The Financial Consequences of Lost Demand and Reducing Boarding in Hospital Emergency Departments

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Study objective: Some have suggested that emergency department (ED) boarding is prevalent because it maximizes revenue as hospitals prioritize non-ED admissions, which reimburse higher than ED admissions. We explore the revenue implications to the overall hospital of reducing boarding in the ED.

Methods: We quantified the revenue effect of reducing boarding—the balance of higher ED demand and the reduction of non-ED admissions—using financial modeling informed by regression analysis and discrete-event simulation with data from 1 inner-city teaching hospital during 2 years (118,000 ED visits, 22% ED admission rate, 7% left without being seen rate, 36,000 non-ED admissions). Various inpatient bed management policies for reducing non-ED admissions were tested.

Results: Non-ED admissions generated more revenue than ED admissions ($4,118 versus $2,268 per inpatient day). A 1-hour reduction in ED boarding time would result in $9,693 to $13,298 of additional daily revenue from capturing left without being seen and diverted ambulance patients. To accommodate this demand, we found that simulated management policies in which non-ED admissions are reduced without consideration to hospital capacity (ie, static policies) mostly did not result in higher revenue. Many dynamic policies requiring cancellation of various proportions of non-ED admissions when the hospital reaches specific trigger points increased revenue. The optimal strategies tested resulted in an estimated $2.7 million and $3.6 in net revenue per year, depending on whether left without being seen patients were assumed to be outpatients or mirrored ambulatory admission rates, respectively.

Conclusion: Dynamic inpatient bed management in inner-city teaching hospitals in which non-ED admissions are occasionally reduced to ensure that EDs have reduced boarding times is a financially attractive strategy. [Ann Emerg Med. 2011;58:331-340.]

Please see page 332 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Emergency department (ED) crowding has been identified as a public health problem by the Institute of Medicine.[1] When EDs are crowded, patients leave without being seen and some later return for urgent medical needs.[2-4] Ambulance diversion, a hospital's response to crowding, can delay care for time-sensitive diseases, including thrombolysis for acute myocardial infarction.[5] ED "boarding" is one of the major causes of ED crowding, in which admitted ED patients spend long periods awaiting inpatient beds.[6-8] As boarding increases within an ED, fewer ED resources are available for new patients, which leads to delays in antibiotic administration for pneumonia and pain control and to higher complication rates.[9-12] One study estimated that 15% of the overall time spent in US EDs was by patients boarding.[13] Boarding itself is associated with higher medical error rates and has proven hazardous for patients admitted to intensive care settings.[14-17]

Importance

A recent discussion has begun in academic medical journals and the lay press about whether the practice of ED boarding may actually increase a hospital's revenue.[18,19] Overflow capacity in ED hallways can be used as a temporary holding area, allowing the hospital to operate at higher occupancy than it has in licensed beds. Concerns have been raised that hospitals have perpetuated ED boarding because of insufficient economic incentive to eliminate it. However, data have been mixed. Some studies suggest that the economic effect of ED crowding and

Editor's Capsule Summary

What is already known on this topic

Emergency department (ED) boarding is common in US hospitals and has been associated with poor outcomes. Perceived revenue implications have been proposed as a contributing factor.

What question this study addressed

Whether the practice of boarding increases revenue in general and which strategies can be implemented to reduce ED boarding while maintaining the highest possible hospital revenue.

What this study adds to our knowledge

Reducing ED boarding can increase or decrease hospital revenue, depending on the way the hospital handles the scheduling of non-ED admissions. Solutions that reduce non-ED admissions across the board to accommodate higher ED demands may not enhance overall revenue, whereas those that reduce it through active bed management strategies may dramatically increase revenue.

How this is relevant to clinical practice

When seeking solutions to improve hospital flow, hospital managers can craft approaches that balance the need for proportional and targeted actions on all sources of admissions (ie, reducing boarding and better managing non-ED admissions).

diversion is lost revenue as patients leave without being seen and ambulance patients are directed elsewhere.[20,21] Others conclude that ED crowding and diversion maximizes revenue because ED admissions generate less revenue than non-ED admissions.[22] In a situation in which there is plentiful demand for both ED and non-ED admissions, crowded EDs may allow hospitals to prioritize inpatient beds for elective (non-ED) patients from whom hospitals can collect higher reimbursement.[23,24] During weeks of high diversion, one hospital collected $265,000 more in revenue than during weeks of low diversion.[25] The key tradeoff lies in balancing increased revenue from capturing lost ED demand (decreasing left without being seen and diversion) versus the potential lost revenue from reducing non-ED admissions to open capacity to serve higher ED demand.

Goals of This Investigation

We examined the tradeoff between the higher revenue from capturing ED demand versus potential losses from reducing non-ED admissions by simulating what may happen to hospital revenues if average boarding is reduced by an hour. We also determined how different bed management policies for reducing non-ED admissions to accommodate additional ED demands would affect hospital revenue. Our overall goals were to determine whether reducing boarding increases or decreases hospital revenue and how a hospital could potentially better manage non-ED demand to ensure that reducing boarding would result in increased revenue.

