

ORIGINAL RESEARCH

The Practice of Emergency Medicine

Quantifying the impact of patient boarding on emergency department length of stay: All admitted patients are negatively affected by boarding

Leslie A. Laam PhD¹ | Andrea A. Wary MS Ed² | Ronald S. Strony MD³ |
Michael H. Fitzpatrick MD⁴ | Chadd K. Kraus DO, DrPH⁴

¹ Steele Institute for Health Innovation, Geisinger Health, Danville, Pennsylvania, USA

² Department of Emergency Medicine, Geisinger Health, Danville, Pennsylvania, USA

³ Geisinger Wyoming Valley Medical Center, Geisinger Health, Wilkes-Barre, Pennsylvania, USA

⁴ Geisinger Medical Center, Geisinger Health, Danville, Pennsylvania, USA

Correspondence

Leslie A. Laam, PhD, Geisinger Health Steele Institute for Health Innovation, 100 N. Academy Ave, Danville, PA, USA.
Email: lalaam@geisinger.edu

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Abstract

Background: Patients boarding in the emergency department (ED) as a result of delays in bed placement are associated with increased morbidity and mortality. Prior literature on ED boarding does not explore the impact of boarding on patients admitted to the hospital from the ED. The objective of this study was to evaluate the impact of patient boarding on ED length of stay for all patients admitted to the hospital.

Methods: This was an institutional review board–approved, retrospective review of all patients from January 1, 2015, through June 30, 2019, presenting to 2 large EDs in a single health system in Pennsylvania. Quantile regression models were created to estimate the impact of patients boarding in the ED on length of stay for all ED patients admitted to the hospital.

Results: A total number of 466,449 ED encounters were analyzed across two EDs. At one ED, for every patient boarded, the median ED length of stay for all admitted patients increased by 14.0 minutes ($P < 0.001$). At the second ED, for every patient boarded in the ED, the median ED length of stay increased by 12.4 minutes ($P < 0.001$).

Conclusion: ED boarding impacts length of stay for all patients admitted through the ED and not just those admitted patients who are boarded. This study provides an estimate for the increased ED length of stay experienced by all patients admitted to the hospital as a function of patient boarding.

KEYWORDS

admitted patients, crowding, emergency department boarding, length of stay, patient boarding, quantile regression model

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1 | INTRODUCTION

1.1 | Background

Emergency department (ED) crowding is a significant challenge to the safe and efficient delivery of emergency care in the United States and other countries.¹⁻⁴ A boarded patient is defined as “a patient who remains in the emergency department after the patient has been admitted or placed into observation status at the facility, but has not been transferred to an inpatient or observation unit,”⁵ and boarding is associated with increases in morbidity and mortality.⁶⁻¹⁵ ED boarding is influenced by hospital occupancy constraints and is linked to overall hospital function and efficiency.¹¹ ED crowding contributes to an increase in medical malpractice suits,^{16,17} an increase in morbidity and mortality,^{6-8,11,18} a decrease in performance,^{11,18} and potentially lost revenues.^{11,19} ED boarding also is associated with decreased patient satisfaction in both the ED and inpatient settings.^{18,20}

1.2 | Importance

ED boarding negatively impacts emergency physicians, physician assistants, nurse practitioners, nurses, and ancillary staff.^{11,21,22} ED teams are designed and trained to deliver high-quality episodic care. Patients boarding in the ED require care usually provided by an inpatient care team. The ED's culture and performance may be eroded by poor job satisfaction and decreased staff engagement.²³ ED boarding is impacted by hospital inpatient throughput and occupancy and, therefore, is frequently beyond the direct control of the ED or its operations. EDs can improve “front door” processes to mitigate some of the hospital occupancy constraints. A holistic systems approach, focusing on process improvement and optimization at multiple levels, involving all stakeholders, and including human factors, is necessary to address ED boarding.²⁴ The negative impacts of boarding can be dependent on and impact more than those patients who are boarding, and solutions need to take into account this dynamic in the ED and in other parts of the hospital.²⁵ Although the negative impacts have been well studied, the consequences of boarding on patients who are not being directly boarded is less well understood. Therefore, understanding the impact of boarding on the entire population of patients admitted from the ED may provide a more holistic view of the problem of boarding and subsequently may provide novel solutions that can be applied to ED operations.

