The *n*-by-*T* Target Discharge Strategy for Inpatient Units

Background

Healthcare in the US is a complex, multi-step, multi-setting process. In 2013 the national health expenditures amounted to $2.9 trillion, or 17.5% of the US GDP, and of this 32.1% was attributable to hospital care [1]. Despite these expenses, quality of care seems to be on a downward trend; from 2003 to 2009, the mean waiting time of patients in the emergency department (ED) increased 25%, from 46.5 minutes to 58.1 minutes [2].

This is not merely an isolated symptom of EDs; they are highly connected to inpatient hospitals, with over half of inpatient admissions in the US in 2009 originating in the ED [3]. Because crowding and boarding in the ED and other units upstream from inpatient units, such as Post-Anesthesia Care Unit and Surgical Intensive Care Unit , have been shown to negatively affect quality of care, patient safety, and patient satisfaction, reductions in these barriers would likely reap benefits to both patients and providers [4, 5, 6, 7, 8].

Studies have suggested that improving inpatient bed availability by balancing inpatient discharges with admissions can alleviate, if not eliminate entirely, upstream boarding and crowding [9, 10, 11, 12, 13, 14, 15]. According to one study, 1 in 4 inpatients could have been discharged earlier than they were [16]. With over 35.1 million inpatient discharges in the U.S. in 2010 [17], it is critical to understand key factors such as patient condition and necessary care, anticipated length of stay, patient needs upon discharge, and where the patient will go upon discharge during inpatient discharge planning [18]. When a smooth coordination of the inpatient discharge process fails to take place, it delays inpatient bed release, which delays the transfer to inpatient beds for newly admitted patients from various upstream units.

Recently, timing the inpatient discharges to reduce ED boarding of admitted patients by shifting the discharge distribution curve has been suggested [15]. Although such an approach seems attractive, very little to no suggestions have been made in the literature as to how this can be achieved. Anecdotally, some hospitals have employed their own strategies to improve inpatient discharge processing, such as incentives to physicians to finish their discharge orders earlier in the morning, and even adding overtime or temporary staff during the latter part of the day to help execute planned discharges. But there is lack of clear evidence suggesting the benefits of such strategies.

We contend that the complexity of inpatient discharge process within a unit, and variances across units in a single hospital, render it difficult to devise a generic, optimal, strategy. In lieu of this, it is possible to develop targets that the care providers in the inpatient unit could aim for each day to realize substantial improvements. To this extent, we propose a novel *n*-by-*T* target strategy, which suggests discharging n patients (deemed ready for discharge on a given day) by the T^{th} hour of the day. For instance, 1-by-10 means that one inpatient should be discharged by 10 a.m., while 2-by-12 means that two patients should be discharged by 12 noon. This strategy suggests that if the order writing times by the physician are advanced and discharge process length is reduced, then the inpatient unit could achieve the target of discharging a predetermined number of n patients by the T^{th} hour. The goal is to achieve an improved synchronization of the availability of inpatient beds with the demand of inpatient beds from upstream units to smooth patient flow throughout the hospital. Our motivation to devise such a strategy came from preliminary studies which suggested that reducing discharge process time by unit-allowed maximum of 25% and advancing order writing times by a maximum of 3 hours, independently, resulted in benefits of 8% and 9.1%, respectively, only if implemented unit-wide, across all to-be-discharged patients. Given the difficulty of implementing such strategies at the unit under other process and staffing constraints, the hospital staff preferred the proposed n-by-T strategy, that required reducing both discharge process times and advancing order writing times (a hybrid strategy) for only a fraction of discharge-ready patients, while not imposing excessive work on the nursing staff during morning.

Our focus in this study is addressing the following research questions: *to what extent does the n-by-T target strategy advance the discharge completion times and reduce upstream boarding? How sensitive are these benefits to the inpatient unit's occupancy rate? What benefits and challenges might be experienced during a pilot implementation?*

Methods

Our study was conducted in two phases. Phase I dealt with understanding and representing the current discharge process in the unit via a simulation model in order evaluate various n-by-T strategies over varying occupancy rates. Phase II dealt with conducting a pilot implementation (based on our findings in Phase I) in a live inpatient unit.

