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BRIEF REPORT

Education

The impact of emergency department crowding and patient boarding on resident point-of-care ultrasound education

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This work has not been previously presented.

Abstract

Objectives: Emergency department (ED) crowding negatively affects patient care, but the effect on resident education has been difficult to quantify. We aimed to describe the relationship between ED crowding and residents' ability to meet point-of-care ultrasound (POCUS) education goals.

Methods: We retrospectively reviewed medical records from November 2021 to June 2023 at an academic level 1 trauma center, where emergency medicine residents complete longitudinal POCUS scanning shifts throughout 3 years of training. Residents are expected to complete ≥14 scans per scanning shift. We assessed whether completing the goal POCUS scans on a scanning shift (success: ≥14 scans, near-success: 10–13, failure: <10) was associated with the average National Emergency Department Overcrowding Scale (NEDOCS) score or patient boarding hours during each scanning shift. Ordinal logistic regression was performed, controlling for the type of POCUS device available and the presence of medical students, interns, ultrasound faculty, and multiple residents.

Results: Over 125 scanning shifts, 1340 scans were performed. Residents met the expected number of POCUS scans for 26.4% of scanning shifts, with 34.4% near-success and 39.2% failure. The average NEDOCS was 157.4 ± 31.9. POCUS success was associated with a lower mean NEDOCS (142 vs. 169, $p < 0.001$). After controlling for covariates, every 10-point increase in NEDOCS was associated with 17% lower odds of achieving the goal (odds ratio [OR] = 0.83, 95% confidence interval [CI] 0.73–0.94, $p = 0.003$). Other significant factors were having only one resident on a scanning shift, which was associated with lower odds of success (OR = 0.41, 95% CI 0.18–0.97, $p = 0.043$), and having a cart-based POCUS device available in addition to a handheld POCUS device, which was associated with higher odds of success (OR = 13.58, 95% CI 5.53–33.38, $p < 0.001$).

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Conclusion: As ED crowding increased, residents were increasingly likely to fail to meet their POCUS education goals.

KEYWORDS
overcrowding, patient boarding, POCUS, procedures, resident education, ultrasound

1 | INTRODUCTION

1.1 | Background

Emergency department (ED) crowding and patient boarding are increasingly common, leading to a growing crisis for the healthcare system.[1] ED crowding is a complex problem resulting from ineffective mismatch in the input, throughput, and output needs of the system and is associated with undesirable patient outcomes.[1–5] A major contributor to crowding is the practice of patient boarding, where admitted patients wait in the ED until an inpatient or observation bed becomes available.[6]

1.2 | Importance

Understanding the impact of ED crowding and patient boarding on resident education is important to emergency medicine (EM) training programs, but there is a paucity of literature addressing this need.[7,8] A few studies have attempted to subjectively describe the impact of ED crowding on resident education, including resident surveys about faculty teaching effectiveness based on clinical volume and various crowding measures.[9,10] Another study found that crowding as measured by ambulance diversions was associated with residents seeing less patients per shift and performing fewer procedures.[11] Crowding, as measured by subjective physician opinion, was also associated with procedures being more likely to be given away to consulting services.[12] Overall, the current literature relies on heterogenous and often subjective measures of crowding; however, some objective measures such as the National Emergency Department Overcrowding Scale (NEDOCS) scores have been published.[13]

1.3 | Goals of this investigation

As an essential EM procedure, point-of-care ultrasound (POCUS) is an expected competency for the graduating EM physician.[14] However, no literature was identified describing the impact of ED crowding on resident ultrasound education. Therefore, our goal was to objectively examine the impact of ED crowding and patient boarding on POCUS education opportunities during dedicated longitudinal clinical ultrasound education.

2 | METHODS

2.1 | Study design, setting, and selection

We conducted a retrospective observational study at an academic level 1 trauma center from November 2021 to June 2023. Our ED supports a 3-year EM residency program and has >50,000 patient visits annually. EM residents are scheduled for longitudinal POCUS education scanning shifts, which occur on Monday, Wednesday, and Friday from 09:00 to 17:00 for most weeks throughout the year. EM residents have a prespecified expectation of completing ≥14 POCUS scans per scanning shift. Although the aim is for these scans to be clinically indicated, educational scans also count toward the goal. All ultrasound studies performed in the ED were submitted through a quality assurance workflow for review by a team of ultrasound-trained faculty.

