The Effect of an Ambulance Diversion Ban on Emergency Department Length of Stay and Ambulance Turnaround Time

Laura G. Burke, MD, MPH; Nina Joyce, MPH; William E. Baker, MD; Paul D. Biddinger, MD; K. Sophia Dyer, MD; Franklin D. Friedman, MD, MS; Jason Imperato, MD, MBA; Alice King, MS, RN; Thomas M. Maciejko, EMT-P; Mark D. Pearlmutter, MD; Assaad Sayah, MD; Richard D. Zane, MD; Stephen K. Epstein, MD, MPP

Study objective: Massachusetts became the first state in the nation to ban ambulance diversion in 2009. It was feared that the diversion ban would lead to increased emergency department (ED) crowding and ambulance turnaround time. We seek to characterize the effect of a statewide ambulance diversion ban on ED length of stay and ambulance turnaround time at Boston-area EDs.

Methods: We conducted a retrospective, pre-post observational analysis of 9 Boston-area hospital EDs before and after the ban. We used ED length of stay as a proxy for ED crowding. We compared hospitals individually and in aggregate to determine any changes in ED length of stay for admitted and discharged patients, ED volume, and turnaround time.

Results: No ED experienced an increase in ED length of stay for admitted or discharged patients or ambulance turnaround time despite an increase in volume for several EDs. There was an overall 3.6% increase in ED volume in our sample, a 10.4-minute decrease in length of stay for admitted patients, and a 2.2-minute decrease in turnaround time. When we compared high- and low-diverting EDs separately, neither saw an increase in length of stay, and both saw a decrease in turnaround time.

Conclusion: After the first statewide ambulance diversion ban, there was no increase in ED length of stay or ambulance turnaround time at 9 Boston-area EDs. Several hospitals actually experienced improvements in these outcome measures. Our results suggest that the ban did not worsen ED crowding or ambulance availability at Boston-area hospitals. [Ann Emerg Med. 2013;61:303-311.]

Please see page 304 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Ambulance diversion, the practice of systematic bypass of emergency departments (EDs) by ambulances, is a common but controversial practice used by hospitals nationwide to cope with episodic ED crowding. An estimated 45% of EDs in the United States went on diversion in 2003, turning away approximately 501,000 ambulances.[1] During that year, ambulances were diverted at nearly 70% of urban EDs.[2,3] Despite the common use of ambulance diversion, there is a growing consensus that diversion is ineffective in reducing crowding.[4,5] ED crowding has been conceptualized as an input/throughput/output model.[6] Research has led to the consensus that crowding is largely due to output factors, particularly the practice of boarding admitted patients in the ED[2,7-10] because of lack of inpatient capacity. Ambulance diversion, in contrast, is an input factor, which has little effect on ED crowding.[4]

In addition to being ineffective in reducing ED crowding, diversion may also lead to delays to definitive care[11-13] and result in poor patient outcomes.[14,15] The Institute of Medicine has concluded that "ambulance diversion can lead to catastrophic delays in treatment for seriously ill or injured patients. It also frequently leads to treatment in facilities with inadequate expertise and resources appropriate to the patient's severity of illness, placing the patient at significant risk."[16]

Despite the increasing awareness that diversion may adversely affect patient health, the practice remained pervasive throughout Massachusetts.[17,18] The Massachusetts Department of Public Health provided multiple resources to hospitals, including best practice guidelines, in an effort to achieve voluntary reductions in diversion,[19-21] with limited success.[18] Several hospitals in southeastern Massachusetts implemented a regional ambulance diversion ban. The Conference of Boston Teaching Hospitals, a coalition of 14 Boston-area teaching hospitals addressing policy and public health issues, conducted a 2-week trial ambulance diversion ban, a positive but time-limited endeavor.[22] In light of the growing body of literature

Editor's Capsule Summary

What is already known on this topic

Ambulance diversion, a practice used by hospitals to deal with episodic emergency department (ED) crowding, may lead to delays in patient care.

What question this study addressed

Changes in ED length of stay and ambulance turnaround times associated with introduction of a Massachusetts state ambulance diversion ban in 2009.

What this study adds to our knowledge

Analyzing data from 9 Boston-area EDs, the authors found no increase in ED length of stay or ambulance turnaround time after introduction of the ambulance diversion ban.

How this is relevant to clinical practice

Communities considering introducing an ambulance diversion ban may be encouraged that neither ED length of stay nor ambulance turnaround time increased at 9 Boston-area hospitals after an ambulance diversion ban was introduced in Massachusetts.

and local examples of the negative consequences of diversion, as well as the success of regional no-diversion trials, the Massachusetts Department of Public Health's Boarding and Diversion Task Force voted to end ambulance diversion in Massachusetts. On July 3, 2008, the department released a policy directive ending the practice of ambulance diversion in the state, except in cases of internal hospital disaster.[17] The policy took effect on January 1, 2009, allowing hospitals 6 months to prepare for the changes necessary for its implementation. This policy represented the first statewide ambulance diversion ban in the United States.

Importance

Restricting ambulance diversion has the potential to produce adverse consequences. One feared consequence of prohibiting diversion was further crowding of already overwhelmed EDs that would now be forced to continually accept new patients.[23-25] In addition, there had been significant variation in the use of diversion among hospitals and there was concern that high-diverting EDs would be disproportionately affected.[26] A further concern was that ambulance turnaround times would increase if ambulances were forced to spend a greater amount of time at crowded EDs, awaiting transfer of patients from an ambulance to an ED stretcher. This increased ambulance turnaround time would delay the return to service of emergency vehicles, delaying their response to the next emergency.[27]

Table 1. Characteristics of EDs.*

ED Label	Annual ED Volume (1,000s)	Hospital Beds	ACS† Trauma Center	Diversion Hours‡
A	20–50	<200	No	0
B	20–50	200–500	No	9
C	<20	>500	No	76
D	80–120	>500	Yes	92
E	50–80	>500	Yes	122
F	20–50	<200	No	153
G	20–50	200–500	Yes	227
H	50–80	>500	Yes	769
I	80–120	>500	Yes	858
Characteristics of nonparticipating EDs§				
J	50–80	200–500	Yes	0
K	20–50	<200	No	1
L	20–50	<200	No	172
M	<20	<200	No	Unknown

ACS, American College of Surgeons.
*Study EDs are labeled A through I. The remaining Boston EDs are labeled J through M.
†ACS designated trauma center.
‡Diversion hours: Total diversion hours for 2008 before the diversion ban.
§Nonparticipating Boston hospitals included a pediatric hospital, a specialty hospital, and 2 general hospitals for which ED length of stay data were unavailable.