1.3 | Goal of this investigation

The goal of this study was to quantify how patient boarding in the ED impacts ED length of stay for all patients admitted to the hospital from the ED.

The Bottom Line

Emergency department (ED) boarding results in increased wait times for both new and admitted patients, potentially compromising care for all. An analysis of 466,449 ED encounters at two EDs showed that for every additional patient boarded, the ED length of stay was extended at least 12 minutes for every admitted patient.

2 | METHODS

The Geisinger Institutional Review Board determined exempt status for this study.

2.1 | Setting

The following two EDs in the Geisinger Health system were included in this study: Geisinger Medical Center (GMC) and Geisinger Wyoming Valley (GWV). The hospitals and EDs have unique attributes as described in the next sections and outlined in Table 1.

2.1.1 | Geisinger Medical Center

GMC is a rural academic medical center in Central Pennsylvania providing quaternary care, including designation as a level 1 trauma center (pediatric level 2 trauma), a comprehensive stroke center, and a chest pain center with percutaneous coronary intervention and other advanced cardiac treatment capabilities.

The GMC ED is staffed with board-certified emergency physicians and pediatric emergency physicians complemented by physician assistants and nurse practitioners. The GMC ED sponsors an emergency medicine residency program. The GMC ED employs a split flow design for triage and treatment of patients, bedside registration, a dedicated pediatric treatment area, and ED-based ancillary services, including care managers, clinical pharmacists, phlebotomists, and in-department radiology.

2.1.2 | Geisinger Wyoming Valley

GWV is a suburban academic teaching hospital in Northeastern Pennsylvania providing tertiary care, including designation as a level 2 trauma center, a comprehensive stroke center, and a chest pain center with percutaneous coronary intervention and other advanced cardiac treatment capabilities.

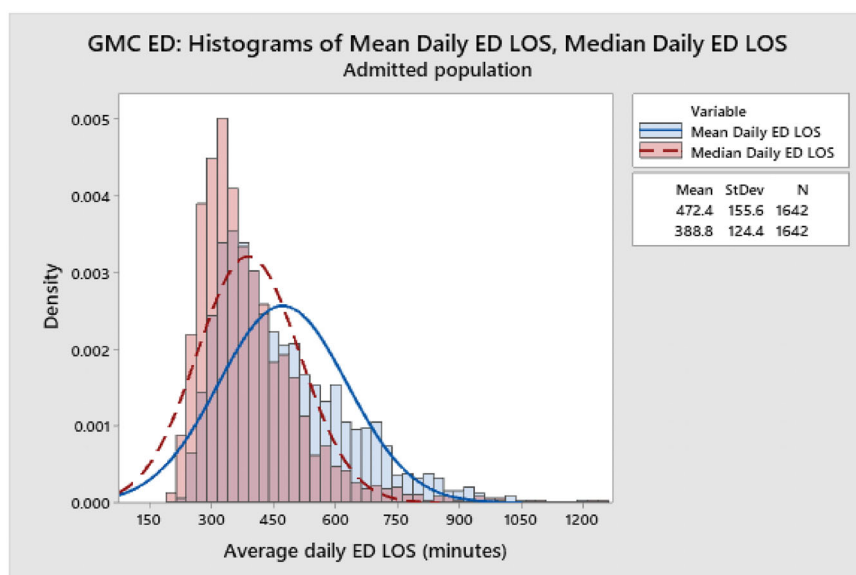
The GWV ED is staffed with board-certified emergency physicians and pediatric emergency physicians complemented by physician

TABLE 1 Study site characteristics for the Geisinger Medical Center and Geisinger Wyoming Valley emergency departments

ED characteristic	2015		2016		2017		2018		January 2015 to June 2019	
	GMC	GWV	GMC	GWV	GMC	GWV	GMC	GWV	GMC	GWV
Average daily hospital occupancy, %	98	100	98	103	100	104	99	99	95	101
Total ED volume	46,519	54,911	46,517	57,380	45,178	60,246	44,398	60,958	21,590	28,752
Pediatric patients (% of ED patients <18 years of age)	15	15	15	15	15	14	16	15	18	15
ED ambulance arrivals, %	28	28	28	28	28	27	29	26	29	26
ED LWBS, %	0.8	3.0	0.9	1.5	0.7	0.4	0.7	0.2	0.5	0.3
Hospital admission rate from ED, %	35	20	33	21	33	22	34	23	35	23
ESI acuity level 1, %	3	2	2	3	2	3	3	3	4	4
ESI acuity level 2, %	27	23	27	23	28	21	28	20	28	20
ESI acuity level 3, %	47	54	51	56	60	60	64	61	64	62
ESI acuity levels 4 and 5, %	23	21	20	19	10	16	5	16	4	14
Hospital bed size									594	291
Residency program									Yes	No

ED, emergency department; ESI, Emergency Severity Index; GMC, Geisinger Medical Center; GWV, Geisinger Wyoming Valley; LWBS, left without being seen.