MATERIALS AND METHODS

Study Design, Setting, and Selection of Participants

A stepped approach was used to estimate the revenue implications of the balance between reducing boarding and the need to reduce non-ED admissions to accommodate new ED demand (left without being seen and diversion). We first calculated the expected value of lost ED demand, specifically the expected revenue from serving additional left without being seen patients and patients who were diverted to other hospitals. We then calculated the expected value of revenue change from reducing the mean boarding time by 1 hour, using 2 methods: (1) a financial model informed by the results from regression analyses, and (2) a discrete-event simulation model to validate and extend the first analysis by simulating how specific types of inpatient bed management policies (with regard to reducing the inflow of non-ED admissions) may increase revenue (or not).

In the simulation, we calculated the percentage reduction in non-ED admissions necessary to serve the increased number of ED admissions that would result from reducing boarding with 2 potential bed management policies. First, we estimated how reducing non-ED admissions by a fixed proportion would affect overall revenue. This was termed a "static" policy. Next, we estimated how various types of "dynamic" management policies affected revenue. Dynamic policies were defined by 2 parameters: the proportion of reduction in non-ED admissions and the specific trigger point (ie, the bed number at which a reduction would be deployed). Various static and dynamic bed management strategies were tested to determine which allowed the ED to maintain current service levels and which, if any, resulted in higher overall revenue at the hospital level.

The data included for the calculations were all ED patients registered and all non-ED patients (direct admissions and transfers) admitted to a single, inner-city teaching hospital during a 2-year period (fiscal year 2007 to 2008). Excluded were patients admitted to inpatient rehabilitation, psychiatry, and labor and delivery because they are not treated in the study ED and do not compete directly with ED patients for inpatient beds. Also included were actual data on ambulance diversion (separated by medical and trauma) during the study period. Left without being seen patients were included if they were triaged, and each had a triage level that was used for analysis. Patients who left before treatment was complete or left against medical advice were included as treated and discharged patients because they still resulted in revenue.

For each ED patient, we used data on arrival date, time, and mode (ambulance versus nonambulance), triage level, disposition, and actual revenue received. We used timestamps for patient movement through the ED: earliest arrival, placement in treatment room, inpatient bed request, and departure from the ED. From these timestamps, durations were calculated for wait time (earliest arrival until room placement), service time (room placement to departure for outpatients or bed request for admitted patients), and boarding time (bed request to departure for admitted patients). Timestamps were obtained directly from the electronic medical record, which stores timestamps in real time as a regular part of ED workflow.

Outcome Measures

The main outcome was direct revenue. Indirect revenue, including federal payments to support resident education, was not included. We did not include direct or indirect costs and assumed that hospital costs were largely fixed.[26] Therefore, we did not calculate actual contribution margins or profitability because cost allocation methods vary widely between hospitals. Therefore, changes in revenue served as a proxy for changes in hospital profitability. Revenue was classified by the patient type, not by where the revenue charge was incurred. For example, the total revenue generated from a patient who began a visit in the ED and was then admitted for 3 days would be classified as ED-admission revenue.

Primary Data Analysis

To quantify the revenue lost by left without being seen and diversion, we estimated the expected value of left without being seen patients and both medical and trauma diversion hours. The expected dollar value of a left without being seen patient was estimated by the following weighted sum:

$$E[LWBS] = \sum_{i=1}^{4} \Pr(\mathit{Triage\ Level}_i)\Big[\Pr(\mathit{admit}_i)E\big[\text{Revenue}_{admit_i}\big] + (1-\Pr(\mathit{admit}_i))E\big[\text{Revenue}_{out_i}\big]\Big]. \quad (1)$$

Triage level probabilities were calculated from observed left without being seen patients. Because there were no data on admission rates for left without being seen patients had they remained for treatment, we used the admission rates for ambulatory patients, conditional on triage level, as a proxy for left without being seen admission rates because the majority of left without being seen patients are ambulatory. However, it is possible that because of self-selection, left without being seen patients would be less likely to be admitted than those who stayed. We therefore conducted a sensitivity analysis on the left without being seen admission rate and reported results for left without being seen admission rates that were assumed in the financial model to be half that of the observed population. However, later in the simulation, we tested an admission rate of zero for left without being seen and the triage-level adjusted rate because of the limitations of the simulation software. The annual lost revenue from left without being seen was obtained by multiplying the expected value of a single left without being seen patient by the number of left without being seen patients.

The value of an hour of medical diversion was calculated as the product of the expected revenue of a single medical ambulance arrival and the expected number of medical arrivals per hour. The value of a medical arrival was calculated similar to that for the left without being seen patients except that admission probabilities and expected revenues were estimated from medical arrivals. The expected ambulance arrival rate was estimated by dividing the number of medical arrivals by the number of hours the hospital was not on medical diversion during the study period. Annual lost revenue from medical diversion was calculated as the product of the expected value of an hour of medical diversion and the number of hours the hospital was on medical diversion in a given year. The value of trauma diversion was estimated similarly from trauma ambulance arrivals.