Preliminary reports from hospitals suggest that the end of ambulance diversion has been a relative success because of operational changes made at individual hospitals in anticipation of the ban.[24,28] Early reports from Boston Emergency Medical Services (EMS) suggest that there has not been an increase in ambulance turnaround time as feared, although this has not been formally studied.[29]

Goals of This Investigation

Our study explores the association between the first statewide ambulance diversion ban and ED crowding and ambulance turnaround time at 9 Boston-area EDs.

MATERIALS AND METHODS

Study Design

We conducted a retrospective, pre-post observational study after the implementation of the statewide ambulance diversion ban on January 1, 2009, to determine changes in ED length of stay and ambulance turnaround time.

Setting

Our study sample consisted of 9 EDs: 7 within the city of Boston and 2 within the neighboring city of Cambridge (Table 1). The cities have a combined population of approximately 723,000. All of the participating hospitals are teaching hospitals, and 7 of the 9 EDs participate in 1 or more emergency medicine residency programs.

Selection of Participants

The participating EDs accounted for 77% of total ED volume in 2008 for Boston and all ED visits in Cambridge.

The remaining Boston EDs included a pediatric hospital that never used ambulance diversion, an ED at a surgical subspecialty hospital with minimal ambulance volume, and 2 community EDs for which complete data were unavailable. All participating EDs receive ambulance traffic from Boston EMS, which handles approximately 98% of 911 ambulance transports for Boston.

Interventions

A ban on routine use of ambulance diversion was implemented on January 1, 2009. Building on its efforts during the previous decade to address ED crowding and ambulance diversion, in 2007 the Massachusetts Department of Public Health convened an ambulance diversion and patient flow task force, with numerous stakeholders participating, including EMS providers, nurses, physicians, and hospital administrators. After reviewing the growing body of literature and local examples of the negative consequences of diversion, as well as the success of regional no-diversion trials, consensus emerged that ambulance diversion should be eliminated and patient flow changes initiated within hospitals as a first step to reducing ED crowding. The task force formally voted to end ambulance diversion in Massachusetts in June 2008, and the ban was announced on July 3, 2008, eliminating diversion except in cases of internal hospital disaster as of January 1, 2009.[17] As part of its announcement, the Massachusetts Department of Public Health reiterated the need to use the previously distributed resources to improve patient flow. In addition to these resources, regular conference calls were held for hospitals to exchange ideas and strategies for preparing for the ban.

Methods of Measurement

Measurements of total monthly ED volume and median ED length of stay for admitted and discharged patients were derived from the electronic tracking system of the individual participating EDs. Median length of stay was chosen a priori rather than mean to minimize the possibility of data skewing because of prolonged boarding times of behavioral health patients. Mean monthly ambulance turnaround time was provided by Boston EMS and obtained from its computerized log.

Data Collection and Processing

EDs provided monthly 2008 and 2009 data for total ED volume, median length of stay in minutes for admitted patients, and median length of stay in minutes for discharged patients. ED volume was standardized by multiplying total monthly volume by a ratio of 30.5 during the number of days in the respective month. Boston EMS provided the mean ambulance turnaround time by month to each hospital from January 2008 to December 2009. Turnaround time is defined as the time the ambulance arrives at the hospital subtracted from the time they clear or go back in service. All data provided were approved by the institutional review board at the respective institution. The number of diversion hours by month for each hospital was obtained from the Massachusetts Department of Public Health. Data were analyzed with Stata (version 11; StataCorp, College Station, TX).

Outcome Measures

The primary goal of our study was to determine whether there was a change pre- to postdiversion ban in any of the following outcomes: ED length of stay for discharged patients, ED length of stay for admitted patients, ambulance turnaround time, and ED volume. ED length of stay was defined as time of ED arrival to departure. ED length of stay is a National Quality Forum–endorsed metric[30,31] that is used as a proxy for the measurement of ED crowding.[7,32,33] Ambulance turnaround time is defined as the time from ambulance arrival to the ED until leaving the hospital. We included ambulance turnaround time to evaluate the effect of the ban on EMS availability and measured ED volume to characterize the magnitude of the effect of the ban on individual hospitals.

Primary Data Analysis

Because the diversion ban went into effect on January 1, 2009, the preperiod was defined as January through December 2008 and the postperiod as January through December 2009. We used univariate linear regression to compare the unadjusted change in the outcome measures overall and by individual hospital. We then included hospital fixed effects to account for time-invariant differences between the hospitals. We imposed a first-order autoregressive variance-covariance structure to adjust for autocorrelation of the outcome. In the preliminary analyses, we included a linear trend to account for ongoing changes in the outcomes unrelated to the diversion ban. The trend was not significant for any of the outcomes and was therefore dropped from the analysis.

