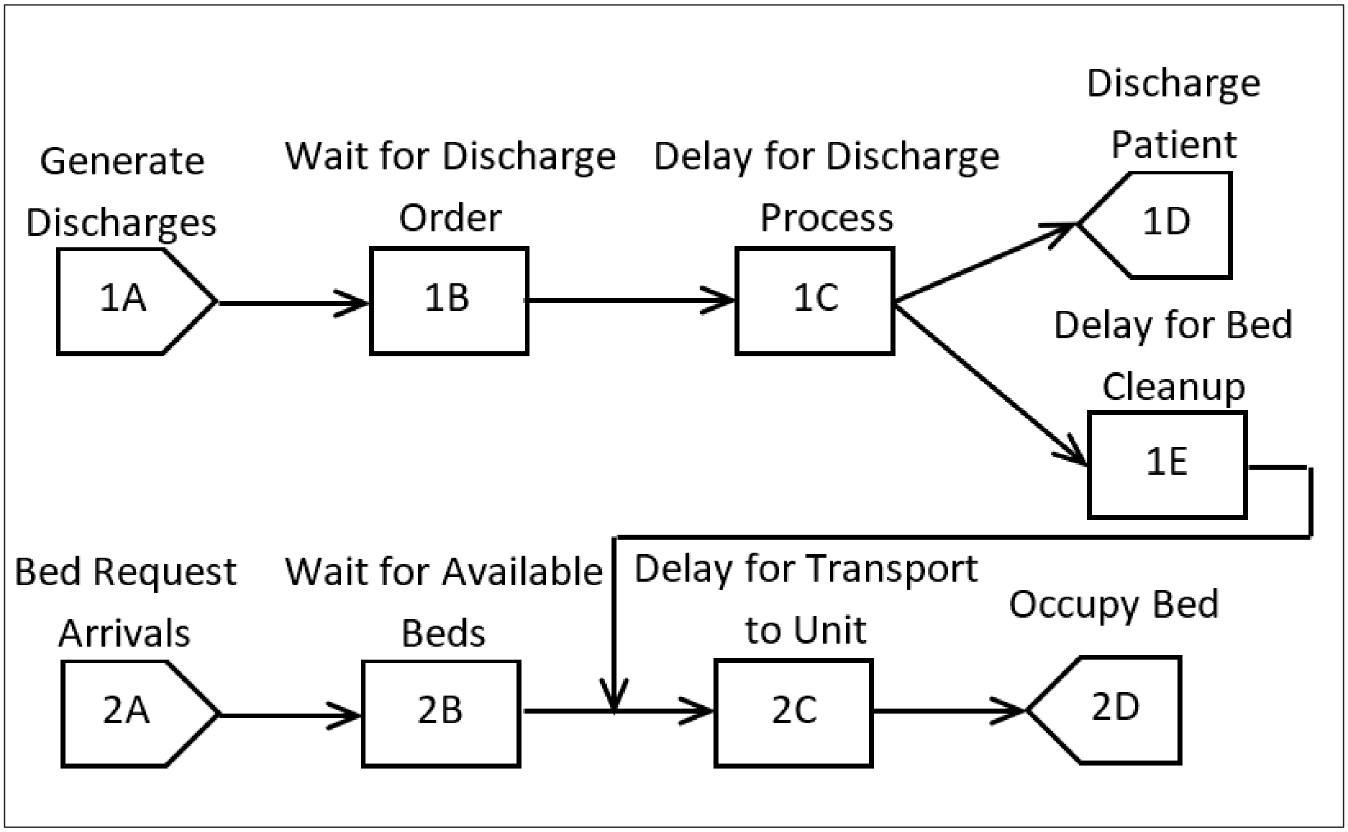



Figure 1: Schematic of the Simulation Model for Inpatient Discharges and Upstream boarding

repetition leveraging different random seeds to reduce variances in the outcomes.

**Simulation inputs**

A total of 1303 cleaned patient records from the neurology unit were extracted from the hospital's electronic health record for the year 2015. The average discharge time of day in this unit was 2 PM, and the average boarding time for upstream patients was 3.5 hours. See the Appendix for the resulting distributions used to characterize the simulation model inputs.