Next, we estimated the effect of boarding on revenue through 2 methods: first with a financial model informed by regression and second with discrete-event simulation. The regression method used ordinary least squares regression and drew on the relationship between the mean daily boarding and the number of daily left without being seen patients. Because the number of ED arrivals (ie, daily demand) influences both boarding times and left without being seen, we used the following model:

$$\mathit{CountLWBS\_Day}_t = \beta_0 + \mathit{AvgBoarding}_t \times \beta_1 + \mathit{CountArrivals}_t \times \beta_2 + \varepsilon_t \quad (2)$$

We used similar models for hours of medical and trauma diversion, replacing the count of left without being seen with the number of hours of diversion per day.

Because of the relatively low explanatory power in the relationship between boarding and left without being seen and diversion (R^2 of 0.43, 0.25, and 0.24, respectively, for left without being seen, medical diversion, and trauma diversion), discrete-event simulation was used to validate the estimates of the changes in boarding on revenue. Simulation was also used to extend the analysis to estimate how the increased inpatient load from the new ED demand would affect overall hospital operations; specifically, the potential reduction in non-ED admissions necessary to serve the new inpatient load generated by more ED admissions. With the simulation model, we created a virtual ED and hospital by using patient-level data to estimate probability distributions of patient flow. The model permitted us to change a parameter (ie, mean boarding time) and observe the effects on revenue.

The discrete-event simulation model had 3 ED arrival streams: medical ambulance, trauma ambulance, and ambulatory (Figure 1). Each stream was an independent Poisson arrival process estimated from data and designed to mirror ED operations. To simulate left without being seen behavior, we drew on abandonment and impatience models from queuing theory.[27] Each patient was assigned a maximum waiting time drawn from a probability distribution. A Weibull distribution with shape parameter greater than 1 was used to simulate increasing impatience.[28(p406)]

Diversion was triggered by queue length. After crossing a trigger point, the relevant arrival stream was diverted from the ED for 4 hours (which mirrored study hospital policy). After time expired, the arrival stream reopened if the queue length

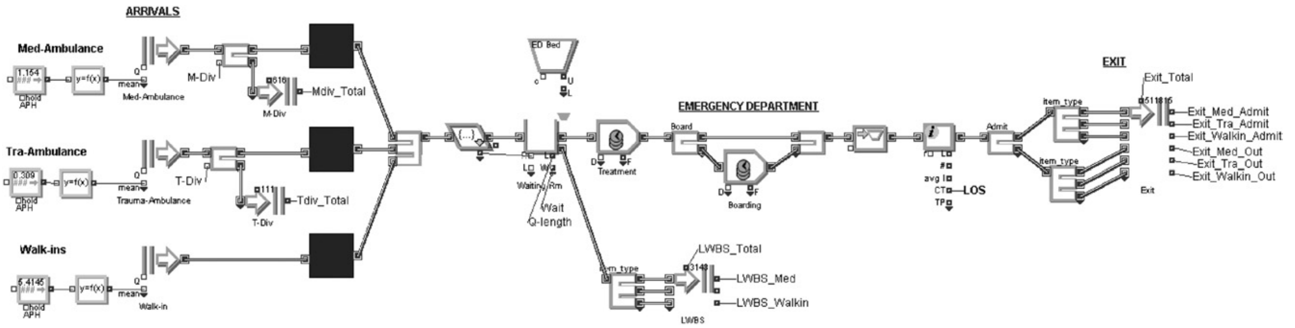

Figure 1. Discrete-event model of the ED.

Table 1. Descriptive statistics of the study population (fiscal year 2007 to 2008, by arrival type).

Arrival Type	Medical Ambulance	Trauma Ambulance	Walk-in
Count	17,856	4,914	92,462
Median age, y	46	38	36
Male, %	46	70	39
White, %	19	32	21
Black, %	70	55	66
Arrival rate, patients/h (SE)	1.12 (0.02)	0.30 (0.01)	5.41 (0.03)
Admit probability, %	34	57	18
Boarding probability, %	96	6	94
Service time for admitted patients			
Distribution type	γ	γ	γ
Scale	2.10	2.60	1.99
Shape	1.73	1.60	2.02
Mean (SD)	3.63 (2.74)	4.16 (4.33)	4.02 (3.07)
Median (IQR)	3.03 (3.06)	3.27 (3.11)	3.33 (3.25)
Service time for outpatients			
Distribution type	Gamma	Gamma	Gamma
Scale	3.19	5.96	3.53
Shape	1.59	1.24	1.06
Mean (SD)	5.07 (5.17)	7.39 (6.74)	3.74 (5.00)
Median (IQR)	3.85 (3.75)	4.98 (6.55)	2.57 (3.33)
Boarding time			
Distribution type	Weibull	Weibull	Weibull
Scale	3.64	3.19	3.52
Shape	0.955	0.936	0.891
Mean (SD)	3.73 (4.71)	3.30 (3.77)	3.75 (5.18)
Median (IQR)	2.34 (2.87)	2.03 (3.11)	2.19 (2.88)
Mean time in ED, h (SD)	6.2	6.5	6.0
LWBS, %	2	0	8
Time on diversion, %	9	7	NA
Mean revenue, $ (SD)	4,672 (12,350)	16,529 (36,370)	2,530 (9,849)
Median revenue, $ (IQR)	497 (6,031)	5,412 (15,351)	334 (742)