We used a difference of differences analysis for the secondary analysis. EDs were divided into 2 groups, high and low diverters, according to the mean annual diversion hours in the preperiod. High diverters were EDs with mean diversion hours before the ban greater than the sample mean and low diverters were EDs with mean diversion hours less than the sample mean. We again used a general linear model with a first-order autoregressive variance-covariance structure to test for an association between the ban and the outcomes. Specifically, each outcome was regressed on the following: the main effect for the postperiod, a dichotomous indicator for each hospital (hospital fixed effects), and an interaction between the postperiod and high diverters. Main effects for the high versus low diverters were not included in the model because it would be collinear with hospital fixed effects. We first determined the changes pre to post separately for the high and low diverters and then for the fully specified model. The parameter of interest was the interaction of the

Table 2. Changes in ED volume, length of stay, and turnaround time by hospital after the ambulance diversion.*

ED Label	Monthly ED Volume Change, %	Length of Stay, Admitted Patients, Minutes			Length of Stay, Discharged Patients, Minutes			Ambulance Turnaround Time, Minutes		
		Preban	Postban	Change	Preban	Postban	Change	Preban	Postban	Change
A	9.5 (3.0 to 17.4)	170.0	172.8	2.8 (−9.9 to 15.4)	114.8	114.3	−0.5 (−6.4 to 5.4)	16.8	16.1	−0.7 (−8.1 to 6.6)
B	3.9 (−2.0 to 9.4)	287.0	269.4	−17.5 (−29.6 to −5.5)	139.0	128.6	−10.4 (−17.4 to −3.5)	26.4	24.4	−2.0 (−3.2 to −0.7)
C	1.0 (−3.9 to 6.2)	284.2	263.2	−21.0 (−39.4 to −2.6)	173.3	170.8	−2.5 (−8.3 to 3.3)	29.4	27.6	−1.8 (−2.9 to −0.6)
D	2.9 (−2.0 to 8.3)	304.6	289.0	−15.6 (−32.3 to 1.1)	189.2	189.3	0.1 (−6.3 to 6.4)	28.5	25.4	−3.1 (−4.2 to −2.0)
E	−4.5 (−13.1 to 5.3)	336.4	338.0	1.6 (−18.1 to 21.3)	258.8	257.3	−1.5 (−12.4 to 9.3)	26.9	25.5	−1.4 (−2.5 to −0.4)
F	4.7 (1.0 to 8.3)	306.2	284.3	−21.9 (−37.3 to −6.6)	191.8	175.0	−16.8 (−29.2 to −4.4)	22.2	19.0	−3.2 (−6.1 to −0.5)
G	3.3 (−2.0 to 8.3)	392.2	376.5	−15.7 (−51.3 to 20.0)	152.5	155.3	2.8 (−3.5 to 9.0)	25.8	23.7	−2.1 (−3.3 to −0.9)
H	4.9 (1.0 to 17.4)	386.5	364.4	−22.1 (−34.9 to −9.5)	235.9	218.9	−17.0 (−26.1 to −7.9)	29.2	26.4	−2.8 (−3.8 to −1.7)
I	7.0 (4.1 to 10.5)	455.5	427.5	−28.0 (−54.1 to −1.9)	239.5	220.0	−19.5 (−28.7 to −10.3)	30.0	27.0	−3.0 (−3.9 to −2.1)

*95% CIs shown in parentheses.

postperiod and high diverters; this parameter measured the expected change in each outcome among the high diverters after the ban relative to the change in the outcomes among the low diverters during the same period.

Sensitivity Analyses

We performed a sensitivity analysis to test whether our results were sensitive to assumptions about a washout period. To test these assumptions, we included a 6-month washout

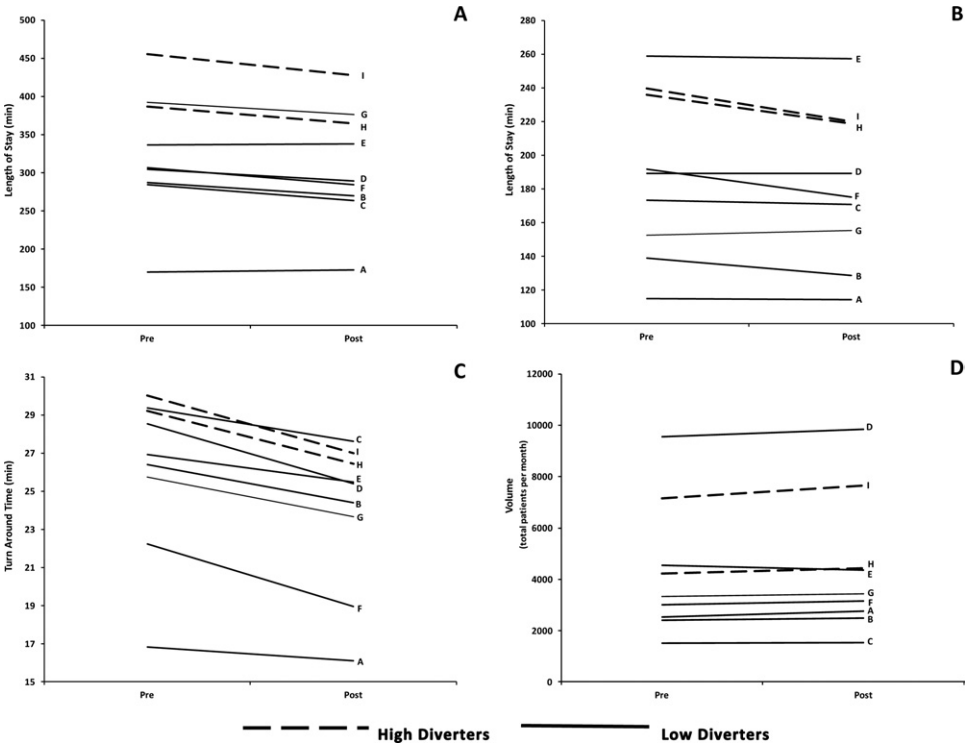

Figure 1. Changes in ED length of stay by hospital among *A*, admitted patients and *B*, discharged patients. *C*, Changes in ambulance turnaround time by hospital. *D*, Changes in total hospital volume before and after a ban on ambulance diversion by hospital.