2.2 | Measurements and outcomes

The primary outcomes were the number of scans submitted per scanning shift and scan quality. These variables and scan demographics were abstracted from an emergency ultrasound quality assurance database. The number of scans submitted for each scanning shift was categorized as success (≥14 scans per shift), near-success (10–13 scans), or failure (<10 scans). Although pre-specification of the near-success category was arbitrary, the authors believed this was an educationally significant differentiation. Quality scores given to each scan by ultrasound-trained faculty during the quality assurance process were also described using ordinal categories chosen based on standard definitions of clinical significance (1–2 = inadequate for diagnosis, 3 = adequate for diagnosis, and 4–5 = easily supports the diagnosis).

The primary predictors were the cumulative boarding hours present in the ED during the duration of each scanning shift, using time-zero as when the decision to admit the patient has been made, and the average NEDOCS score during each scanning shift, as measured (on the hour) between 09:00 and 17:00. Boarding hours were obtained by leveraging system-level electronic medical record (EMR) queries available from an existing partnership unrelated to the current study with an external consulting group (courtesy of Berkeley Research Group's DRIVE analytics platform). NEDOC scores were queried using summary tools in the EMR. Covariates included the presence or absence of a medical

student, intern, or ultrasound faculty on a scanning shift, resident learners per scanning shift (one or multiple), and day of the week.

During the first portion of the study period, only handheld Butterfly iQ+ POCUS devices (Butterfly iQ, Butterfly Network, Inc.) were available for clinical use during scanning shifts; during the later portion of the study period, the SonoSite PX (Fujifilm) cart-based POCUS system was introduced, although the Butterfly iQ+ also remained available. The device type available was included as a categorical factor. The introduction of the Butterfly iQ+ system did not represent the introduction of POCUS to the ED: the cart-based Phillips Sparq was previously used for scanning shifts and clinical care, but this device was retired from clinical use with the introduction of Butterfly iQ+; therefore, no studies performed with the Sparq were included in the current study.

2.3 | Data analysis

For comparisons of the distribution of predictor variables and mean differences, Pearson chi-square test was performed for categorical variables with post hoc testing using Bonferroni correction for pairwise comparisons, and analysis of variance with Tukey's HSD post hoc for normally distributed continuous variables. The significance level of all tests was set to 0.05. For non-normally distributed continuous variables, the Kruskal–Wallis tests were used.

Boarding hours and NEDOCS were significantly correlated (0.779, $p < 0.001$); as boarding hours are partially included as a component of NEDOCS, only the standardized measure of NEDOCS was included in the model to avoid multicollinearity. Following univariate analysis, cumulative ordinal logistic regression with proportional odds was performed for categories of degree of success for achieving the goal number of scans on a scanning shift. The model predicted the dependent variable over the intercept-only model ($\chi^2(8) = 61.457$, $p < 0.001$).

Analysis was performed in SPSS (IBM SPSS Statistics for Macintosh, version 28.0). This study received Institutional Review Board approval with a waiver of signed informed consent.

3 | RESULTS

3.1 | Demographics

Over the study period, 1340 scans were performed across 125 scanning shifts. Of the scanning shifts, 66.4% were supported by an ultrasound faculty as opposed to a general clinical faculty working in the ED. Of the submitted scans, 797 (59.5%) were for clinical patient care and the remainder were performed for resident education.

3.2 | Boarding and crowding

Cumulative patient boarding hours during a scanning shift and NEDOCS scores were significantly correlated (0.779, $p < 0.001$). The mean cumulative boarding hours during the 125 scanning days was 134.9 (±45.0) hours, ranging from 45.3 to 240.6 h. The average crowding, as measured by mean NEDOCS during scanning days, was 157.4 (±31.9), with a range of 76.2–240.2. Using the NEDOCS definition, "overcrowding" was present during 120/125 (96%) of scanning shifts.

The Bottom Line

This study evaluated the effect of emergency department (ED) crowding on point of care ultrasound (POCUS) training shifts. The key finding was that ED crowding harmed POCUS training. In addition to addressing crowding, new strategies may need to be devised to ensure training shifts are productive, even under adverse conditions.

3.3 | Scanning shift success

Over the entire study period, the goal number of scans was met on 33/125 (26.4%) of scanning shifts. A summary of the frequency of success for meeting scanning shift goals by NEDOCS categories is shown in Figure 1. Scanning shift characteristics and predictor variable descriptive statistics are reported in Table 1. When controlling for scanning shift characteristics and the available POCUS device, ED crowding as measured by mean NEDOCS score remained significantly associated with decreased odds of successfully completing scanning shift goals (Table 2).