SE, Standard error; *SD,* standard deviation; *IQR,* interquartile range; *LWBS,* left without being seen.

was below the trigger point; otherwise, another 4 hours of diversion occurred.

Most parameters were estimated directly from the study data (Table 1). However, several parameters could not be directly estimated: abandonment time distributions, diversion triggers, and number of beds. Therefore, we used sensitivity analysis and an evolutionary optimizer to tune the model to match the real results, and independence was verified between simulation samples by checking for autocorrelation with the Portmanteau test, which found no significant autocorrelation.

The simulation compared a base model with a model in which the mean boarding time was reduced by 1 hour (by reducing the scale parameter in a Weibull distribution). When comparing simulations, we used a paired-*t* confidence interval (CI).[29] To estimate the revenue effects from the changed model, the estimated change in the number of patients served per day by type was multiplied by the expected revenue for each given patient type.

Next, we estimated the reduction in non-ED admissions that would be required if boarding were reduced. Reducing boarding creates additional demand for inpatient beds in 2 ways: ED-

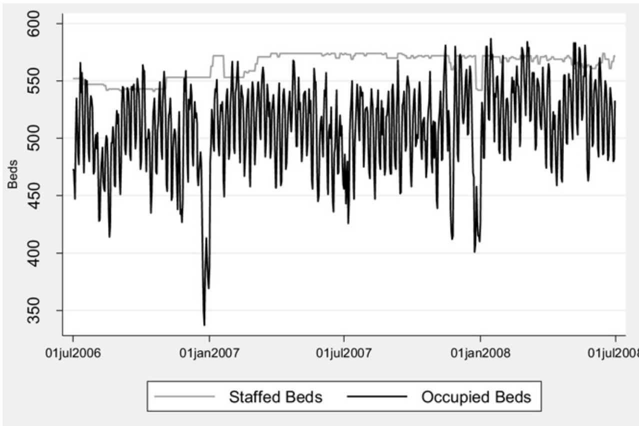

Figure 2. Hospital census during the study period.

admitted patients move to inpatient beds earlier, and lower boarding reduces lost demand (diversion and left without being seen), increasing ED admissions. The required reduction of non-ED admissions depends on the degree to which the overall hospital is capacity constrained (ie, the number of beds available on any given day). Consider 3 scenarios:

1. Inpatient beds are not capacity constrained. In this scenario, the hospital can serve the new demand without any cancellations or reductions. It is implicit that boarding is not directly caused by a lack of inpatient beds (as is frequently assumed[30]) but results from other inefficiencies.
2. Inpatient beds are completely capacity constrained. In this case, each patient-hour of increased ED demand from lower boarding and higher ED admissions would require elimination of a patient-hour of non-ED admission.
3. Inpatient beds are periodically capacity constrained. If the hospital is not always at capacity, only a portion of new demand would necessitate reductions of non-ED admissions.

The first 2 scenarios serve as boundaries to the potential financial outcomes from reducing boarding (ie, best and worst case scenario). The third scenario is of primary interest, and simulation was used to test how various non-ED admission reduction policies would allow the hospital to serve the increased ED demand and maximize estimated revenue. Policies tested included a simple across-the-board reduction of the non-ED admission rate (ie, a static model) and dynamic policies that actively scaled back non-ED admissions by specific proportions only when the hospital census was above a given trigger point.

To test these policies, we assumed a hospital capacity of 565 beds, which was the average staffed-bed capacity of the study hospital (Figure 2). Capacity data were calculated from actual arrivals and departures of ED and non-ED admissions. Staffed beds were determined from random daily snapshots of hospitals' staffed beds with Navicare software (Hill-Rom, Batesville, IN), the management tracking system for staffed beds and census.

We first determined in a base-case model the proportion of ED admissions who boarded in the ED directly because of capacity constraints (ie, no appropriate bed was available). This served as the service-level target for all potential scheduling policies. Mean boarding time was then reduced by 1 hour and the service level for a total of 80 potential policies was measured (10 static and 70 dynamic policies). The first question was whether a policy matched or exceeded the service level, determined as a policy in which no additional inpatient capacity would be needed. We then simulated the increase or decrease in daily revenue from the increase in ED demand and reduction policy for non-ED admissions. The objective was to find the non-ED admission policy or set of policies that would match or exceed the target service levels and maximize net revenue gains under the reduced boarding scenario.