Table 3. Change in outcomes after the ambulance diversion ban.

Outcome (Sample Mean)	Adjusted Change* (95% CI)
Volume, % (4,262.6)	3.6 (0.7 to 6.6)
ED LOS, admitted (312.8), min	−10.4 (−19.2 to −1.6)
ED LOS, discharged (182.2), min	−0.7 (−5.3 to 4.0)
TAT (25.0), min	−2.2 (−3.3 to −1.2)

LOS, Length of stay; *TAT*, ambulance turnaround time.
*Adjusted changes in the outcome were estimated with general linear regression. The model was adjusted for hospital fixed effects and first-order autoregressive autocorrelation.

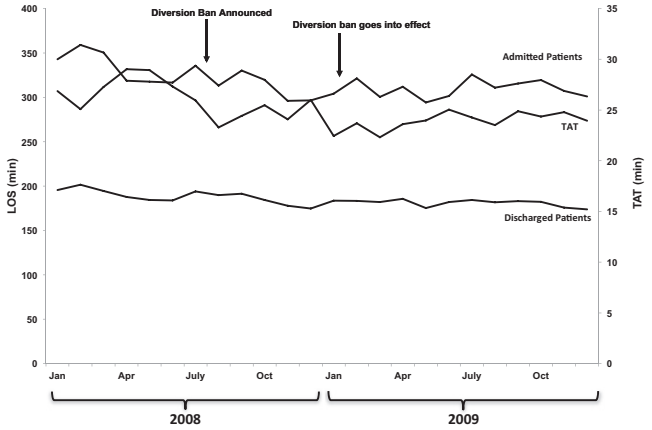

Figure 2. Length of stay for admitted and discharged patients and ambulance turnaround time by month.

period from July 2008 through December 2008 in our analysis, comparing low- to high-diverting hospitals.

RESULTS

Main Results

We present the characteristics of the 9 EDs in Table 1. In analysis of the outcomes by individual ED, 4 EDs showed an increase in ED volume, 4 demonstrated a decrease in length of stay for discharged patients, 5 had a decrease in length of stay for admitted patients, and all but 1 experienced a decrease in turnaround time (Table 2, Figure 1). After adjusting for hospital fixed effects and autocorrelation of the outcomes, there was a 3.6% increase in overall monthly ED volume after the ban (95% confidence interval [CI] 0.7% to 6.6%). There was also a 10.4-minute decrease in length of stay for admitted patients (95% CI –19.2 to –1.6 minutes) and 2.2-minute decrease in ambulance turnaround time (95% CI –3.3 to –1.2 minutes) (Table 3, Figure 2). We found no change in length of stay for discharged patients.

The trend in diversion hours for our study sample before the diversion is presented in Figure 3. The trend in diversion hours for individual hospitals is presented in the Appendix E1. (available online at http://www.annemergmed.com). Two EDs (H and I) accounted for approximately 70% of the total diversion hours before the ban. These 2 were the only EDs with

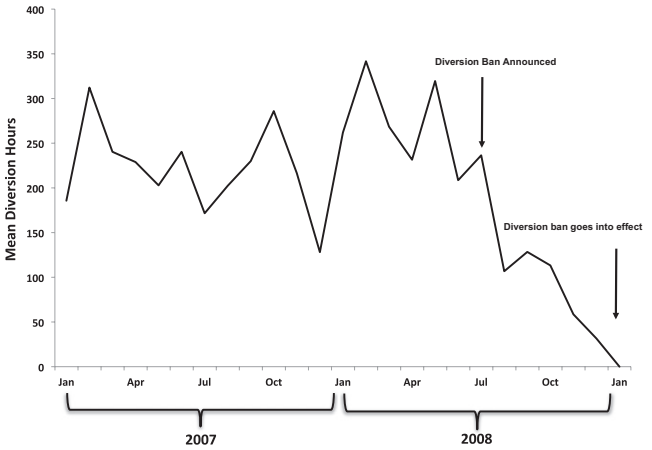

Figure 3. Total ED diversion hours per month for all study hospitals, January 2007 to January 2009.

mean diversion hours before the ban greater than the sample mean and thus were classified as high diverters. We hypothesized that high diverters would have a larger increase in length of stay relative to the low diverters because they would be more greatly affected by the ban. The purpose of this comparison is to evaluate the effects of the ban that are independent of any background trends in the outcomes, such as increasing ED volume.

Despite an overall increase in volume after the ban, this increase was not observed for either high- or low-diverting hospitals when stratified. High diverters experienced a 9.7-minute decrease (95% CI –18.9 to –0.6 minutes) in length of stay for discharged patients, as well as a 2.9-minute decrease (95% CI –5.1 to –0.7 minutes) in ambulance turnaround time. Low diverters experienced a 2-minute decrease in ambulance turnaround time as well (95% CI –3.2 to –0.8 minutes). The magnitude of the decrease in length of stay for admitted patients was greater for high diverters (–17.6; 95% CI –36.0 to 0.8 minutes) compared with that of low diverters (–8.6; 95% CI –18.4 to 1.2 minutes), although the decrease was not statistically significant in either group. Furthermore, there was no difference in the relative change between high and low diverters in any of the outcomes (Table 4).

Sensitivity Analyses

Our results were not sensitive to the washout period. There were no observed increases in length of stay in any of the outcome measures after the diversion ban. There were decreases in length of stay for admitted patients in both high- and low-diverting hospitals. There was also a decrease in length of stay for discharged patients among high diverters and in turnaround time for both groups. There were no significant differences in the differential changes between high and low diverters (Table 5).

LIMITATIONS

Our study has several limitations. First, this was a retrospective study with a relatively small sample size in a single, urban area. As a

Table 4. Estimated change in outcomes between high and low diverters after the ambulance diversion ban, adjusting for hospital fixed effects and first-order autocorrelation.