FIGURE 1 Histograms of two measures of central tendency for daily ED length of stay at the GMC ED, illustrating data are not normally distributed for either measure. ED, emergency department; GMC, Geisinger Medical Center; LOS, length of stay



assistants and nurse practitioners. The GWV ED employs a split flow design for triage and treatment of patients, has a rapid evaluation area, bedside registration, a dedicated pediatric treatment area, an observation unit, and ED-based ancillary services, including care managers, clinical pharmacists, phlebotomists, and in-department radiology.

2.2 | Study design and population

This was a retrospective study capturing all patients presenting to the GMC ED and GWV ED from January 1, 2015, through June 30, 2019. The study period included a total of 466,449 ED encounters at two sites for 1642 days. The unit of analysis for statistical modeling is a daily average (eg, daily mean volume, mean percent of admissions, median

daily length of stay), so each model has 1642 observations with each observation representing a day from January 1, 2015, through June 30, 2019.

2.3 | Variables and study definitions

2.3.1 | Emergency department length of stay

Histograms of the daily mean ED length of stay and the daily median ED length of stay illustrate non-normality of the data (Figures 1 and 2). Length of stay is defined as the time from when a patient arrives to the ED until the time the patient arrives on the inpatient or observation unit. The outcome variable chosen for this study is the daily median

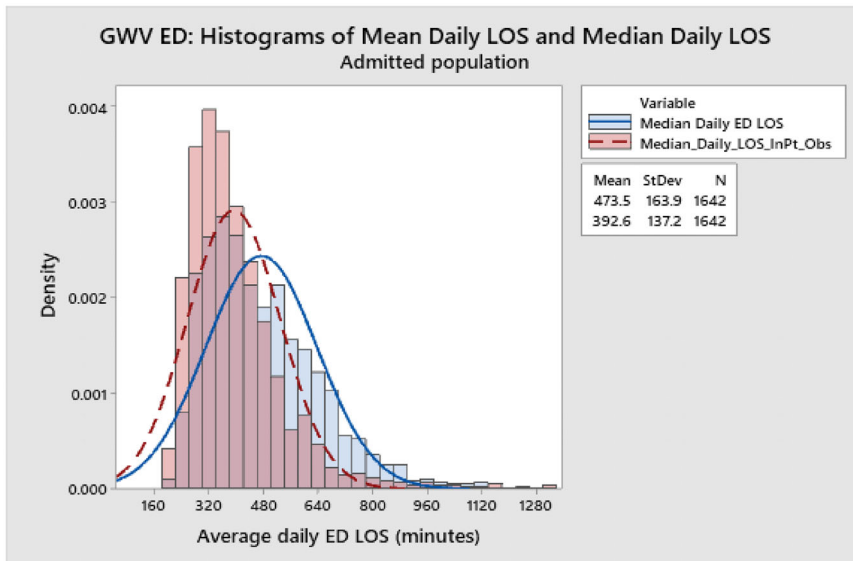


FIGURE 2 Histograms of two measures of central tendency for daily ED length of stay for the GWV ED, illustrating data are not normally distributed for either measure. ED, emergency department; GWV, Geisinger Wyoming Valley; LOS, length of stay; Median_Daily_LOS_inPt_Obs, Median daily length of stay for inpatient and observation status