Setting

We focused on an inpatient trauma unit at Kettering Medical Center (KMC), the flagship hospital in the Kettering Health Network – a faith-based hospital network in the Midwest U.S. KMC was founded in 1964 and currently houses 386 inpatient beds. The hospital has nearly 50,000 emergency visits and over 20,000 inpatient admissions annually. The facility has previously been recognized by the U.S. News and World Report as one of the best regional hospitals and by Truven Health Analytics as a top 100 hospital nationwide. Our research focused on one unit of the hospital: a 21-bed inpatient trauma unit, which completed 1,789 inpatient discharges during 2013. This study was approved by KMC's Institutional Review Board.

Data Collection

We used two modes of data collection at the unit: job shadowing to map the current process, and retrospective, de-identified, patient data from the hospital's electronic health record (i.e., Epic) to understand system inputs and outcomes. A collective of over thirty hours were spent in job shadowing the unit nurses to map the steps followed by them when discharging a patient, starting from the physician writing the discharge order all the way to the nurses physically transferring the patient out of the inpatient room. The retrospective data from Epic included time-stamps for order writing and discharge completion for each of the 1,789 discharged inpatients. We were also provided time-stamps for bed requests from upstream units for each day in 2013. Descriptive statistics were used to identify the distributions for the model inputs.

Outcomes of Interest

We focused on four measures, two time-based and two capacity-based. The two time-based measures were (i) mean discharge completion time, measured as the mean time of day when patients are physically discharged from the inpatient room, and (ii) mean boarding time of upstream patients, measured as the difference of when the bed request was placed and when the patient actually occupied the inpatient room (including variable transportation times). For this inpatient unit, the upstream units included the ED, Surgery, Medical/Surgical Intensive Care Unit (MSICU), Surgical Intensive Care Unit (SICU), Clinical Decision Unit (CDU), Coronary Care Unit (CCU), Cardiac, Dialysis, and Other (in order of frequency). The two capacity-based measures were related to an increase in the annual availability of (i) inpatient bed hours (due to possible advancement in the mean completion time) and (ii) upstream bed hours (due to possible reduction in mean boarding times).

Phase 1: Modeling Current and *n*-by-*T* Discharge Strategies

At a micro level, each unit handles their discharges slightly differently given the patient cohort and acuity, physician rounding patterns, staffing levels (e.g., nurse, social worker, case manager), disposition locations, and bed capacity. The unit staff ensures that all the vital elements of the discharge plan are completed to achieve a timely discharge: e.g., discharge orders written, patient education, medication reconciliation and instructions to patient, physical/occupational therapy, insurance approvals, availability at disposition location, and transportation arranged. The room then must be cleaned by the hospital cleaning staff, only after which it becomes available in the electronic health system (i.e., EPIC) to allow the transfer of a patient (at an upstream unit with an outstanding bed request) into this room at this unit.

Based on our observational study and preliminary analysis of the data, we realized that, at a macro level, the overall discharge process can be aggregated into 4 temporal events; (i) time of day when discharge order is written by the physician, (ii) length of time to accomplish all discharge processes (starting from a written order until patient is physically transferred out of the room), (iii) time of day when the bed request is placed for a patient in the upstream unit, and (iv) time of day this patient enters the empty room. Length of time to clean the bed after a discharge and length of time to transport a new patient into the room are two other secondary, but important, elements. This allowed us to develop an aggregate process map depicting the patient flow that was used in developing a discrete-event simulation model (see Figure 1). An aggregate approach was also deemed most appropriate by the hospital staff in order to identify and evaluate a generic strategy with the potential of implementation across all inpatient units at this hospital.

The simulation model was designed to emulate a typical **24-hr day-of-discharge process (midnight to midnight)** with multiple discharges based on the unit-specific data. Each patient who was to be discharged on a given day was assigned a specific time of day by when their discharge order would be written by the physician and the subsequent amount of time that is required to accomplish the discharge process before discharging the patient. Once the discharge process was complete, and after the time to clean the room had elapsed, the inpatient bed was made available for boarding patients in the upstream units. These patients continued to arrive, starting midnight, and demand inpatient beds based on a non-stationary Poisson arrival rate per hour of day. They were held in a queue (to emulate boarding) until an inpatient bed was available, at which point, after some delay for transportation to the unit, the first waiting patient from the queue seized the bed.