Outcome (Low Diverters Mean) (High Diverters Mean)	95% CI		
	Change Among Low Diverters	Change Among High Diverters	Differential Change*
Volume, % (3,857.1) (1,568.0)	3.0 (−0.2 to 6.4)	5.4 (−0.7 to 12.0)	2.4 (−4.6 to 10.3)
LOS, admitted, min (290.9) (408.5)	−8.6 (−18.4 to 1.2)	−17.6 (−36.0 to 0.8)	−9.1 (−29.9 to 11.8)
LOS, discharged, min (172.1) (228.55)	0.4 (−4.5 to 5.3)	−9.7 (−18.9 to −0.6)	−10.1 (−20.5 to 0.3)
TAT, min (24.1) (28.2)	−2.0 (−3.2 to −0.8)	−2.9 (−5.1 to −0.7)	−0.9 (−3.4 to 1.6)

*Differential change in the outcome between high- and low-diverting hospitals after the ban.

Table 5. Estimated change in outcomes between high and low diverters after the ambulance diversion ban, adjusting for hospital fixed effects and first-order autocorrelation and a 6-month washout period (July to December 2008).

Outcome (Low Diverters Mean) (High Diverters Mean)	95% CI		
	Change Among Low Diverters	Change Among High Diverters	Differential Change*
Volume, % (3,857.1) (1,568.0)	1.7 (−2.3 to 5.8)	2.4 (−4.2 to 9.4)	4.1 (−2.4 to 11.0)
LOS, admitted, min (290.9) (408.5)	−16.8 (−27.7 to −5.8)	−27.0 (−44.7 to −9.2)	−10.2 (−29.0 to 8.6)
LOS, discharged, min (172.1) (228.55)	0.2 (−5.9 to 6.2)	−10.4 (−20.0 to −0.8)	−10.6 (−20.6 to 0.5)
TAT, min (24.1) (28.2)	−3.4 (−4.7 to −2.1)	−4.4 (−6.5 to 2.3)	−1.0 (−3.2 to −1.3)

*Differential change in the outcome between high- and low-diverting hospitals after the ban, adjusting for autocorrelation by month and a 6-month washout period (July to December 2008).

result, we were unable to control for geographic effects of diversion on ED volume; diversion at one ED may have had a greater effect on volume at nearby EDs than those farther away. We also did not have the power to detect a time trend in ED volume in our sample, despite an ongoing increase in ED volume during the previous 5 years throughout the state.[34] Because we were unable to detect such a trend, it was not possible to distinguish how much of the change in length of stay and turnaround time was due to background changes in volume as opposed to the ban itself. However, given that we observed decreases in length of stay and turnaround time rather than increases, any background increase in volume would likely lead to an underestimation of the decrease in length of stay and turnaround time.

Second, the decline in diversion hours in the latter half of 2008 suggests that the effect of the diversion ban may have been realized before the January 1, 2009, implementation date. If the operational changes were made several months in advance, then the preban period would not be representative of a true baseline. This may have resulted in our having underestimated the actual decrease in length of stay as well.

Third, we used monthly median length of stay, which lacks the precision to find isolated periods of increased crowding within each month. This lack of precision might mask variations in crowding that occurred.[35] Further study with shorter intervals is necessary to determine the frequency of any such periods of crowding.

Fourth, there is an inherent limitation in the use of time stamps used to calculate length of stay and turnaround time that rely on human data entry. However, we do not have reason to suspect a systematic difference in the accuracy of these stamps in the pre- and postdiversion ban periods.

Fifth, it is possible that the study hospitals were not significantly crowded before the diversion ban. If that were the case, the policy change might not have been expected to produce significant changes in our outcome variable. However, the Massachusetts Department of Public Health Boarding and Diversion Task Force, consisting of representatives from every key stakeholder organization, perceived crowding to be significant and persistent enough to warrant this substantial policy change. The view of the task force is also consistent with national reports of ED crowding.[36]

Sixth, ED length of stay may have limitations as a proxy for ED crowding.

DISCUSSION

Ambulance diversion is currently used across the United States as a means to control ED crowding. In our study of the effect of an ambulance diversion ban on 9 Boston-area EDs, we found that despite an overall increase in ED volume, there was no evidence of an increase in length of stay for admitted or discharged patients. We also found a decrease in ambulance turnaround time, suggesting an increased availability of ambulances to respond to 911 calls.[27]

We also compared the effects of the ambulance diversion ban between high- and low-diverting EDs. We hypothesized that if the diversion ban did in fact lead to an increase in ED crowding, then those EDs with a high rate of diversion would experience a greater relative increase in length of stay. Contrary to this hypothesis, there was no difference between high and low diverters in the relative change in length of stay for either admitted or discharged patients. When we analyzed high and low diverters separately, neither saw an increase in length of

Table 6. Key interventions made by study hospitals before the implementation of the statewide ambulance diversion ban.