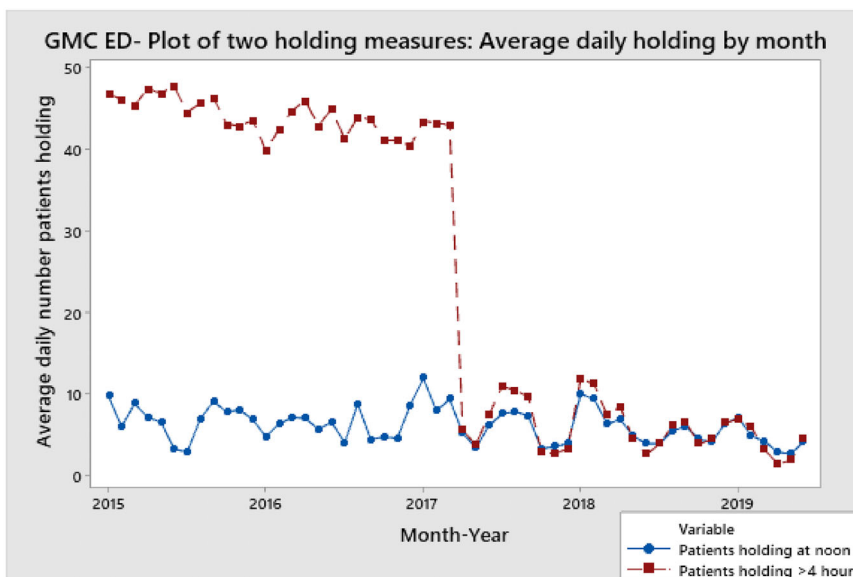


FIGURE 3 Two measures of holding at GMC ED. A significant decrease in patients holding for > 4 hours occurred in 2017 through continuous quality improvement efforts and partnerships between the ED and patient placement services. The two measures became closely correlated after that drop. ED, emergency department; GMC, Geisinger Medical Center

ED length of stay for patients admitted to the hospital as inpatient or observation status. Median length of stay was chosen over mean length of stay because median is the measure of central tendency reported for ED quality metrics and national benchmarking.

2.3.2 | Patient boarding

Two measures for patient boarding were identified *a priori* and include the number of patients boarding at noon and the number of patients boarding for >4 hours. Each boarding measure is the total number of patients per day who were either boarding at noon or boarding for >4 hours. These two measures are consistently used for operational purposes in both EDs. The number of patients holding at noon provides a discrete number of beds that are not available to the rest of the ED. Patient census begin to increase at 11:00 am each day. By noon, the ED staff has a sense of daily flow based on how many beds are occupied by

boarding patients. Process modifications or notification to leadership of the current state in the ED are determined by this indicator. In addition, there are hospital quality metrics that aim to discharge patients from inpatient units by 11:00 am, which is directly connected with the state of the ED at noon.

Second, the number of patients holding for >4 hours is an indicator of patient experience and safety. As continuous quality improvement methods were employed, the number of patients holding for >4 hours decreased while the number of patients holding at noon remained steady at the GMC ED (Figure 3); whereas, both measures closely aligned at the GWV ED (Figure 4).

2.3.3 | Calendar year

A variable for calendar year was included to be a general measure for environmental changes. Several improvement initiatives and projects

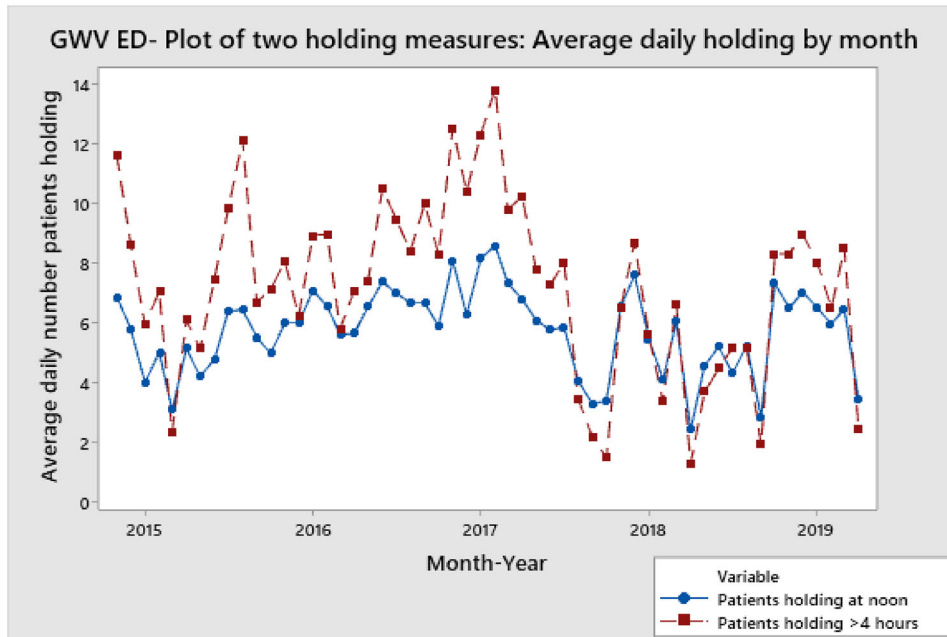


FIGURE 4 Two measures of holding at GWV ED. The two measures are closely correlated, although each are used for different operational purposes. ED, emergency department; GWV, Geisinger Wyoming Valley