Several IU configurations were evaluated to mimic the behavior across different units. Accordingly, *B* (number of empty beds) was set equal to an integer in the range [0, 3], indicating 100% to 85% occupancy, in that order. The variable D was used as the mean of a Poisson distribution to model units with low (D = 2), medium (D = 4), and high (D = 6) daily workload in terms of the number of discharges. Because the peak time of discharge can vary across units, *P* was set to one of 3 levels (12 PM, 2 PM, and 4 PM).

**Simulation outputs**

Three outcomes were estimated using the simulation model: (1) total upstream boarding time, (2) reduction in boarding, and (3) discharge completion times. Total upstream boarding time, defined as the time elapsed from a bed request placed to a patient occupying a bed, was used as the main outcome measure. Boarding time was collected for each patient in the model, then averaged across all patients across all replications and seeds for each of the 12 IU configurations.

The outcomes for each incremental value of *n* were averaged across all repetitions and reported as a percentage change from the baseline case where *n* = 0.

The time of day for discharge completion of each patient being discharged was also collected to examine how much the time varied with increments of *n* for specific IU configurations.

## RESULTS

Figure 2A illustrates the "absolute" percentage reduction in boarding time per patient with increases in *n* for various IU configurations (with *B* fixed at 0). From this graph, the following phenomena can be observed: (1) there is a limit to the maximum percentage reduction in boarding time for any given configuration, and even all-by-noon does not reduce upstream boarding by 100%; (2) the benefits are generally higher with larger (later in the day) values of *P*; (3) for a given *P*, larger values of *D* have a higher maximum benefit, but they reach saturation more slowly as *n* increases.

Figure 2B summarizes information in terms of "relative" reduction in upstream boarding times. This reduction is calculated as the ratio of reduction for a given *n* and the maximum reduction achievable (at *n* = 12 in our study). Notice the diminishing returns in the benefits as *n* increases—nearly 75% of the relative reduction can be achieved with only 50% of daily discharges. For instance, when *D* = 2, approximately 75% of the maximum possible reduction in boarding time is achieved by discharging only 1 patient (ie, 50% of average discharges) by noon every day. This possibility is true for all other values of *D*, regardless of the value of *P*.

Figure 3 summarizes the results across all values of *B*. Each vertical line displays the range of "absolute" percent reduction in boarding time (from the case where *n* = 0) as *n* increases from 1 (bottom-most marker) to 12 (top-most marker). Notice that the benefits decrease as *B* increases (alternatively, occupancy rate decreases), although the interaction between *P* and *D* remains the same.

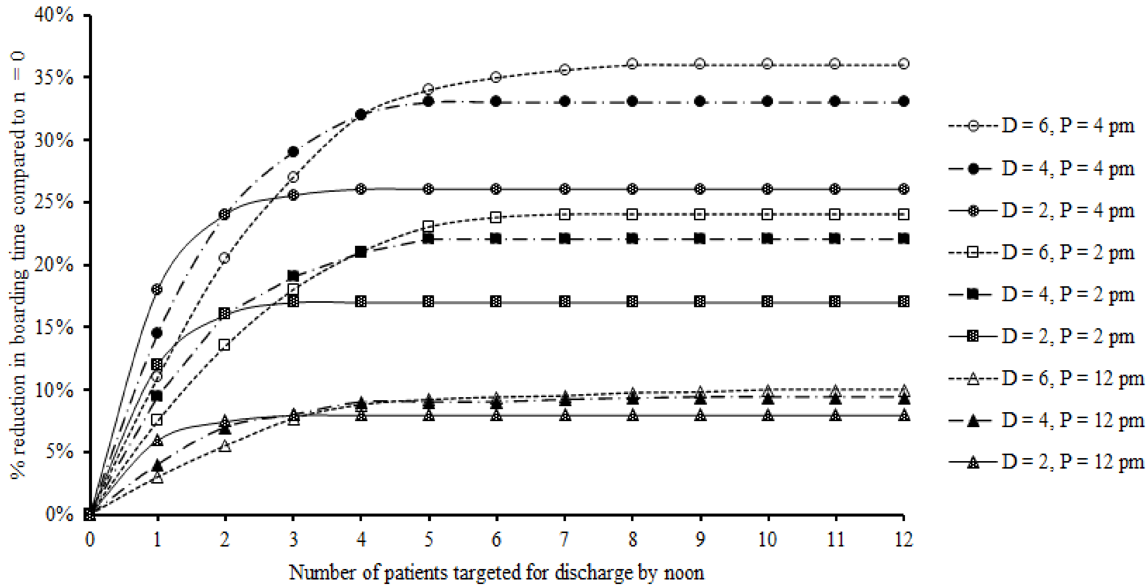
With regards to the relative reduction in boarding time, the pattern we observed in Figure 2B also occurred across all values of *B*. That is, for a given IU configuration, roughly 75% of the maximum possible reduction in upstream boarding time could be achieved with only 50% of the average daily discharges for that unit.