ED	Intervention
A	Code Help implementation*
	Inpatient bed rounds twice a day to decompress the ED
	Streamline physician and nurse handoff for admitted patients
	Improved ED efficiency (100% bedside registration, improved diagnostic turnaround time)
	Emergency physician and nursing staffing backup and float pool
B	Ensured strict compliance with Code Help
C	Multidisciplinary and multidepartmental hospital system designed to address patient flow with the emergency preparedness/disaster notification system
D	Multidisciplinary and multidepartmental hospital system designed to address patient flow with the emergency preparedness/disaster notification system
E	Previous commitment to limiting diversion
	Reduction in target hospital occupancy level
	Increased transparency in hospital bed availability and real-time electronic inpatient bed capacity dashboard
F	Implementation of a surge plan when levels of boarding met a predetermined threshold
	Gradual reduction in use of diversion by requiring administrative approval for the use of diversion
	Changed culture to reduce use of diversion before the ban
	Use of nontraditional spaces such as the PACU for boarding ED patients
G	"Priority alert" that expedites the movement of admitted patients to an inpatient bed by several mechanisms (electronic RN report, expedited housekeeping, additional involvement by the hospital nursing management)
	Implementation of an "admission/discharge/transfer center" run by senior RN with assistance of the admitting office and a "bed czar" physician
	Prioritization of inpatient bed assignments
H	Establishment of a threshold for deploying physicians at triage
	Establishment of a 10-bed surge pod on the inpatient unit to care for boarding ED patients and an associated protocol for activation
	Use of nontraditional space for boarding ED patients (PACU, off-hour postprocedure unit, etc)
	Expansion of the ED (30%) with comprehensive ED flow process redesign
I	Meetings with senior leadership to address anticipated problems after the diversion ban
	Color-coded ED crowding monitoring system programmed in the ED tracking system
	Identification of hospital leaders who would be notified when threshold levels of ED crowding were reached
	Development of an algorithm to link acceptance of interfacility transfers to ED crowding measures while observing EMTALA rules (this changed the acceptance of transfers when the ED was severely crowded)
	Twice-daily rounds involving admitting office, hospital nursing supervisors, and ED staff to monitor throughput
	Internal medicine coverage of appropriate admitted patients waiting for inpatient bed

EMTALA, Emergency Medical Treatment and Labor Act; *PACU*, postanesthesia care unit; *RN,* registered nurse.
*Code Help: A policy that the Massachusetts Department of Public Health requires all hospitals to maintain to address ED crowding caused by the boarding of admitted patients. Additional information available at http://www.mass.gov/eohhs/docs/dph/quality/healthcare/code-help/code-help-letter-070810.pdf.

stay. In fact, high diverters saw a decrease in length of stay for discharged patients, whereas low diverters did not, although the relative difference between the groups was not statistically significant. Together, these results support the findings from our primary analysis; length of stay for admitted and discharged patients did not increase, suggesting that the diversion ban did not worsen ED crowding. Additionally, there was no increase in ambulance turnaround time as feared, suggesting that the ambulance diversion ban did not pose an increased burden for EMS providers.

The concept of an ambulance diversion ban was initially met with some concern within Massachusetts.[26] It was feared that ED crowding and EMS turnaround time would worsen if hospitals were unwilling or unable to implement the operational changes necessary to improve patient flow. Our study suggests that among these Boston-area hospitals, neither of these feared outcomes was realized. Although not the aim of this study, an informal query of the site investigators about hospital interventions was performed. Responses indicated that planning and real-time trouble shooting involved many levels of the hospitals' operational structure, including registration, housekeeping, high-level central administrators, and clinical chiefs. One common theme was that efforts were directed at addressing patient flow through the entire hospital, not just within the ED (Table 6). Not surprisingly, hospitals with greater crowding reported making more significant operational changes.

ED crowding has been conceptualized as an input/throughput/output model.[6] Research has led to the consensus that crowding is largely due to output factors, particularly the practice of boarding admitted patients in the ED[2,7-10] because of lack of inpatient capacity. Ambulance diversion, in contrast, is an input factor, which has little effect on ED crowding.[4] Our study amplifies this previous research because a ban on ambulance diversion did not have a significant adverse effect on ED crowding. This was the first statewide ambulance diversion ban in the United States, and, to our knowledge, this is the first study to evaluate the effect of such a policy on measures of ED crowding.

The observed decreases in length of stay might seem unexpected but may be explained by both the input/throughput/output model

and the circumstances of the implementation of the ambulance diversion ban. In its letter to Massachusetts hospitals in July 2008, the Massachusetts Department of Public Health specifically stated that "in preparation for this [ambulance diversion ban], we strongly encourage a review that all necessary steps have been taken to avoid ED overcrowding and boarding."[17] Diversion hours among the study hospitals started to decrease shortly thereafter (Figure 3). We hypothesize that this was due to concerted efforts by hospitals to make the operational changes necessary to improve patient outflow from the ED (output) to compensate for an anticipated increase in ED inflows (input). These changes may have led to greater ED outflow, thereby improving ED crowding and decreasing ED length of stay and ambulance turnaround time.

In conclusion, we found no evidence of an increase in ambulance turnaround time or ED crowding as measured by length of stay in 9 Boston area EDs after the nation's first statewide ambulance diversion ban. Our findings support the anecdotal reports of the ban's success and are consistent with existing literature that diversion is not an effective means to mitigate ED crowding. That the ban did not result in length of stay increases is likely due to the relatively small contribution that input factors play in ED crowding. Furthermore, the observed length of stay decrease for discharged patients treated at high-diverting hospitals suggests that those hospitals in particular made operational changes that significantly improved patient flow. We suggest that the combination of these 2 factors, the lesser contribution of ED inputs (ambulance volume) and the greater contribution of ED outputs (hospital-wide operational changes), are responsible for the ban's apparent success. If our findings are confirmed by other studies, then broadly eliminating ambulance diversion may improve continuity of care and EMS availability without increasing ED crowding.

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Author affiliations: From the Beth Israel Deaconess Medical Center, Boston, MA (Burke, Joyce, Epstein); the Boston Medical Center, Boston, MA (Baker); the Massachusetts General Hospital, Boston, MA (Biddinger); Boston Emergency Medical Services, Boston, MA (Dyer, Maciejko); the Tufts Medical Center, Boston, MA (Friedman); the Mount Auburn Hospital, Cambridge, MA (Imperato); the Brigham and Women's Hospital, Boston, MA (King, Zane); the St. Elizabeth's Medical Center, Boston, MA (Pearlmutter); and the Cambridge Health Alliance, Cambridge, MA (Sayah).

Dr. Zane is currently affiliated with the University of Colorado School of Medicine, Denver, CO.