To model a specific n-by-T strategy, we modified the validated simulation model such that the flow of the first n patients (among those who are to be discharged that day) was altered, and those patients were simply assigned a discharge completion time (hour of day) with a triangular distribution; e.g., if T = 10 a.m., then Triangular(8, 9, 10) hr, and if T = 12 noon, then Triangular(9, 10.5, 12) hr. By changing the number of extra beds available at midnight to model the occupancy rate of the unit (e.g., 85% occupancy means approximately 18 of 21 beds occupied; i.e., 3 extra beds available at the start of the day), we were able to evaluate the impact of the variants of n-by-T on completion and boarding times under different levels of unit occupancy.

We used AnyLogic v7.2 (The AnyLogic Company, St. Petersburg, Russian Federation) to develop the discrete-event simulation model. The model was validated individually via face validation by the research team and KMC personnel, and via external validation by statistically comparing if the simulated values reasonably matched KMC's data [19].

Phase 2: Pilot Implementation at the Unit

The promising results derived from the simulation of the *n*-by-*T* strategy in Phase 1 (discussed in the Results section) encouraged the hospital to implement a pilot of one of the variants, the 2-by-12 strategy, in their trauma unit. The pilot period was between June and December of 2014. This pilot was meant to identify requirements for a structured implementation study to be conducted later. Essentially, the unit nurse tried to work with her nursing staff in order to identify 2 patients at the beginning of their shift (usually 7 a.m.) and make an effort to get the attending surgeons to sign off on the discharge orders immediately. That would leave them 2-3 hours to finish the discharge processes relevant to those 2 patients in an effort to discharge them by 12 p.m. (noon). This was not possible every day owing to several reasons (discussed later in the Discussion section). We were provided with the implementation data for analysis by the unit staff. Statistical tests were used to compare the actual outcome measures for the days on which the target strategy was successfully implemented with those prior to the implementation period (Jan-May, 2014).

Results

Phase 1: Modeling the Current System

We first analyzed the current discharge process at the trauma unit. We were provided with 1789 unique patient records for the year 2013, out of which 1604 records had all the relevant data elements for our study. Figure 2 displays the following two phenomena: (i) for patients who are discharged on a given day, the corresponding distribution of order writing times and inpatient discharge times by hour of day, and (ii) the arrival rate of inpatient bed requests from upstream units. Notice that discharge orders get written starting in the morning and often leading into the afternoon, a trend that is likely to exist in many trauma or surgical units. Consequently, the beds also get released throughout the day, with mean discharge completion time occurring during late afternoon (16.2 hr; median = 16.27 hr). The resulting mean boarding for upstream patients arriving throughout the day was calculated from the actual data as 2.41 hr (median = 1.63, s.d. = 2.16). We also noticed that the discharge process length distribution was not identical throughout the day and depended heavily on when the physician wrote the discharge order; long for mornings and short for after 3 p.m. The simulation model, which used the inputs based on actual data at the trauma unit (Table 1) to emulate the current system, was able to capture the complex dynamics of the inpatient unit reasonably well based on discharge completion and boarding time statistics (Table 2). Considering the schedules before and after 7 a.m. (shift change), the transportation time from the upstream unit to the inpatient unit was modeled as TRI(0.25,1.5,6.0) and TRI(0.25,0.75,4.0) hrs, respectively.

Phase 1: Modeling the Effects of *n*-by-*T*

We next captured the distributions of discharge completion time generated by several specific instances of the *n*-by-*T* strategy using the validated simulation model (Figure 3). Note that *n* patients were guaranteed to be discharged prior to the set time each day, essentially resulting in a different distribution for these patients compared to the rest. This is evident from the switch in discharge completion time distribution from unimodal (as observed in the current unit) to bimodal. Notice that the peaks in the distributions for when n=1 and n=2 are different, and that only a marginal change was observed when *T* changed for a given *n*. That is, the mean completion time for cases when n=1 and n=2 (10 a.m. $\leq T \leq$ noon) were in the ranges 14.59–14.82 hr and 13.03–13.48 hr, respectively; an advancement of 1.38–1.61 hr and 2.72–3.17 hr when compared to the mean of 16.2 hr for the current strategy. Figure 4 depicts this in terms of hours advanced in the mean discharge completion times. The mean boarding times were around 2.13 hr and 2.04 hr, a reduction of 11.6% and 15.4%, respectively, over the current strategy (mean of 2.41 hr). While these benefits were reasonably high, they remained relatively unaltered irrespective of the value of *T* (between 10 a.m. and noon), as the mean discharge completion times changed very little during this time-frame.