Figure 4 illustrates the effect of increasing *n* on discharge completion time. These data show the percentage of discharges completed by each hour of day for the configuration in which *B* = 0, *D* = 4, and *P* = 2 PM (essentially, the neurology unit that we consider). We selected several values of *n* > 0 to compare with *n* = 0. Note that *n* = 0 (solid line) refers to the existing discharge pattern at the unit, with the observed peak at 2 PM. As more patients are targeted for DBN, the curve for completion time shifts from a unimodal curve (with a single mean time to discharge completion later in the day) to a bimodal curve (with a much earlier mean). Similar to the above-noted diminishing returns on reducing relative boarding time, diminishing returns are also associated with completion times. For example, the peak dropped from 2 PM to 9 AM in the following order: (*n*, peak time) = (0, 2 PM), (1, 9:30 AM), (2, 9:15 AM), (3, 9:05 AM), (4, 9 AM), (5, 9 AM), (10, 9 AM), (12, 9 AM).

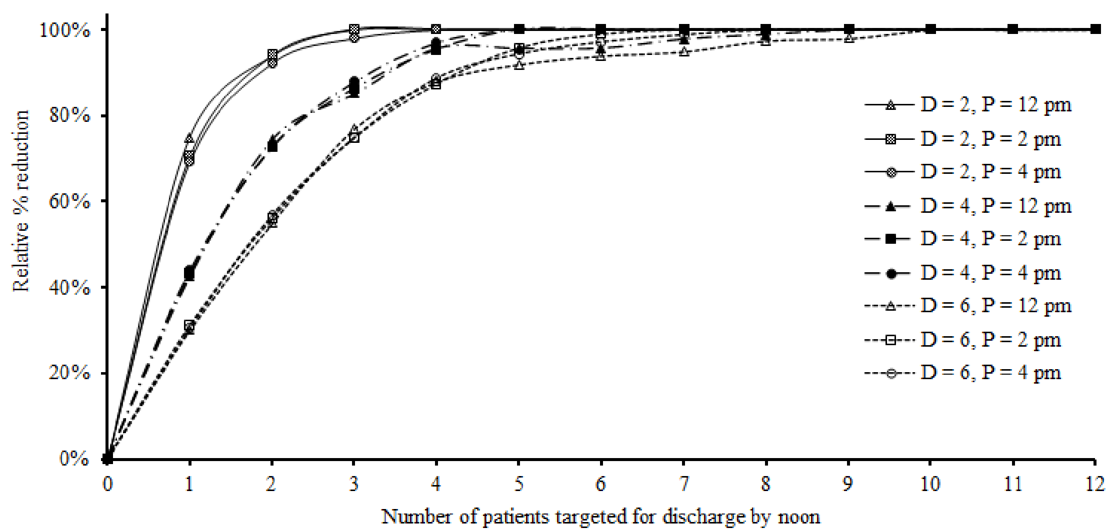
## DISCUSSION

Although improvements in the discharge process in IUs have been shown to improve boarding time for emergency departments and other upstream units, there is no single best practice for achieving this improvement. The frequently suggested DBN strategy has several barriers to implementation and sustainability, as well as inconsistent positive impact. We identified several discharge strategies that are less aggressive and time-based through a simulation study using data from a neurology unit at a tertiary care hospital in Maine. The key finding of our study was that, for units in which the average discharges equals average admissions (balanced units), we observed diminishing returns in *relative* reduction in boarding times as the number of DBNs increased. The simulation showed that, across a variety of IU configurations, over 75% of the maximum reduction in upstream boarding time can be reduced by discharging half the number of average discharges in that unit.

