Emergency Medicine Resident Efficiency and Emergency Department Crowding

Ryan Kirby, MD, Richard D. Robinson, MD, Sasha Dib, MD, Daisha McLarty, MD, Sajid Shaikh, MS, Radhika Cheeti, Amy F. Ho, MD, Chet D. Schrader, MD, Nestor R. Zenarosa, MD, and Hao Wang, MD, PhD

ABSTRACT

Objectives: Provider efficiency has been reported in the literature but there is a lack of efficiency analysis among emergency medicine (EM) residents. We aim to compare efficiency of EM residents of different training levels and determine if EM resident efficiency is affected by emergency department (ED) crowding.

Methods: We conducted a single-center retrospective observation study from July 1, 2014, to June 30, 2017. The number of new patients per resident per hour and provider-to-disposition (PTD) time of each patient were used as resident efficiency markers. A crowding score was assigned to each patient upon the patient's arrival to the ED. We compared efficiency among EM residents of different training levels under different ED crowding statuses. Dynamic efficiency changes were compared monthly through the entire academic year (July to next June).

Results: The study enrolled a total of 150,920 patients. A mean of 1.9 patients/hour was seen by PGY-1 EM residents in comparison to 2.6 patients/hour by PGY-2 and -3 EM residents. Median PTD was 2.8 hours in PGY-1 EM residents versus 2.6 hours in PGY-2 and -3 EM residents. There were no significant differences in acuity across all patients seen by EM residents. When crowded conditions existed, residency efficiency increased, but such changes were minimized when the ED became overcrowded. A linear increase of resident efficiency was observed only in PGY-1 EM residents throughout the entire academic year.

Conclusion: Resident efficiency improved significantly only during their first year of EM training. This efficiency can be affected by ED crowding.

In recent years, studies focusing on various provider efficiencies have been reported including physicians working in community hospitals and academic attending physicians supervising residents, medical students, or advanced practice providers (APPs; e.g., physician assistants, nurse practitioners).^{1–6} Different provider efficiency measurements were used in different studies including new patients per provider per hour, relative value units (RVUs) generated per shift, or mean

patient emergency department (ED) length of stay.^{1–3} Study results had variable conclusions on provider efficiency due to the differences of efficiency measurements, ED volumes, interventions, patient acuity, and ED crowding conditions.^{1,7,8} Such diverse provider efficiency reported in the literature raises the question of whether it is necessary to provide standard training on provider efficiency during EM residency training. Unfortunately, few studies in the current literature

From the Department of Emergency Medicine, Integrative Emergency Services (RK, RDR, SD, DM, AFH, CDS, NRZ, HW), and the Department of Information Technology (SS, RC), John Peter Smith Health Network; and the Department of Medical Education, University of North Texas Health Science Center (RDR), Fort Worth, TX.

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Address for correspondence and reprints: Hao Wang, MD, PhD; e-mail: hwang01@jpshealth.org.

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report on resident efficiency.^{2,3,5} Although previous studies addressed resident efficiency in general, there were neither efficiency comparisons among residents of different training levels nor dynamic comparisons during the entire academic year, which makes resident efficiency assessment less informative.

ED provider efficiency links closely with patient flow and ED crowding.⁸ Patient flow is measured through several time intervals such as the time interval from patient arrival to patient seen by an ED provider (e.g., door-to-provider time), the time interval from patient seen by an ED provider to patient disposition (e.g., provider-to-disposition [PTD] time), or the time interval from patient arrival to patient departure from the ED (e.g., patient total length of stay [LOS]).^{9–11} If an ED runs at its full capacity while no-flow occurs (e.g., unable to move patients out from ED) during a certain time range, this results in crowding.¹¹ ED crowding can be measured using different crowding estimation tools.¹¹ The National Emergency Department Overcrowding Score (NEDOCS) is one of the most commonly used scoring systems and is validated widely across the nation.^{12–14} Briefly, NEDOCS are calculated based on the total number of patients in the ED, number of critical care ED patients, and number of admit holds in the ED along with the longest time in department of ED admitted patients and patients in the waiting room. The score has also been adjusted by total number of ED and hospital beds to match for different ED/hospital settings (see Data Supplement S1, available as supporting information in the online version of this paper, which is available at <http://onlinelibrary.wiley.com/doi/10.1002/aet2.10327/full>, for detail descriptions). In general, ED crowding is associated with prolonged patient ED stays.^{15,16} However, such findings neither had a direct link with provider efficiency nor further addressed the association between provider efficiency and severity of ED crowding. More specifically, no literature has reported such an association among residents with different levels of training experience.

Emergency medicine residency programs are generally sponsored in tertiary referral centers with EDs that see a relatively high volume of patients. ED crowding has become more common especially at extremely high-volume EDs.¹⁷ It is important to determine EM resident efficiency during different crowding statuses of an ED, thus providing accurate information to develop future curricula on resident-specific training on ED crowding. We hypothesized that resident efficiency

might be affected by ED crowding. Therefore, we aim to 1) compare efficiency and its dynamic changes within an entire academic year among EM residents of different training levels and 2) determine resident efficiency under ED of different crowding statuses.

METHODS

Study Design and Setting

This is a retrospective single-center observational study. The study hospital is an urban tertiary referral center with an ED that sponsored an ACGME-accredited 3-year emergency medicine (EM) residency program with 12 residents per class. It has a total of 573 licensed beds in the hospital and 54 beds in the ED. The study ED has approximately 120,000 patient visits annually. This study was approved by the John Peter Smith Health Network Institutional Review Board.