We also estimated an increase in annual inpatient bed hours due to advancement in the mean discharge completion time. Based on annual 1789 discharges per year at this unit, the 1-by-*T* strategies (10 a.m. $\leq T \leq$ noon) suggested an increase in 2469-2880 inpatient bed hours annually (corresponding to the advancement in the mean discharge completion times); this number increased to 4866–5671 bed hours with 2-by-*T* strategies. The corresponding increase in the upstream bed hours were nearly 500-662 hours annually for these two sets of strategies.

Phase 1: Modeling the Robustness of *n*-by-*T* to Occupancy Rate

While the above results corresponded to the unit's mean occupancy rate of 85%, the unit managers indicated that it varied throughout the year with some weeks nearing 100%. We, therefore, evaluated how occupancy rate of the unit would impact the performance of the *n*-by-*T* strategy (in particular, the 2-by-*T* of specific interest to the unit). Intuitively, changes in the occupancy rate (availability of empty beds at midnight) directly affect the rate at which new bed requests occupy empty inpatient beds (hence, boarding time) and does not affect the inpatient process to discharge patients (hence, mean discharge completion time) for a given *n*-by-*T* strategy. Table 3 shows the changes in the boarding times for occupancy rates ranging between 80% and 100%, for both 2-by-10 and 2-by-12 strategies. While 2-by-12 already would offer over 12% in boarding time reduction compared to the current system at 85% occupancy, this relative reduction would double (26.1%) during days (or weeks) when the unit experiences 100% occupancy; the corresponding upstream bed hours increased from 519 to 3238 hours.

Phase 2: Analysis of Pilot Implementation

The above findings encouraged the hospital to conduct a pilot implementation of the 2-by-12 strategy in the same trauma unit during June-Dec 2014. Figure 5 indicates that the total weekly discharges by noon collected from the hospital's electronic health record increased by 2.4 discharges/week during the pilot when compared to the pre-implementation phase (152 days). A deeper analysis of the pilot data revealed that the unit was able to realize 2-by-12 only 12.67% of the total days (27 out of 213 days). Table 4 summarizes the outcomes for only these 27 days of successful pilot implementation compared to the pre-implementation outcomes. The distribution of the discharge completion times was found to be significantly different than that realized during the pre-implementation stage (p-value < 0.0001; Kolmogorov-Smirnov test); the strategy advanced the mean discharge completion time by nearly 2 hours per patient. Further, mean boarding time was also found to be significantly lower (p-value = 0.0269; Kolmogorov-Smirnov test); the strategy reduced boarding time by nearly 15%.

Discussion

With inpatient flow pathways greatly impacting hospital operations and unnecessary delays, care coordination between intra-organizational operations and units becomes critical. In particular, the daily discharge of inpatients, a multi-step process, requires strong coordination among care providers in the unit (e.g., physicians, nurses, social workers, and case managers) and supporting processes and technology, while accounting for patient-specific factors, with implications on care quality, safety, and cost [20, 21]. We noticed through job shadowing at a trauma unit that physician order writing times and discharge process durations were largely responsible for delays at that unit. While it is well-established that discharge timing of inpatients affects upstream boarding, no known approaches are available to suggest how best to advance the discharges. To this extent, we proposed a novel *n*-by-*T* target strategy that care providers could aim for every day, resulting in both advancing of dischage completion times and reducing boarding times. In particular, the 2-by-10 and 2-by-12 strategies were of special interest to this hospital. These strategies were considered during a pilot implementation, which confirmed the benefits (mean discharge time advanced by 2 hours and boarding reduced by 14.5%). Clearly, a target strategy such as the *n*-by-*T* provides a clear and easy guidance to the care providers in order to execute prompt release of inpatient beds for patients waiting upstream.