Prior studies that explored the efficacy and effectiveness of the DBN strategy largely focused on a specific unit. For example, Wertheimer et al. discussed increasing the rate of DBNs in medical units based on a daily responsibilities checklist, identification of patients ready for DBN the day before discharge, and a new website for better communication among hospital staff. [4] They were able to increase DBN from 11% over the 8-month baseline period to an average of 38% over the 13-month intervention period. Similarly, Kane et al. reported a 25% improvement in DBNs across medical, surgical, telemetry, and intensive care units.[7] Also, Bardes et al. described an increase in




**(a)** Absolute reduction in the upstream boarding times




**(b)** Relative reduction in the upstream boarding times

**Figure 2.** Reduction in Boarding Times with *n* Across Various Inpatient Unit Configurations

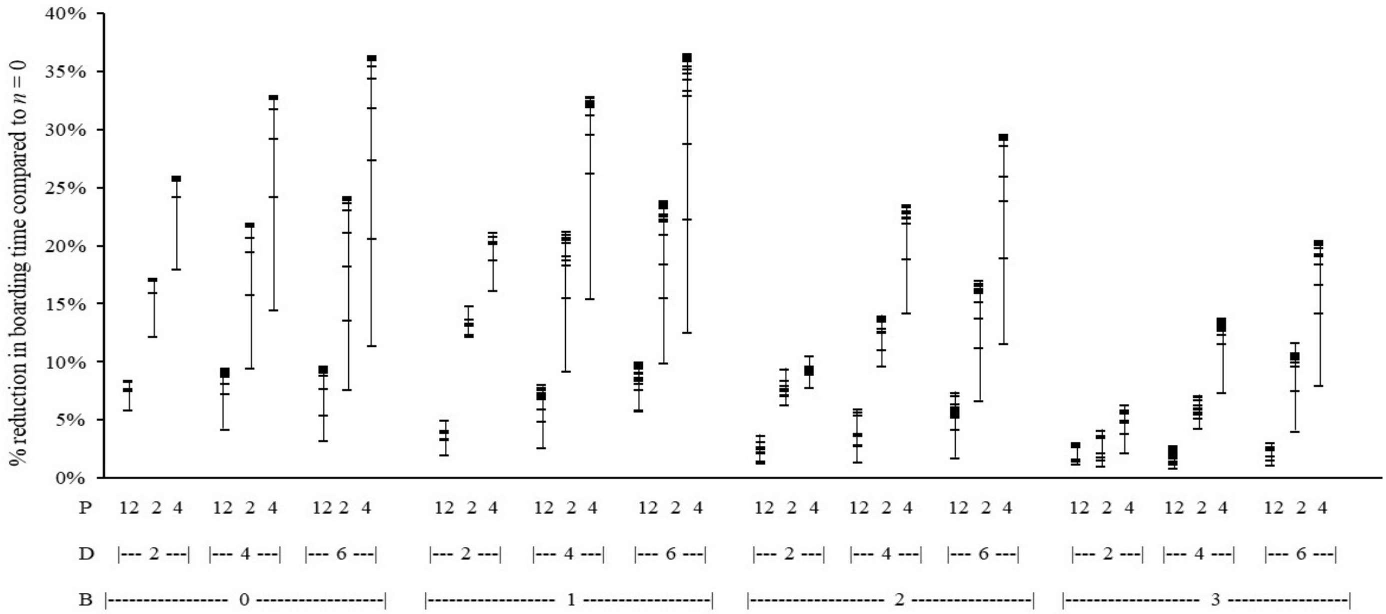



**Figure 3.** Boarding Time Reduction Across All Inpatient Unit Configurations

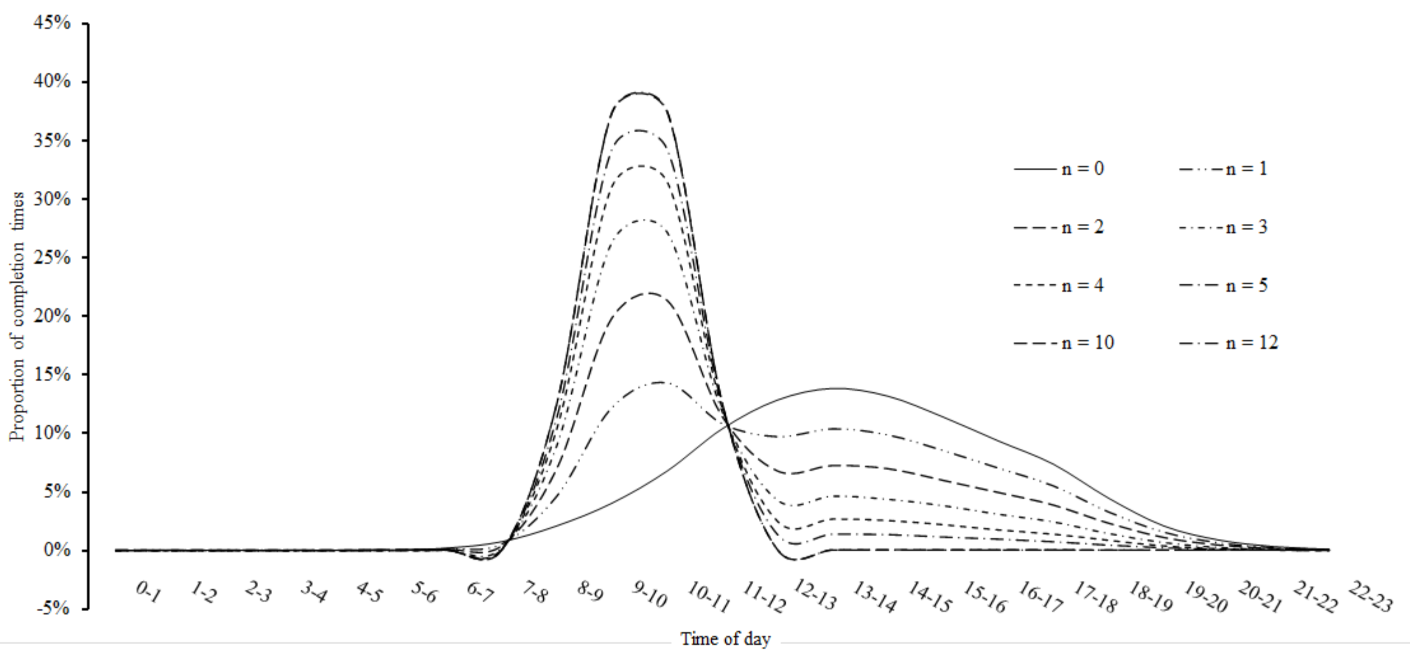



**Figure 4.** Impact of *n* on Peak Discharge Time of Day

DBNs from 25.5% to 51.2% for ED patients through the implementation of a dedicated discharge team.[15] Moreover, Lyons et al. showed that a 21.5% DBN rate can be achieved across several different specialties over a 12-month period by standardizing the discharge process.[1]

All these studies suggest a desire to achieve 100% of discharges before noon, but it is unclear if all the upstream boarding could have been eliminated if this target was attained. Our study suggests that although discharging more patients before noon leads to a reduction in upstream boarding time, discharging all-by-noon does not completely eliminate upstream boarding. There is an upper bound on the achievable maximum reduction in boarding time, and this upper bound is unit-specific. Balanced units with higher occupancy level (ie, *B* in our study) often have a higher upper bound than units with more empty beds available at midnight. Similarly, busy units (ie, *D*) and those with a later peak completion time (ie, *P*) have a higher potential for substantially reduced upstream boarding. These findings imply that, when deciding to invest in efforts to improve the discharge process, hospitals may have more fruitful outcomes by selectively targeting units for implementation of a DBN strategy based on the characteristics of those units.