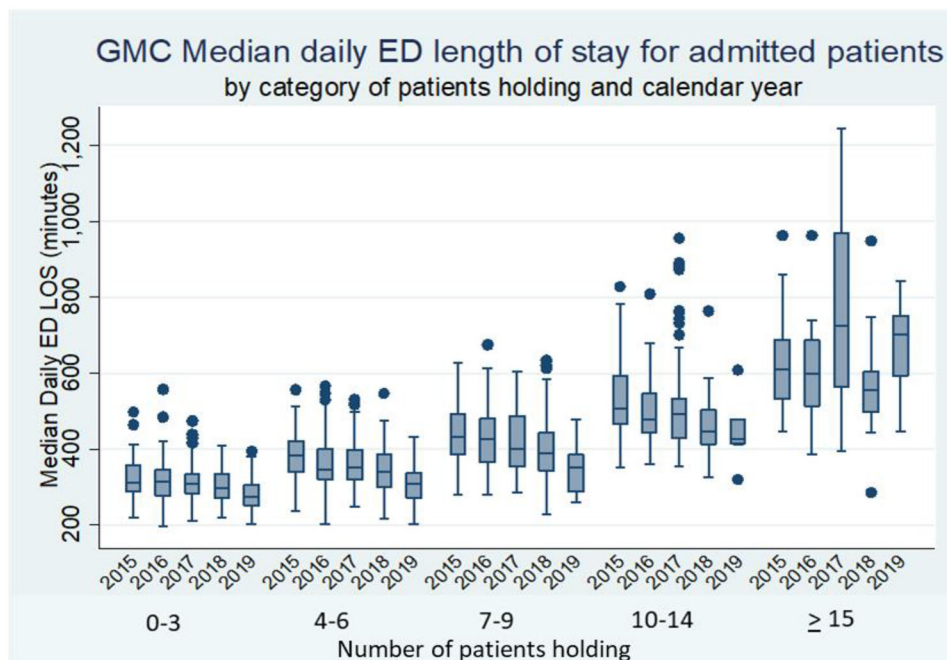


FIGURE 5 Box-and-whisker plot for GMC ED describing the by-year relationship between the number of patients boarding at noon and the median daily ED length of stay. This plot demonstrates a monotonically decreasing median length of stay by year until the number of patients holding reaches 10. After this point, greater variation in median length of stay by year is observed. ED, emergency department; GMC, Geisinger Medical Center; LOS, length of stay

using a continuous quality improvement approach were initiated in late 2015 and early 2016 to improve ED length of stay. Evaluation of each quality improvement initiative/project was conducted to determine if the project had the expected positive effect. For example,

rapid improvement projects including provider-in-triage pilot, ED flow expeditor, and the implementation of a rapid evaluation area each indicated a significant reduction in ED length of stay, but each initiative was conducted using a phased implementation that overlapped with