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Address for correspondence: Laura G. Burke, MD, MPH, E-mail lgburke@bidmc.harvard.edu.

REFERENCES

1. Burt CW, McCaig LF, Valverde RH. Analysis of ambulance transports and diversions among US emergency departments. *Ann Emerg Med*. 2006;47:317-326.
2. Institute of Medicine. IOM report: the future of emergency care in the United States health system. *Acad Emerg Med*. 2006;13: 1081-1085.
3. American Hospital Association. Chicago. Chartbook 2004: trends affecting hospitals and health systems. Chapter 3. Utilization and volume. Available at: http://www.aha.org/research/reports/tw/chartbook/2006orearlier/cb2004chapter3.ppt. Accessed November 30, 2012.
4. Scheulen JJ, Li G, Kelen GD. Impact of ambulance diversion policies in urban, suburban, and rural areas of central Maryland. *Acad Emerg Med*. 2001;8:36-40.
5. Asplin BR, Magid DJ. If you want to fix crowding, start by fixing your hospital. *Ann Emerg Med*. 2007;49:273-274.
6. Asplin BR, Magid DJ, Rhodes KV, et al. A conceptual model of emergency department crowding. *Ann Emerg Med*. 2003;42:173-180.
7. Forster AJ, Stiell I, Wells G, et al. The effect of hospital occupancy on emergency department length of stay and patient disposition. *Acad Emerg Med*. 2003;10:127-133.
8. Rathlev NK, Chessare J, Olshaker J, et al. Time series analysis of variables associated with daily mean emergency department length of stay. *Ann Emerg Med*. 2007;49:265-271.
9. Schull MJ, Lazier K, Vermeulen M, et al. Emergency department contributors to ambulance diversion: a quantitative analysis. *Ann Emerg Med*. 2003;41:467-476.
10. Hoot NR, Aronsky D. Systematic review of emergency department crowding: causes, effects, and solutions. *Ann Emerg Med*. 2008; 52:126-136.
11. Redelmeier DA, Blair PJ, Collins WE. No place to unload: a preliminary analysis of the prevalence, risk factors, and

consequences of ambulance diversion. *Ann Emerg Med*. 1994;23:43-47.
12. Schull MJ, Morrison LJ, Vermeulen M, et al. Emergency department gridlock and out-of-hospital delays for cardiac patients. *Acad Emerg Med*. 2003;10:709-716.
13. Kellermann AL. Crisis in the emergency department. *N Engl J Med*. 2006;355:1300-1303.
14. Yankovic N, Glied S, Green LV, et al. The impact of ambulance diversion on heart attack deaths. *Inquiry*. 2010;47:81-91.
15. Shen YC, Hsia RY. Association between ambulance diversion and survival among patients with acute myocardial infarction. *JAMA*. 2011;305:2440-2447.
16. Committee on the Future of Emergency Care in the United States Health System Board on Health Care Services, Institute of Medicine of the National Academies. *Future of Emergency Care: Hospital-Based Emergency Care at the Breaking Point*. Washington, DC: National Academies Press; 2007.
17. Auerbach J, Dreyer P. Circular letter: DHCQ 08-07-494. Changes to ambulance diversion policies. July 3, 2008. The Commonwealth of Massachusetts Executive Office of Health and Human Services Department of Public Health. Available at: http://www.mass.gov/eohhs/docs/dph/quality/hcq-circular-letters/hospital-general-0807494.pdf. Accessed May 21, 2012.
18. Massachusetts Executive Office of Health and Human Services (EOHHS). Monthly diversion statistics: total hours on diversion in Massachusetts hospitals—EMS region by month (July 1, 2002 to November 30, 2008). Available at: http://www.mass.gov/eohhs/provider/licensing/facilities/health-care-facilities/hospitals/ambulance-diversion/monthly-diversion-statistics.html. Accessed May 21, 2012.
19. Koh HK, Hollander R. Massachusetts Department of Public Health Ambulance Diversion Task Force. Best practice guidelines for hospitals regarding ambulance diversions. December 16, 1999. Available at: http://www.mass.gov/eohhs/docs/dph/quality/healthcare/ad-best-practice-1999.pdf. Accessed May 21, 2012.
20. Koh HK, Hollander R. December 11, 2000. The Commonwealth of Massachusetts Executive Office of Health and Human Services. Department of Public Health. December 11, 2000. Available at: http://www.mass.gov/eohhs/docs/dph/quality/healthcare/ad-addtl-recommendations.pdf. Accessed May 20, 2012.
21. Ferguson C. Management of emergency department patients awaiting admission: letter from Commissioner Christine Ferguson to chief executive officers, Massachusetts acute care hospitals. The Commonwealth of Massachusetts Executive Office of Health and Human Services: Dept of Public Health. January 5, 2005. Available at: http://www.mass.gov/eohhs/docs/dph/quality/healthcare/ad-emergency-management.pdf. Accessed May 21, 2012.
22. Friedman FD, Rathlev NK, White L, et al. Trial to end ambulance diversion in Boston: report from the Conference of the Boston Teaching Hospitals Consortium. *Prehosp Disaster Med*. 2011;26:122-126.
23. Minutes from meetings from the Massachusetts Department of Public Health Boarding and Diversion Task Force. April 9, 2008. Massachusetts Dept of Public Health.
24. Minutes from meetings from the Massachusetts Department of Public Health Boarding and Diversion Task Force. September 24, 2008. Massachusetts Dept of Public Health.
25. Kowalczyk L. Hospitals shorten the wait in ERs: diverting ambulances soon to come to end. *Boston Globe*. December 24, 2008:A1.
26. Kowalczyk L. State orders hospital ERs to halt "diversions": bid to ease overcrowding seen to sometimes delay care. *Boston Globe*. September 13, 2008:A1.
27. Eckstein M, Chan LS. The effect of emergency department crowding on paramedic ambulance availability. *Ann Emerg Med*. 2004;43:100-105.
28. Kowalczyk L. State's ER policy passes checkup. Hospitals accept ambulance rule; wait times don't spike for patients. *Boston Globe*. December 14, 2009:A1.
29. Minutes from meetings from the Massachusetts Department of Public Health Boarding and Diversion Task Force. March 25, 2009. Massachusetts Dept of Public Health.
30. National Quality Forum. National voluntary consensus standards for emergency care—phase II: hospital-based emergency department (ED) candidate consensus standards. 2008. Available at: http://www.qualityforum.org/QPS/QPSTool.aspx?Exact=false&Keyword=los#qpsPageState=%7B%22TabType%22%3A1,%22TabContentType%22%3A1,%22SearchCriteriaForStandard%22%3A%7B%22TaxonomyIDs%22%3A%5B%5D,%22SelectedTypeAheadFilterOption%22%3A%7B%22ID%22%3A470,%22FilterOphttp://nonsolus/home/index.asp. Accessed November 30, 2012.
31. National Quality Forum. National voluntary consensus standards for emergency care—phase II: hospital-based emergency department (ED) candidate consensus standards. 2008. Available at: http://www.qualityforum.org/QPS/QPSTool.aspx?Exact=false&Keyword=los#qpsPageState=%7B%22TabType%22%3A1,%22TabContentType%22%3A2,%22SearchCriteriaForStandard%22%3A%7B%22TaxonomyIDs%22%3A%5B%5D,%22SelectedTypeAheadFilterOption%22%3A%7B%22ID%22%3A471,%22FilterOptionLabel%22%3A%220496%22,%22TypeOfTypeAheadFilterOption%22%3A4,%22TaxonomyId%22%3A0%7D,%22Keyword%22%3A%220496%22,%22PageSize%22%3A%2225%22,%22OrderType%22%3A12,%22OrderBy%22%3A%22DESC%22,%22PageNo%22%3A1,%22IsExactMatch%22%3Afalse,%22QueryStringType%22%3A%22%22,%22ProjectActivityId%22%3A%220%22%7D,%22SearchCriteriaForForPortfolio%22%3A%7B%22Tags%22%3A%5B%5D,%22FilterTypes%22%3A0,%22PageStartIndex%22%3A1,%22PageEndIndex%22%3A25,%22PageNumber%22%3Anull,%22PageSize%22%3A%2225%22,%22SortBy%22%3A%22Title%22,%22SortOrder%22%3A%22ASC%22%7D,%22ItemsToCompare%22%3A%5B%5D,%22StandardID%22%3A471,%22EntityTypeID%22%3A1%7D. Accessed November 30, 2012.
32. Lucas R, Farley H, Twanmoh J, et al. Emergency department patient flow: the influence of hospital census variables on emergency department length of stay. *Acad Emerg Med*. 2009;16:597-602.
33. Cardin S, Afilalo M, Lang E, et al. Intervention to decrease emergency department crowding: does it have an effect on return visits and hospital readmissions? *Ann Emerg Med*. 2003;41:173-185.
34. Hospital inpatient and emergency department utilization trends fiscal years 2004-2008. Massachusetts Division of Health Care Finance and Policy Publications. Available at: http://archives.lib.state.ma.us/bitstream/handle/2452/50116/ocn663905459.pdf?sequence=5. Accessed November 30, 2012.
35. McCarthy ML, Ding R, Pines JM, et al. Comparison of methods for measuring crowding and its effects on length of stay in the emergency department. *Acad Emerg Med*. 2011;18:1269-1277.
36. Hospital emergency departments: crowded conditions vary among hospitals and communities. United States General Accounting Office. Report to the ranking minority member, Committee of Finance, US Senate. March 2003.