3.4 | Quality

There was no significant association between the quality of scans and boarding hours or NEDOCS score. The quality of scans performed during scanning shifts and predictor variable descriptive statistics are reported in Table 3.

4 | LIMITATIONS

First, this study was subject to the limitations of a retrospective study, including reliance on the accuracy of POCUS database records. However, this database is the official method of tracking the number of scans that residents perform during their training, which was the outcome of interest. Second, site-specific factors may moderate the impact of crowding seen in our single-center experience. Third, the ultrasound devices available for use in the ED changed during the study period with the introduction of a cart-based POCUS system in addition to a handheld POCUS system. Although we accounted for this in our main analysis by including device availability as a covariate, caution should be used in interpreting the significance of device availability for POCUS

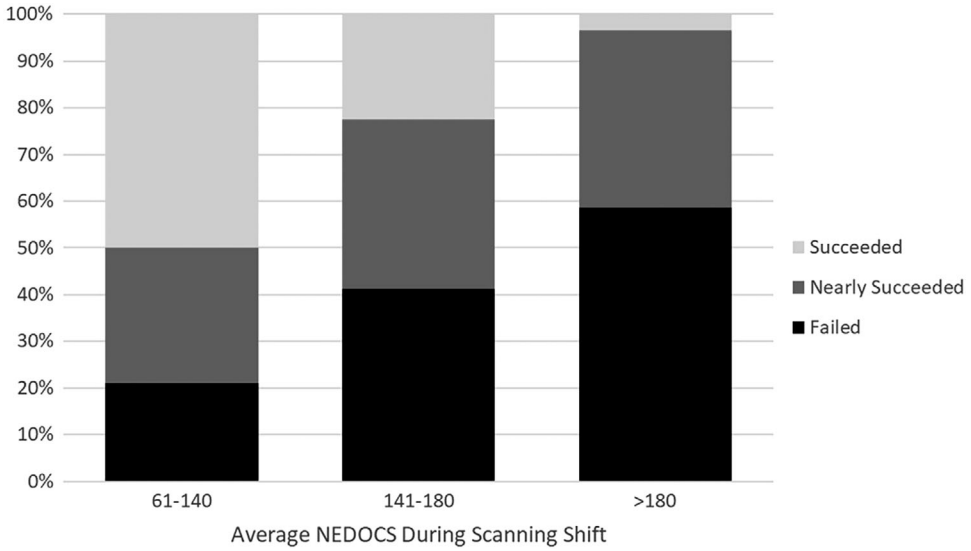

FIGURE 1 Percentage of scanning shifts where residents reached their prespecified expected number of scans by mean National Emergency Department Overcrowding Scale (NEDOCS) score during scanning shift. Failed: <10, nearly succeeded: 11–13, succeeded: ≥14 scans. Standard NEDOC category bins were used, with 61–100 ($n = 5$) collapsed with 101–140 ($n = 33$), and 141–180 ($n = 58$) and >180 ($n = 29$) reported individually.

TABLE 1 Emergency medicine residents' degree of success for meeting their prespecified goal number of scans on point-of-care ultrasound scanning shifts by scanning shift characteristics and emergency department patient boarding and crowding conditions.

Characteristics	Success: 14+ scans ($N = 33$), *n* (col %)	Near-success: 10–13 scans ($N = 43$), *n* (col %)	Failure: <10 scans ($N = 49$), *n* (col %)	*p*-Value
Boarding hours (mean, SD)	118.0 (37.0)[a]	128.6 (46.8)[a]	152.0 (43.2)[b]	0.001[†]
NEDOCS (mean, SD)	141.5 (27.0)[a]	157.0 (33.4)[a,b]	168.5 (29.4)[b]	<0.001[†]
Device available				<0.001[‡]
Butterfly iQ	3 (5.9)*	13 (25.5)	35 (68.6)*	
SonoSite and Butterfly iQ	30 (40.5)*	30 (40.5)	14 (18.9)*	
Medical student present				0.163[‡]
Yes	0 (0)	4 (66.7)	2 (33.3)	
No	33 (27.7)	39 (32.8)	47 (39.5)	
Intern present				0.039[‡]
Yes	21 (37.5)*	17 (30.4)	18 (32.1)	
No	12 (17.4)*	26 (37.7)	31 (44.9)	
Multiple residents present				0.103[‡]
Yes	26 (32.5)	24 (30.0)	30 (37.5)	
No	7 (15.6)	19 (42.2)	19 (42.2)	
Faculty present				0.384[‡]
Yes	25 (30.1)	28 (33.7)	30 (36.1)	
No	8 (19.0)	15 (35.7)	19 (45.2)	
Day of week				0.877[‡]
Monday	10 (30.3)	16 (37.2)	14 (28.6)	
Wednesday	13 (39.4)	14 (32.6)	17 (34.7)	
Friday	10 (30.3)	13 (30.2)	18 (36.7)	

Abbreviations: NEDOCS, National Emergency Department Overcrowding Scale; SD, standard deviation.