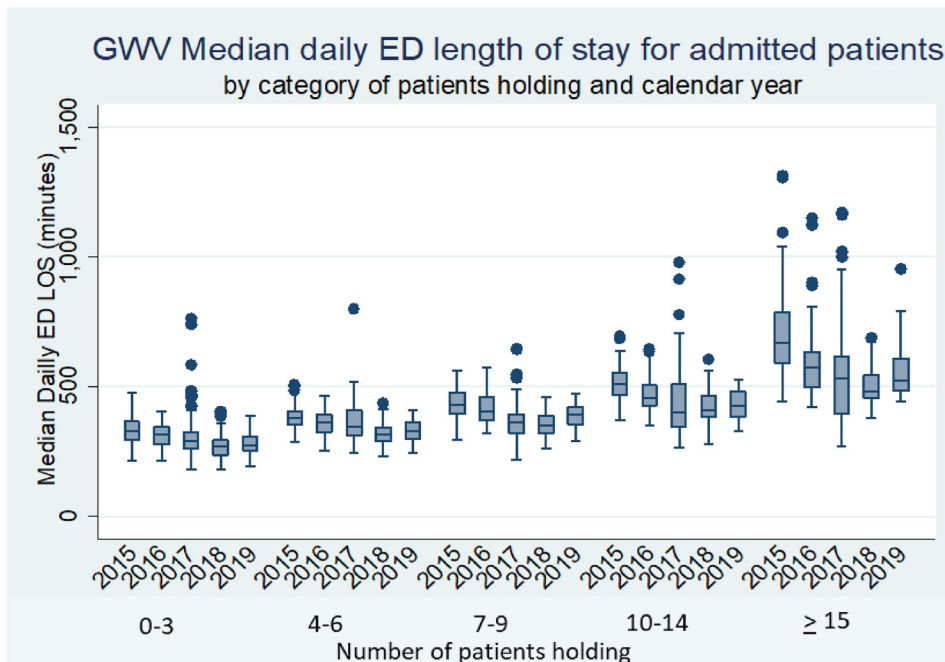


FIGURE 6 Box-and-whisker plot for GWV ED describing the by-year relationship between the number of patients boarding for > 4 hours and the median daily ED length of stay. This plot demonstrates a monotonically decreasing median length of stay from 2015 to 2018 until the number of patients holding reaches 10. At this point, greater variation in median length of stay by year is observed. The data from 2019 appear to mirror the 2017 data and break the pattern of continuously decreasing. ED, emergency department; GWV, Geisinger Wyoming Valley; LOS, length of stay

one another and occurred during the study period. Although not analyzed in this study, the cumulative effects of these initiatives led to department cultural changes that focused on improved throughput and decreased ED length of stay during the course of the calendar year variable.

2.3.4 | Other covariates

The total number of patients transferred to another facility each day was included as a variable because these are primarily patients with behavioral health needs that require admission to an inpatient unit and often stay in the ED for a prolonged period until the transfer can occur. Additional study variables included in the regression model are the following: total daily volume (count), daily behavioral health admissions (count), daily ambulance arrivals (count), acuity (percent of Emergency Severity Index triage levels 1 and 2), and hospital occupancy (percent).

2.4 | Data analysis

2.4.1 | Quantile regression

A quantile (median) regression model was created to estimate the conditional median ED length of stay given the factors associated with ED length of stay for admitted patients. Quantile regression was determined to be preferred over ordinary least

squares regression because of the non-normality of the data. A separate model was created for each study site. Analyses were performed using STATA version 14.1 (StataCorp, College Station, TX).

2.4.2 | Post hoc analysis

Post hoc analysis was conducted using box-and-whisker plots comparing the change in length of stay by patients boarding and calendar year (Figures 5 and 6). The patient boarding variable selected for each study site is based on the results of the regression model.

3 | RESULTS

3.1 | Characteristics of study observations

A summary of THE descriptive statistics by calendar year for each ED is provided in Table 2.

3.2 | Regression results

Results from the quantile regression model are provided in Table 3. Quantile regression produces unbiased estimates. At GMC, the number of patients boarding at noon has the greatest impact on median ED

TABLE 2 Descriptive statistics for Geisinger Medical Center and Geisinger Wyoming Valley emergency departments by calendar year

ED descriptive statistic variables	2015		2016		2017		2018		January 2015 to June 2019	
	GMC	GWV	GMC	GWV	GMC	GWV	GMC	GWV	GMC	GWV
Daily volume, mean (SD)	127.4 (12.8)	150.4 (15.5)	127.1 (14.9)	156.8 (16.2)	123.8 (15.1)	165.1 (17.1)	121.6 (14.7)	167 (20.1)	119.3 (14.6)	158.9 (17.6)
Daily volume of patient holding at noon, mean (SD)	6.9 (4.8)	5.2 (3.3)	6 (4)	6.4 (3.4)	6.4 (4.8)	6.1 (4)	5.9 (4)	5.1 (3.8)	4.3 (3.6)	6 (4.1)
Daily volume of patient holding >4 h, mean (SD)	45.4 (7.3)	7.5 (5.9)	42.6 (7.2)	8.2 (5.6)	15.3 (17.3)	8.2 (6.9)	6.4 (5.6)	5 (5.1)	3.9 (5)	7.1 (6.3)
ED length of stay minutes of discharged patients, mean (SD)	248.4 (40.4)	257.6 (41.9)	259.6 (40.3)	245.6 (42)	258.9 (48)	225.4 (36.5)	255.1 (44.6)	217.9 (33.9)	243.6 (38.4)	219.2 (30.1)
ED length of stay minutes of discharged patients, median (IQR)	201.5 (47.8)	229 (57.5)	215.5 (56.6)	211.3 (57.1)	209.5 (49.8)	184.5 (43.3)	206 (45.5)	180 (36)	198 (42)	185 (32.5)
ED length of stay minutes of admitted patients, mean (SD)	513.5 (162.3)	522.4 (175.6)	470.5 (136.1)	511.1 (143.9)	497.7 (179.6)	485.8 (176)	453.9 (133.2)	388 (126.3)	379.4 (120.5)	446.8 (148.3)
ED length of stay minutes of admitted patients, median (IQR)	401 (162)	409 (162)	364 (132)	395 (129.9)	368 (147.5)	352.5 (151.3)	345.5 (113.8)	302.5 (101.8)	292.5 (76)	351 (136.5)