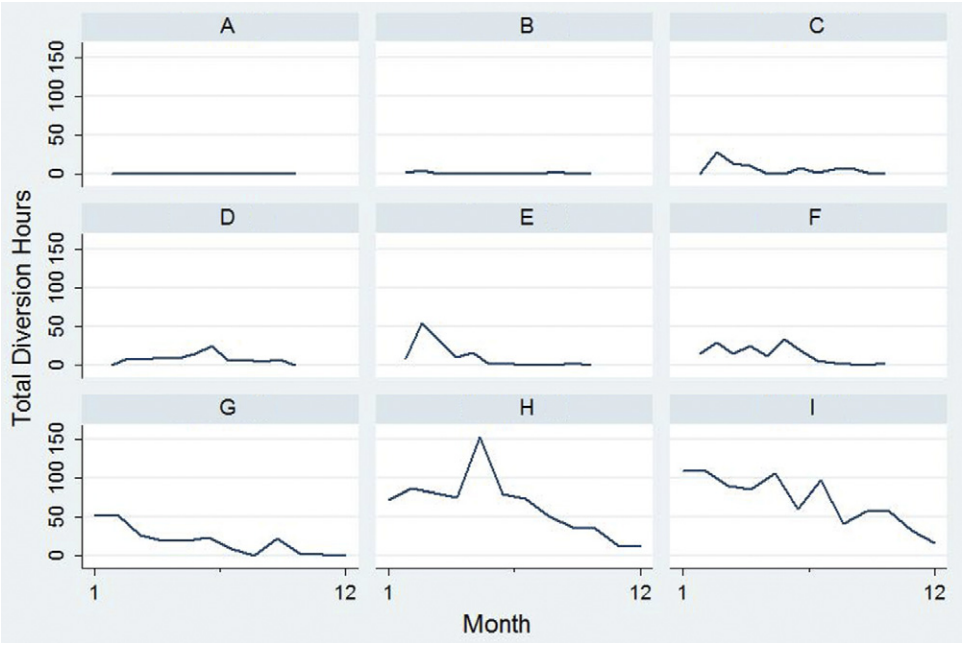

Figure E1. Monthly diversion hours by emergency department in 2008.