[†]Analysis of variance, Tukey HSD; alphabets (a and b) indicate significant differences between column means at alpha 0.05. That is, means with the same superscript do not significantly differ at the specified corrected alpha.

[‡]Chi-square, Bonferroni correction; asterisk (*) indicates differences between row proportions at alpha 0.05.

TABLE 2 Odds of completing the prespecified number of point-of-care ultrasound scans expected during a scanning shift, reported as proportional odds of success (≥14 scans) relative to near success (10–13 scans) and failure (<10 scans).

Predictor	Unadjusted OR (95% CI)	*p*-Value	Adjusted OR[a] (95% CI)	*p*-Value
NEDOCS (per 10-unit increase)	0.82 (0.73–0.91)	<0.001	0.83 (0.73–0.94)	0.003
Device available		<0.001		<0.001
Butterfly iQ	Ref		Ref	
SonoSite and Butterfly iQ	9.70 (4.42–21.29)		13.58 (5.53–33.38)	
Medical student present		0.662		0.540
Yes	Ref		Ref	
No	1.41 (0.30–6.55)		1.79 (0.28–11.57)	
Intern present		0.026		0.221
Yes	Ref		Ref	
No	0.47 (0.24–0.91)		0.59 (0.26–1.37)	
Multiple residents present		0.185		0.043
Yes	Ref		Ref	
No	0.63 (0.32–1.25)		0.41 (0.18–0.97)	
Faculty present		0.196		0.200
Yes	Ref		Ref	
No	0.63 (0.32–1.27)		0.55 (0.23–1.37)	

Abbreviations: CI, confidence interval; NEDOCS, National Emergency Department Overcrowding Scale; OR, odds ratio.
[a]Adjusted for factors shown and day of week (not shown) using an ordinal logistic regression proportional odds model.

TABLE 3 Point-of-care ultrasound image quality scores for scans submitted on scanning shifts by scanning shift characteristics and emergency department boarding and crowding conditions.

Characteristics	Inadequate (1–2) (*N* = 141), *n* (col %)	Average (3) (*N* = 675), *n* (col %)	Above average (4–5) (*N* = 524), *n* (col %)	*p*-Value
Boarding hours (median, IQR)	124.4 (94.3, 150.8)	124.4 (94.3, 130.2)	126.8 (97.9, 157.3)	0.216[a]
NEDOCS (median, IQR)	148.8 (127.3, 168.4)	145.1 (130.2, 176.0)	153.4 (131.0, 176.2)	0.125[a]
Device available				<0.001[b]
Butterfly iQ	34 (9.7)	130 (37.1)*	186 (53.1)*	
SonoSite and Butterfly iQ	107 (10.8)	545 (55.1)*	338 (34.1)*	
Medical student present				0.770[b]
Yes	5 (9.1)	26 (47.3)	24 (43.6)	
No	136 (10.6)	649 (50.5)	500 (38.9)	
Intern present				0.005[b]
Yes	72 (10.8)	363 (54.4)*	232 (34.8)*	
No	69 (10.3)	312 (46.4)*	292 (43.4)*	
Faculty present				0.012[b]
Yes	92 (9.6)	466 (48.8)	396 (41.5)*	
No	49 (12.7)	209 (54.1)	128 (33.2)*	

Note: Scans are scored on a scale of 1–5 by ultrasound faculty during the quality assurance process.
Abbreviations: IQR, interquartile range; NEDOCS, National Emergency Department Overcrowding Scale.
[a]Analysis of variance.
[b]Chi-square, Bonferroni correction; asterisk (*) indicates differences between row proportions at alpha 0.05.

success as other unmeasured factors related to hospital flow may have changed over time.

5 | DISCUSSION

As ED crowding increased, we found that EM residents were progressively more likely to fail to meet their ultrasound education goals. To our knowledge, this association has not previously been examined, and is highly concerning for resident education.