Our findings corroborate with previous research that focuses on inpatient discharge planning. In particular, we noticed a strong relationship between rising hospital occupancy and increasing ED length of stay [9]. We noticed that as the trauma unit became busier (i.e., occupany rate increased), the benefits from the *n*-by-*T* strategy became more prominent (ranging from 6-28% based on occupancy rate). During a 100% occupancy rate, no empty beds would be available in the inpatient unit for the first few bed requests that arrived between midnight and mid-morning (say 9 a.m.), causing them to accrue significant boarding. For less than 100% rates, there would always be one or more empty beds, minimizing boarding of the first few bed requests. We further confirmed previous observations that shifting the discharge distribution curve earlier in the day could mitigate ED boarding [15,22]. The resulting bimodal distribution of the discharge times, which is intuitive, causes the mean distribution time to shift toward the earlier part of the day (often by over 2 hours). The benefits of the *n*-by-*T* strategy on increasing the capacity-based measures (i.e., availability of inpatient and upstream bed hours) are worth noting. An increase in the number of inpatient bed hours can be significant, as these highly-demanded and expensive beds would now be available to schedule additional patients (e.g., electives or transfers). Similarly, an increase in the bed hours at upstream units (e.g., ED, ICU, PACU) means patients in those units no long occupy such beds for unnecessarily long time. This means a reduction in waiting or crowding at these units. In some sense, the proposed *n*-by-*T* target discharge strategies allow for prompt release of medically-ready patients, making way for sicker patients in the upstream waiting.

The pilot confirmed the findings of our simulation model both in terms of advancing discharges and reducing boarding times. The nursing manager noticed that while the 2-by-12 target strategy helped, to some degree, avoid a rush in the afternoon to execute planned discharges, it also gave her the ability to better schedule her nurses during the day, potentially avoiding costly overtimes. We also noticed that during pre-implementation only 4.16% of all patients were discharged by 12 noon based on the actual data from the unit; it increased to 29.78% for 2-by-12, clearly indicating the impact of these target strategies.

While the benefits were clear, the challenges during implementation could not be overlooked. First, identifying the two patients to be discharged earlier in the day could be challenging. The unit runs a daily nursing huddle, so the nurses know for the most part who are likely to be discharged the following day and what activities would be involved. However, recording this diligently every day and helping the involved nurse to coordinate with the physician, social worker, consulting physician, and other support services the following morning can be challenging. It was noticed that timely completion on behalf of the consulting physician was a major challenge. Second, the disposition type could lead to difficulties in the inpatient emptying the bed in a timely manner (e.g., delays from family member to pick up the inpatient, or unexpected delays from insurance company on pre-certifications). Finally, nurses in the unit expressed a desire for continuous feedback that would enable them to evaluate their performance each day in light of the target and show the improvement over the original unit. Provision of appropriate training and education to all providers in the unit, along with an appropriate system to continuously monitor the status of the unit, would help mitigate some of these problems and increase daily compliance to a specific *n*-by-*T* strategy for consistent benefits. We further note that during high unit occupancy, even though literature suggests that individuals tend to speed up their processing, the possible necessity of additional staffing and the resulting cost implications should be considered carefully against the benefits when implementing this target strategy.

Our research study design and findings, however, must be viewed in light of the following limitations. First, we assumed a typical day for our modeling purposes. However, our model can easily incorporate trends and seasonalities corresponding to a specific day of week, week of month, or even month of year. Second, we assumed that the newly admitted patients will be transferred to the inpatient trauma unit using a first-come-first-serve queuing discpline. However, this may not be the case where certain patients may have to be fast-tracked if they require immediate care. Third, the limited data did not allow us to incorporate and subsequently evaluate the effects of the support service processes. Fourth, the avaialability of daily occupancy rates did not aid us in establishing (i) if the number of patients to be disharged on a given day was correlated to unit occupancy, and (ii) if discharge process times were truly dependent on time-of-day or based on other system state (current load or congestion). Fifth, we assumed in the model that all other medically-ready patients to be discharged on a given day, but not part of the *n*-by-*T* strategy, will continue to experience processes and times similar to the current system. Finally, we focused on a trauma unit, a specialized inpatient unit at the hospital. The generalizability of our findings would need to be evaluated across both medical and surgical units across geographically disparate hospitals.

Our study was both confirmatory and exploratory. We confirmed previous findings that the completion time of inpatient discharges has an impact on the boarding of patients being admitted from upstream units. We explored the impact of the proposed *n*-by-*T* strategy as a clear target for providers in the unit to better plan and execute daily discharges. This strategy, in some sense, is a combination of early order writing and shorter discharge process times on a select set of patients in an effort to release inpatient beds earlier in the day. This was shown through our experiments and via a pilot implementation to mitigate upstream boarding. Other perceived benefits of the pilot, but not recorded and quantified, included reduction in discharge delays and improved bed utilization at both upstream and inpatient units.

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