Another key observation is that a unit does not need to significantly invest in trying to achieve "all" discharges by noon. Because the studies mentioned earlier could not achieve this goal, such a goal may not be realistic in the first place given practical difficulties. In contrast, a study design like ours could inform the unit managers at the appropriate level ahead of time (instead of such expensive intervention studies) based on the unit's characteristics. By extrapolating one unit's data alongside the unit's workload, occupancy level, and discharge completion time, we noticed that it is possible to gain nearly 75% of the upper bound value in upstream boarding time reduction by discharging only 50% of the daily average number of discharges. For instance, a 16% reduction in upstream boarding, out of a maximum of 21% when discharging all-by-noon, can be achieved by discharging only 2 patients by noon in a unit with *D* = 4 (and *P* = 2 PM and *B* = 0). This observation, if implemented in practice, could provide IUs with a daily target that is more achievable than discharging all-by-noon while providing comparable benefits to patient flow.

Additionally, simply guaranteeing one patient discharged by noon every day significantly altered the curve of discharges throughout the day, shifting almost 50% of discharges to before noon (up from roughly 25%). Increasing values of *n* do not increase the percent completed before noon as drastically.

Some studies examined optimized targets that vary by hour of day.[16,17] However, such hourly targets, as opposed to a daily target, may be difficult to implement in practice for a number of reasons: (1) many hospitals do not possess an information technology infrastructure that supports live, prescriptive decision-making; (2) agile decision-making may be difficult to implement with staff who are focusing on patient care in the moment; (3) confusion may arise over the fluctuating targets, leading to a lack of adherence; and (4) targets could be abandoned altogether. Other studies used advanced predictive analytics to drive discharge behavior.[16] The results of our study suggest that a hospital need not choose stringent and/or complex policies. Instead, they can achieve beneficial results through simpler policies, such as targeting half of the average daily DBNs.

Based on the characteristics of the units, some units may benefit more from DBN. Our results indicate that a unit with a typical later peak time of discharge could benefit more from n-by-12 than a unit with an earlier peak time of discharge. Additionally, a unit with a higher number of discharges per day could benefit more from *n*-by-12 than a unit with fewer discharges per day. However, the unit with a higher number or discharges will need to discharge more patients by noon to achieve a comparable level of their improvement potential. Between these 2 characteristics, the peak discharge time of day has a stronger impact on improved absolute boarding time than the number of discharges. Finally, units with a higher occupancy rate can benefit more from *n*-by-12. These findings have practical validity as well. Units with later peak discharge times have more opportunity for improvement, and units with more patients are more likely to have a set of identifiable discharge patients on any given day then a small unit.

Our study does have some limitations. First, our study used data from only one unit at a hospital. The simulation-based analysis generated different units by varying factors to imitate the behavior of various types of units. For this reason, further study should be conducted to generalize our findings to other units. Second, we assumed that any *n* value by noon is achievable; we did not model the dynamics in the unit during morning hours and what changes the unit would have to introduce to make this work. Future work could include a variable to model the success rate of a unit in achieving its *n*-by-noon target. And finally, we did not directly consider the impact of discharge disposition on discharge processing time or resultant upstream delays. Future studies could subset patients by discharge disposition to examine, for example, the impact of transfers to a tertiary care hospital, which can delay unrelated to bed availability. These patients would likely not be suitable targets for discharge-by-noon, but this study does not provide recommendations for which patients should be selected for early discharge. Any future implementation in practice should involve clinical input while developing such a selection process.

## CONCLUSIONS

In summary, while setting a discharge target can aid an IU in better achieving earlier discharges and reducing upstream patient boarding, it is not necessary to use DBN in its original form of "all" by noon. In this study, we showed that a policy seeking to discharge all possible patients by noon suffers from the law of diminishing returns. We also showed that across units of different configurations, 75% of the benefit can be achieved by only discharging 50% of the patients in the same timeframe.

**Conflict of interest:** None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