Analyses were performed with Microsoft Excel 2007 (Microsoft, Redmond, WA), Stata (version 10; StataCorp, College Station, TX), ExtendSim (version 8; Imagine That Inc., San Jose, CA), and JMP (version 8.0; SAS Institute, Inc., Cary, NC). This study received approval from the institutional review board.

RESULTS

Characteristics of Study Subjects

A total of 92,456 ED outpatients, 25,753 ED admissions, and 36,393 non-ED admissions were used for analysis during 2 years. Median hospital length of stay for ED and non-ED admissions was 3 days. Mean revenue for ED outpatients was $647, ED admissions $2,268 per patient-day, and non-ED admissions $4,118 per patient-day (Table 2).

There were 3,186 left without being seen encounters during fiscal year 2007 and 3,845 during fiscal year 2008. The expected value for 1 left without being seen patient was $1,096, assuming admission of left without being seen patients occurs at half the rate of the observed ambulatory population, conditional on triage level. In sensitivity analysis, when all left without being seen patients were outpatients, the expected value was $478, and when left without being seen patients were admitted at the same rate as those who stayed by triage level, the expected value was $1,714. Treating all left without being seen patients (assuming an admission rate of half the observed ambulatory rate) would have resulted in an additional $3.5 million in revenue in fiscal year 2007 and $4.2 million in revenue in fiscal year 2008.

There were 618 and 1,020 medical diversion hours and 479 and 794 trauma diversion hours in fiscal year 2007 and fiscal year 2008, respectively. During off-diversion times, there were 1.2 nonambulance arrivals per hour for medical patients and 0.3 ambulance arrivals per hour for trauma patients. The expected revenue for a medical ambulance arrival was $4,670 and the expected revenue for a trauma arrival was $16,526. The expected lost revenue from 1 hour of medical diversion was $5,388 and the expected lost revenue from each hour of trauma diversion was $5,110. Medical diversion resulted in forgone revenue of $3.3 million and $5.5 million in fiscal year 2007 and fiscal year 2008, respectively. Trauma diversion resulted in $2.4 million and $4.1 million in forgone revenue in fiscal year 2007 and fiscal year 2008, respectively. The overall estimated lost

Table 2. Descriptive statistics of the study population in a single hospital during a 2-year period (fiscal year 2007 to 2008).

Variables	ED Outpatients	ED Admissions	Non-ED Admissions
Patient count (%)	92,456 (60)	25,753 (17)	36,393 (24)
Revenue, $, millions (%)	59.8 (5)	338.7 (26)	929.2 (70)
Mean length of stay, days (SD)	N/A	5.8 (9.1)	6.2 (9.4)
Median length of stay, days (IQR)	N/A	3 (4)	3 (5)
Median revenue/patient per day, $	647	2,268	4,118
Median revenue/patient per day, $ (IQR)	226 (425)	2,242 (1,966)	3,556 (5,482)

N/A, Not applicable.

Table 3. Changes in number of patients served with 1-hour reduction in mean boarding and expected revenue.

Variables	Change in Mean Patients Served (SE)	Expected Revenue per Patient, $ (SE)
ED medical ambulance admission	0.35 (0.02)	12,296 (235)
ED trauma ambulance admission	0.11 (0.01)	24,352 (856)
ED ambulatory admission	0.00 (0.01)	11,704 (159)
ED medical ambulance outpatient	0.85 (0.03)	723 (32)
ED trauma ambulance outpatient	0.09 (0.01)	6,361 (319)
ED ambulatory outpatient	2.81 (0.04)	499 (6)

revenue from lost demand was $9.3 million for fiscal year 2007 and $13.8 million for fiscal year 2008.

For the 25,753 ED admissions in fiscal year 2007 and fiscal year 2008, the mean boarding time was 3.7 hours (SD 5.2 hours), and median boarding time was 2.2 hours (interquartile range 1.1 to 4.1 hours). A 1-hour change in average boarding time was associated with a change of 1.1 (95% CI 0.9 to 1.3) patients per day who left without being seen. Regression analyses found that a 1-hour reduction in average boarding time was associated with a reduction of 1.2 hours per day (95% CI 0.9 to 1.5 hours) in medical diversion hours and 0.7 hours per day (95% CI 0.5 to 1.0 hours) in trauma diversion hours. Using the estimated values of left without being seen and diversion, a 1-hour reduction in average boarding time would increase revenue by $11,301 per day. This estimate ranged from $10,628 to $11,974 as the left without being seen admission rate assumption was varied from 0% to the observed ambulatory admission rate. In the simulation, if all left without being seen patients were outpatients, this would result in $9,693 increased revenue per day, or $3.5 million per year. When left without being seen admission rates mirror ambulatory admission rates, reducing boarding by an hour would increase revenue by $13,298 per day, or $4.9 million per year. The estimated values used in the simulation for each patient type according to the study data are listed in Table 3.