ED, emergency department; GMC, Geisinger Medical Center; GWV, Geisinger Wyoming Valley; IQR, interquartile range.

length of stay with a coefficient of 14.05 minutes. This suggests that for every one patient boarding at noon in the GMC ED, the daily median ED length of stay for all patients admitted to the hospitals increases by 14 minutes.

At the GWV ED, the boarding measure of greatest magnitude was the number of patients boarding for >4 hours. This result suggests that for every one patient boarding for >4 hours at GWV, the daily median ED length of stay for those admitted to the hospital was increased by 12.36 minutes.

At GMC, the coefficient for calendar year was -6.81 minutes, suggesting a 6.81-minute decrease in median ED length of stay each calendar year from 2015 to 2019. At GWV, the coefficient for calendar year was -15.45 , suggesting that each year that elapsed resulted in a 15-minute reduction in ED length of stay for admitted patients.

Other covariates in the model behaved as expected with some significant associations. The number of transfers at both sites had a significant association of increased ED length of stay for each additional transfer. This was expected given that transfer patients are held in the ED until the receiving facility can accommodate their arrival. Ambulance arrivals and Emergency Severity Index levels 1 and 2 acuity patients were significantly associated with ED length of stay at GMC but had only a marginal impact. Finally, hospital occupancy was significantly associated with ED length of stay where the higher the occupancy, the longer the ED length of stay.

4 | LIMITATIONS

Our study has several limitations. First, it is possible that variables were inadvertently excluded from the regression model. However, included variables reflect those that are clinically relevant and have appeared in the literature. Second, the study sites are high acuity EDs in tertiary/quaternary hospitals with unique services, and therefore the results of our study may not be generalizable to all EDs. However, the type of ED where a patient is boarded is unlikely to have an effect on the overall detrimental impact of boarding on length of stay. Third, the study EDs and the hospitals where they are located had a number of quality improvement initiatives take place during the study period. The details and impact of these initiatives are beyond the scope of this article, although our results might inform future quality-focused projects.

The scope of this study is limited, and several deeper analyses could provide salient information about the impact of boarding on ED patients. First, future analyses should evaluate the effect of specific bed requests on the results, such as intensive care, critical care, pediatrics, and so on. In addition, the evaluation of ED length of stay on discharged patients is another aspect worth investigating. Finally, prior studies have shown that ED physicians may change their admitting practices based on hospital occupancy.²⁶ This art and culture of medical practice is important to consider as we evaluate patient boarding from a holistic systems perspective.

TABLE 3 Median regression output for admitted patient lengths of stay in the Geisinger Medical Center and Geisinger Wyoming Valley emergency departments

Daily ED median length of stay	GMC ED	GWV ED
	Coefficient (95% CI)	Coefficient (95% CI)
Patients boarding at noon	14.05 (13.0 to 15.15) ^{***}	5.52 (3.98 to 7.05) ^{***}
Patients boarding >4 h	0.48 (0.14 to 0.83) ^{**}	12.36 (11.42 to 13.30) ^{***}
Transfer patients	4.22 (1.26 to 7.18) ^{**}	3.35 (−0.84 to 7.54)
Calendar year	−6.81 (−11.74 to −1.87) ^{**}	−15.45 (−18.71 to −12.18) ^{***}
Behavioral health admissions	−0.79 (−3.16 to 1.57)	Not applicable
Total volume	0.12 (−0.24 to 0.49)	−0.09 (−0.37 to 0.19)
Ambulance arrivals	−0.88 (−1.56 to −0.21) [*]	−0.20 (−0.82 to 0.42)
ESI acuity levels 1 and 2	1.14 (0.59 to 1.69) ^{***}	0.27 (−0.28 to 0.82)
Daily admitted, %	−0.80 (−1.69 to 0.08)	−2.31 (−3.51 to −1.12) ^{***}
Hospital occupancy, %	3.31 (2.71 to 3.91) ^{**}	1.22 (0.63 to 1.80) ^{***}