Although the association between POCUS education and crowding has not been previously reported, if considering POCUS as an EM procedure, this finding is consistent with scarce data from the prior literature. The presence of crowding as defined by >2 h of ambulance diversion per shift has been associated with residents performing fewer procedures (0.9 vs. 1.3) and seeing fewer patients per shift (12.3 vs. 13.9).[11] When crowding was measured by subjective attending physician opinion, procedures were more likely to be given away to consulting services, but there was no association with the number of procedures performed.[12] The choice of which measure to use to capture crowding is varied throughout the prior literature, and some measures, such as ambulance diversion time, are not applicable at our center. Although NEDOCS was chosen for its relative objectivity, presumed generalizability to other large academic medical centers, and good correlation with cumulative boarding hours in our population, prior criticism has suggested that it may be less applicable to very high-volume ED settings.[15] Even in the current study, using NEDOCS for binary characterizations of "overcrowding" would have been unhelpful, as 96% of scanning shifts occurred during "overcrowded" conditions as defined by NEDOCS. However, we believed that NEDOCS was the best measure given the available data. Our current quantitative findings are alarming with respect to the ability to provide high-quality resident education in crowded EDs, with a dose–response suggesting that increasing severity of crowding is associated with increasingly severe effects on education.

During conditions of high ED crowding, residents were very unlikely to meet their scanning goal. This may be due to combination of factors, including new patients being evaluated only in triage, the waiting room, or a hallway where the privacy to complete a POCUS examination may be lacking. While POCUS itself is infrequently invasive, having patients partially disrobe in a public space to complete an examination invades privacy. The added work and time of finding a private space to complete a POCUS examination (when all the treatment spaces are already full) may contribute to the high failure rate. Although residents could have performed educational scans on boarding patients to meet their scanning shift goals, this might not help residents learn how to integrate POCUS into their ED practice. In addition, scanning boarding patients to improve scanning shift numbers also presents challenges during times of high crowding, due to some patients' care being assumed by admitting teams (taking ED beds out of service), the sickest patients being boarded in ED rooms (either unable to consent to educational studies or not in clinical condition to participate in them), and diminishing educational value for repeat educational examinations on the same patients (for those boarding for multiple days).

Other significant factors for meeting POCUS goals included having multiple residents on a single scanning shift, which likely improved efficiency, as one resident could complete documentation while the other resident prepared for another scan. Changes in device availability during the study period were notable, as only a Butterfly iQ+ handheld device was available during approximately the first one-third of the study period, followed by return of cart-based POCUS systems. Although not the focus of the current study, these findings suggest that machine type and availability are significant factors for POCUS education.

Ultimately, improving resident success toward their POCUS education goals will require both addressing the patient boarding and crowding crisis at a system level, and developing novel strategies to maximize education in the current environment. Although a certain number of completed POCUS examinations are likely necessary to achieve competency, when fewer scans are completed in a day a faculty may have more time to provide quality feedback for each scan performed. This may be reflected in the similar POCUS quality scores observed regardless of crowding conditions. Faculty educators must ensure that they find ways to provide quality education with less quantity. Prior resident surveys about faculty teaching quality found no difference in teaching scores by perceptions of workload or patient volume; faculty with highly rated teaching skills and interpersonal skills had superior teaching scores regardless of perception or reality of the clinical volume.[9,10]

Future work is needed to identify specific mechanisms resulting from crowding that ultimately contribute to educational failures, and to examine the effectiveness of strategies to improve POCUS education despite ED crowding.

Overall, we found that ED crowding and patient boarding negatively impacted residents' POCUS learning opportunities in the ED, with a dose–response suggesting that increasing severity of crowding is associated with increasingly negative effects on education.

AUTHOR CONTRIBUTIONS

Conceptualization and data collection: Brandon Michael Wubben, Nicholas Chmielewski, Paul Van Heukelom, and Cory Wittrock. *Data analysis*: Brandon Michael Wubben. *Critical review and evaluation of results*: Brandon Michael Wubben and Cory Wittrock. *Primary authorship of the paper*: Brandon Michael Wubben. *Review and editing of the paper*: Brandon Michael Wubben, Nicholas Chmielewski, Paul Van Heukelom, and Cory Wittrock. *Study supervision*: Cory Wittrock.

CONFLICT OF INTEREST STATEMENT

Cory Wittrock owns stock in the following companies: Gilead, GE Healthcare Biosciences, Butterfly Network Inc., Boston Scientific Corporation, and Teladoc Inc. The remaining authors declare they have no conflicts of interest.

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