A 1-hour reduction in mean boarding led to an increase in inpatient bed demand of 4.4 bed-days per day (1.3 days for reducing boarding and 3.1 days for accommodating additional ED admissions). Assuming that inpatient beds are never capacity constrained, reducing boarding by an hour would increase hospital revenue by $3.5 million per year and require no reduction in non-ED admissions. Assuming that inpatient beds are always capacity constrained, the new inpatient demand would necessitate non-ED admission cancellations worth $18,172 per day. The hospital would therefore experience a net revenue reduction of $8,479 per day, or $3.1 million per year if it reduced mean boarding time by 1 hour in a completely capacity-constrained situation.

In the scenario that inpatient beds are intermittently capacity constrained, the financial results depend on the non-ED admission policy. Tables 4 and 5 demonstrate the daily change in revenue under different static and dynamic bed management policies. In the case in which left without being seen patients are considered outpatients, 1% reduction in ED admissions or lower did not meet current service levels, and there were no static policies that resulted in increased revenue for the hospital. The 70 dynamic policies tested ranged from trigger censuses of 530 to 560 beds and a 1% to 10% reduction. Of those, 55 met current service levels and 35 policies would result in higher revenue. The optimal strategy was a 5% reduction in non-ED admissions at 560 beds, resulting in $7,418 higher revenue per day, or $2.7 million per year (Figure 3). In the case in which left without being seen patients were admitted at the ambulatory admission rate, all static policies met current service levels and a 1% reduction in non-ED admissions was the only higher revenue policy, resulting in $612 in greater revenue per day, or $223,000 per year. Of the 70 dynamic policies tested, 25 met current service levels, and of those, 14 would result in higher revenue. The optimal strategy was an 8% reduction at 555 beds, resulting in $10,009 per day, or $3.6 million per year.

LIMITATIONS

A major limitation of our study is that we used data from a single hospital. Other hospitals with different processes may experience different revenue effects than we found.[31] For example, Massachusetts hospitals that are by law no longer permitted to go on diversion may experience smaller gains from

Table 4. Non-ED admission policy comparison for net change in revenue caused by 1-hour average ED boarding reduction, in which left without being seen patients are all ED outpatients.*

Non-ED Admission Reduction Percentage	Static Policy: No Trigger	Dynamic Policies: Trigger Census at Which Reduction Is Implemented						
		530	535	540	545	550	555	560
1%	(2,993)†	5,112†	6,060†	6,939†	7,717†	8,302†	8,768†	9,140†
2%	(15,679)	1,156	2,889	4,614	5,974	7,087†	7,971†	8,637†
3%	(28,365)	(2,469)	120	2,339	4,452	5,933	7,198†	8,190†
4%	(41,051)	(5,984)	(2,466)	719	2,869	5,029	6,533	7,719†
5%	(53,738)	(9,121)	(4,842)	(1,049)	1,713	4,104	5,912	7,418
6%	(66,424)	(12,094)	(6,961)	(2,885)	917	3,315	5,415	7,078
7%	(79,110)	(14,174)	(9,179)	(4,735)	(479)	2,512	4,768	6,649
8%	(91,796)	(16,698)	(11,433)	(5,983)	(1,315)	1,742	4,121	6,293
9%	(104,483)	(19,100)	(12,700)	(7,505)	(2,670)	1,072	4,029	6,069
10%	(117,169)	(21,099)	(14,474)	(9,146)	(3,803)	510	3,412	5,694

*Maximum hospital capacity is 565 beds. Compares static policies in which non-ED admissions are reduced across the board versus dynamic policies in which non-ED admissions are reduced by specific percentages at specific trigger censuses. Values represent increase (or decrease) in daily revenue from the policy.
†Policies that require additional bed capacity. All other values can be achieved with no increase in bed capacity. All values are in dollars.

Table 5. Non-ED admission policy comparison for net change in revenue caused by 1-hour average ED boarding reduction; left without being seen patients are admitted at rates mirroring those of patients who stayed for care.*

Non-ED Admission Reduction Percentage	Static Policy: No Trigger	Dynamic Policies: Trigger Census at Which Reduction Is Implemented						
	0	530	535	540	545	550	555	560
1%	612	9,540†	10,433†	11,242†	11,793†	12,357†	12,695†	12,963†
2%	(12,074)	6,140†	7,758†	9,327†	10,432†	11,454†	12,181†	12,694†
3%	(24,760)	3,244†	5,631†	7,518†	9,429†	10,742†	11,785†	12,436†
4%	(37,447)	403	3,592†	5,895†	8,344	9,955	11,367†	12,122†
5%	(50,133)	(2,039)	1,629	4,503†	7,444	9,654	10,782†	11,918†
6%	(62,819)	(4,085)	136	3,379	6,186	8,777	10,366†	11,842†
7%	(75,505)	(6,210)	(1,656)	2,066	5,644	8,229	10,076†	11,485†
8%	(88,191)	(8,146)	(3,398)	879	4,617	7,891	10,009	11,324†
9%	(100,878)	(9,793)	(4,512)	211	3,663	7,421	9,690	11,145†
10%	(113,564)	(12,185)	(6,040)	(1,233)	2,935	6,913	9,252	10,911†