CI, confidence interval; ED, emergency department; ESI, Emergency Severity Index; GMC, Geisinger Medical Center; GWV, Geisinger Wyoming Valley.

^{*}Significant at $P < 0.05$.

^{**}Significant at $P < 0.01$.

^{***}Significant at $P < 0.001$.

5 | DISCUSSION

ED boarding is a significant problem with impacts on morbidity, mortality, and length of stay. Our results suggest that patient boarding has a significant impact on ED length of stay for all admitted patients, even in the midst of observed decreases in ED length of stay at the study sites during the study period. Two measures for patient boarding are those boarding at noon (the time of day patient volume begins to increase) and those boarding for >4 hours. Although both measures are significantly associated with length of stay at each ED, our results suggest that one or the other measure might be a better overall estimate for the impact on length of stay depending on ED characteristics. One thought is that the number of patients boarding at noon is a better estimate for the ED that admits a greater proportion of patients to the hospital (GMC ED).

Our results are novel because they provide an estimate for the association of ED patient boarding on ED length of stay for all admitted patients. At GMC, for every additional patient boarding at noon there was an increased median daily ED length of stay of 14 minutes for patients admitted to the hospital. In other words, two patients boarding in the ED corresponds to a 28-minute increase in median daily ED length of stay, five patients boarding corresponds with a 70-minute increase, and so on. The results are similar for GWV (12 minutes per patient boarding), although the patient boarding metric is the number of patients boarding for >4 hours rather than the number of patients boarding at noon. When our results are applied to boarding at other EDs, it might be necessary to use different measures depending on ED characteristics.

Patient boarding still exists at both EDs in our study. From 2015 to 2019, both measures for patient boarding decreased at GMC and remained consistent at GWV. The consistency in the number of

patients boarding at the GWV ED is best understood in the context of the increase in total patient volume and the significant decrease in length of stay for admitted and discharged patients. This implies that collaborative efforts to address patient boarding have been successful even though the overall number of patients boarding has not changed.

Our results suggest that the median ED length of stay increases as the patient boarding category increases, but within each category the median ED length of stay has decreased during the calendar years. This decrease in boarding across calendar years is likely related to the cumulative effect of quality improvement efforts made within the ED and hospital wide.

The results also suggest that it is possible to decrease the ED length of stay for admitted patients through collaborative quality improvement efforts even with significant ED boarding present. The negative association and magnitude between calendar year and ED length of stay was expected because of the focus on continuous quality improvement and environmental changes over time. An average 15-minute reduction in lengths of stay each year was observed at GWV, and a 7-minute reduction per year in length of stay was observed at GMC.

ED boarding impacts ED length of stay for all patients admitted through the ED and not just those patients who are boarded. This study provides an estimate for the increased ED length of stay experienced by all patients admitted to the hospital as a function of patients boarding. Quantifying the impact of patient boarding on the ED length of stay for the entire patient population admitted to the hospital illuminates the magnitude of the problem of boarding. Prior studies have estimated the impact on morbidity and mortality of the boarded patients, and future studies could use our results to evaluate the impact on morbidity and mortality for all admitted patients related to ED boarding.

CONFLICTS OF INTEREST

Dr. Kraus is on the editorial board at *JACEP Open*.

AUTHOR CONTRIBUTIONS

Leslie Laam contributed to the conception, data analysis, data interpretation, drafting, and revising of the manuscript. Andrea Wary, Ronald Strony, and Michael Fitzpatrick contributed to the drafting of the manuscript. Chadd Kraus contributed to the revising of the manuscript. All authors reviewed the final draft and are accountable for the work as published.

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AUTHOR BIOGRAPHY



Leslie A. Laam, PhD, is Lead Business Intelligence Analyst for Geisinger Health System in Danville, Pennsylvania.

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