*Maximum hospital capacity is 565 beds. Compares static policies in which non-ED admissions are reduced across the board versus dynamic policies in which non-ED admissions are reduced by specific percentages at specific trigger censuses. Values represent increase (or decrease) in daily revenue from the policy.
†Policies that require additional bed capacity. All other values can be achieved with no increase in bed capacity. All values are in dollars.

reducing boarding than hospitals that regularly divert ambulances. We found also that trauma arrivals resulted in considerably higher revenue than medical arrivals, which may not be observed in other hospitals. This may be explained by local factors, such as negotiated agreements with payers, or the fact that in Pennsylvania (the site of the study hospital), a law requires 100% reimbursement of charges for worker's compensation trauma victims. In addition, because in this inner-city hospital ED patients were more likely to be uninsured and have Medicaid insurance than non-ED patients, there was a more than 1.5-fold difference between ED admission and non-ED admission revenue. In hospitals with more balanced payer mixes between ED and non-ED admissions, we would expect the potential revenue gains from reducing boarding to be higher. In addition, because this hospital was an inner-city hospital, the potential revenue losses from diversion would be expected to be higher because of the higher likelihood of penetrating trauma victims requiring operative management.

Our model was also simplistic in that we assumed bed pooling between specific types of beds (ie, pooling floor, telemetry, and intensive care), which may not reflect policies in other hospitals imposing stricter rules about segregating service lines within units. Restrictions on bed pooling would serve to reduce the gains from lower levels of boarding.[28] In addition, we assumed the staffed-bed capacity in our model to be fixed, which was not completely reflective of reality (Figure 2). Staffed-bed variability may be even greater in many hospitals, which may result in less unfilled staffed occupancy. We also made an assumption that hospital expenses are largely fixed, and we used revenue as our main outcome. The degree to which hospital staffing would need to be increased to accommodate the increased demand, particularly if more expensive temporary staffing was used, may decrease our estimates of the financial benefits of reducing boarding. Last, we did not directly calculate how reducing ED crowding and boarding may affect outcomes. Given studies that have demonstrated higher medical error rates and complications associated with crowding,[9-17] it is likely that the effect on outcomes such as lower complications and shorter lengths of stay would serve to further increase hospital revenues if boarding is reduced. It is also possible that reducing boarding

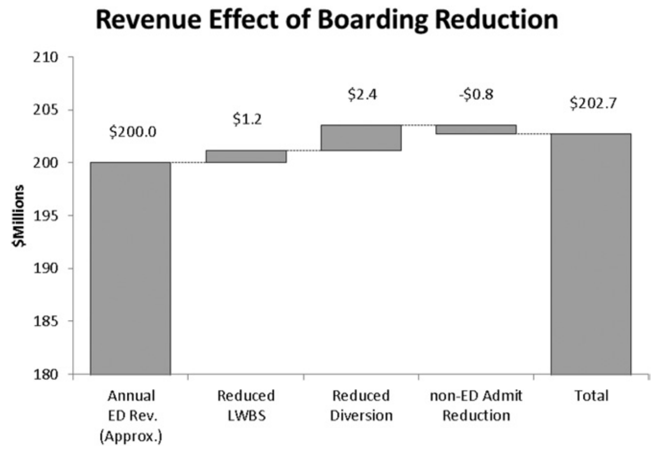

Figure 3. Changes in revenue caused by 1-hour reduction in mean boarding time. Annual ED revenue includes all revenue from both ED outpatients and ED admissions, which includes both ED and inpatient revenue. The increased revenue from leaving without being seen includes the additional captured revenue from fewer patients leaving without being seen when there are lower average boarding times. Similarly, increased revenue from diversion includes the higher number of ambulance arrivals that would occur with lower average boarding and subsequent revenues.

may have downstream effects, such as changing the likelihood of an emergency physician's decision to admit.

DISCUSSION

Studies on the revenue influences of boarding have shown mixed results.[20-25,28] The potential gains from reducing boarding have been estimated in some studies, whereas in others direct comparisons between ED admissions and non-ED admissions have been made that have shown that ED admissions are less profitable than non-ED admissions in broad populations. No studies have directly assessed the tradeoff between potentially lost revenue from left without being seen and diversion and the degree to which any reduction of boarding would necessitate lower numbers of financially attractive, non-ED admissions. We advance the understanding of this balance by demonstrating the potential revenue gains or losses under various conditions from reducing boarding by 1 hour, using data from a single hospital. Specifically, we demonstrate how overall hospital revenue can change dramatically according to the different policies used to manage hospital capacity by selectively reducing non-ED admissions on higher demand days to allow for decreased ED boarding times.

The 2 types of policies tested were static, reducing the average number of non-ED admissions per day, and dynamic, using active scheduling to strategically reduce non-ED admissions on higher-demand days. In the case in which left without being seen patients were outpatients, there was no static policy that allowed the ED to reduce boarding, maintain current service levels, and generate revenue gains, whereas in the case in which left without being seen patients are admitted at the ambulatory rate, a 1% across-the-board reduction was marginally revenue positive. This indicates that across-the-board reductions in non-ED admissions to improve the functioning of the ED are likely not a financially attractive strategy for hospital managers.

However, many dynamic policies allowed for a maintenance of the same non-ED admission rate, as long as the hospital census was below a given trigger point. Once the trigger point was reached, non-ED admissions would be reduced by a given percentage until the census decreased below the trigger point. Assuming that left without being seen patients are outpatients, the optimal dynamic policy called for a 5% reduction in non-ED admissions when the census reached 560, whereas, assuming their admission rate is the same as that of their triaged counterparts who stayed for care, the optimal policy would be an 8% reduction when the hospital census reached 555. During the study period, the hospital admitted approximately 50 non-ED patients a day, so a 5% to 8% reduction would require cancellation of approximately 2 to 4 non-ED patient appointments when the trigger census is reached. This assumes that patient appointments are cancelled and their revenue is lost forever; therefore, if patients could be rescheduled rather than cancelled, our findings may underestimate the lost revenue from non-ED patients.

Our results also show that a wide range of dynamic policies is acceptable and achieves relatively similar results. Hospital managers may have various reasons to select a particular policy (ie, one that favors a lower trigger or a lower reduction rate). There is also a tradeoff that certain trigger rates would require hospitals to spend more days in a "non-ED admission reduction mode." Higher administrative costs, customer service concerns, or the response from inpatient services who gain more revenue from non-ED admissions may also play into which particular active management plan is chosen.

This study also provides evidence that calls into question the commonly held belief that boarding is largely caused by a lack of inpatient beds.[31] In the simulation, increases in ED admissions were accommodated on most days without any change to non-ED admissions, and the staffed beds were mostly higher than the hospital census (Figure 2). In fact, reducing boarding rarely pushes existing patients out, assuming that the hospital is making best use of its staffed space, which may not be the case. Under the various policies tested, reducing non-ED admissions was required only 3% to 20% of the time, suggesting that much of observed ED boarding times may not have been caused by a lack of physical beds, but rather by other inefficiencies in the system that slow transitions of care between hospital units or requirements that specific units house specific types of patients (ie, the gastroenterology patients can be on only one hospital unit), with little pooling between similar types of beds. Future studies in managing hospital capacity should study the effect of pooling and other strategies to better balance non-ED admissions to reduce artificial flow variability through load leveling (ie, surgical schedule smoothing).

Several aspects of this calculation make this study generalizable and not generalizable to other US hospitals. The findings would be most generalizable to other large, high-volume teaching hospitals because they would be likely to experience similar variability in occupancy, demonstrated by large swings in census that frequently decrease below peak capacity. This would be true particularly in hospitals that have not used load leveling of non-ED admission schedule, as was the case in the study hospital. However, in hospitals without the same levels of boarding, left without being seen, and diversion, our results may be less applicable. This may be the case in hospitals with no diversion policies or those that make better use of staffed beds.

In summary, we found that ED boarding leads to unfilled patient need, as measured by ambulance diversion and walk-away rates, and large potential losses in hospital revenue. We also demonstrate that the potential revenue effect of reducing boarding is highly dependent on how a hospital manages the variability in bed capacity in a single inner-city teaching hospital. Specifically, how the hospital chooses to handle inpatient bed management strategies is vital. How non-ED admissions are reduced to accommodate new demand is the primary driver of whether reducing boarding increases hospital revenues. We identified several dynamic admissions policies for non-ED patients that could serve higher demand for ED admissions with minimal effect on non-ED patients and lead to a net revenue gain of $2.7 to $3.6 million per year.

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(continued from p. 330)

DIAGNOSIS:

Spigelian hernia. Computed tomography (CT) of the abdomen demonstrated a ventral hernia containing peritoneal fat and segmental jejunum loops creating a small bowel ileus (Figure 2). At emergency laparotomy, an incarcerated hernia with omentum and 20 cm of ecchymotic small bowel without ischemic changes was found. A 4-$\times$-4-cm^2 fascial defect was repaired and she was discharged 3 weeks later.

Spigelian hernia, also known as spontaneous lateral ventral hernia, accounts for 0.12% to 2.4% of all abdominal wall hernias. They present most commonly in the fifth and sixth decades of life but can be observed at any age, with a female to male ratio of 1.4:1.[1] The common symptoms are intermittent nonspecific pain and a bulging mass (up to 64% in one study).[2] Small bowel obstruction is a rarely reported consequence.[3] Incarceration at the operation is observed in 17% to 24% of reported hernias.[1,2] Image studies are recommended before surgical exploration. CT scan offers the detailed diagnosis and is generally recommended before surgery.

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