Study Participants

Study participants were the residents. From July 1, 2014, until June 30, 2017, patients who presented at the study ED and were evaluated by EM residents were included in this study. Residents included EM residents of different training levels (PGY-1, -2, and -3). We excluded 1) patients who were seen and evaluated by APPs (e.g., physician assistants or nurse practitioners), 2) patients seen only by ED attending physicians, 3) patients seen by non-EM residents, and 4) patients who left without being seen or eloped (Figure 1).

Variables and Outcome Measurements

Patient general characteristics included age, sex, and ethnicity. ED metrics included patient level of acuity

Figure 1. Study flow diagram.

using Emergency Severity Index (ESI), patient LOS, and PTD time. ESI is a triage tool to determine patient level of acuity upon patients' arrival at the ED with ESI-1 being the most emergent and ESI-5 being the least emergent. ED LOS was defined as the time interval in hours beginning at the time of patient arrival at the ED and ending at the time when the patient physically left the ED as documented in the medical record. PTD time was defined as the time interval in hours beginning at the time when the patient was initially seen and evaluated by a provider and ending at the time when the disposition decision was made. The number of new patients per hour was defined as the number of new patients assigned to individual residents within a 1-hour block (e.g., 0800 to 0859). PGY-1 residents have 10-hour clinical shifts while PGY-2 and -3 residents have 9-hour clinical shifts. All residents are required to evaluate any new patients during the first 8 hours of their shifts. Senior EM residents (PGY-2 and -3) have 1 hour of overlap and junior EM residents (PGY-1) have 2 hours of overlap at the end of their clinical shift. Attending physicians have either 8- or 12-hour shifts without any overlap. The study ED has a dedicated "fast-track" area staffed with APPs who saw low-acuity patients (ESI-4 and -5) and higher-acuity patients (ESI-1 to -3) were seen by EM attending physicians and residents. ED crowding status was measured by NEDOCS (see Data Supplement S1). Provider efficiency was based on two outcome measurements: 1) the number of new patients per hour seen by a given resident and 2) PTD time of each patient.

ED Crowding Measurements

National Emergency Department OverCrowding Score is one of the most common ED crowding estimation tools and has been externally validated in other studies.^{12–14} NEDOCS is categorized into different levels of crowding, from not crowded to dangerously overcrowded statuses. The study ED has developed a computer program linked to the electronic medical record and is able to calculate NEDOCS score in real-time every hour. To simplify its crowding statuses, NEDOCS categories were modified to three-tier classification schemes in this study, where scores ≤ 100 are classified as "not crowded," scores > 100 and ≤ 140 are classified as "crowded," and scores > 140 are classified as "overcrowded."¹⁶ Each patient arriving at the ED was assigned a crowding score. ED crowding was measured at the top of each hour throughout the study period.

Crowding scores estimated at the beginning of each hour were assigned to all subjects who arrived throughout the given hourly interval. Patients who arrived at the end of the hour were assigned the same crowding score as measured at the start of the hour (e.g., patients who arrived from 0801 to 0859 were assigned to the crowding score measured at 0800).

Study Protocol

In this study, we divided patients into three groups based on ED crowding status upon patients' arrival at the study ED. Provider efficiency outcomes were analyzed and compared under different crowding statuses of the ED (e.g., not crowded, crowded, overcrowded). Additionally, we divided residents into four groups (EM PGY-1, EM PGY-2, EM PGY-3, EM residents with different genders). Provider efficiency outcomes were measured and compared among these four groups.

Data Analysis

We used a one-way analysis of variance for continuous data comparisons among different groups and Pearson chi-square test for categorical data comparisons. We calculated both mean and median for ED LOS, PTD, and number of new patients per hour per resident. We used a Wilcoxon rank-sum test for median comparisons between groups. All analyses were performed using STATA 14.2 software with a p -value < 0.05 considered a statistically significant difference.

RESULTS

This study included a total of 150,920 patients seen and evaluated initially by 61 EM residents of different training levels. The median age of patients was 46, 53% were male, and 26% were Hispanic. Of these, 30,228 patients were evaluated by PGY-1 residents, 59,520 patients by PGY-2 residents, and 61,172 patients by PGY-3 residents. When NEDOCS was used for ED crowding assessment hourly, 39.7% (59,883/150,920) of patients arrived at the ED under not crowded status, 28.3% (42,716) of patients arrived under crowded status, and 32.0% (48,321) patients arrived under overcrowded status. Table 1 shows the general information of the study patient population.

Using the number of new patients per resident per hour to determine resident efficiencies, we found that senior EM residents (PGY-2 and -3) tended to see more new patients per hour than PGY-1 EM residents. Additionally, senior EM residents (PGY-2 and -3) saw more

Table 1
Study Population Demographics

	Total Number of Analyzed Patients (N = 150,920)
Age (years)	46 (32–57)
Gender, male	80,291 (53)
Ethnicity, Hispanic	38,548 (26)
	Total Number of Residents (N = 61)
Sex	
Male	37 (61)
Female	24 (39)

Data are reported as median (IQR) or *n* (%).
IQR = Interquartile Range.

new patients per hour when the ED was at higher crowding statuses, indicating resident efficiency increased with advanced EM training (Table 2). When PTD was used for resident efficiency measurement, we found a similar trend among residents of different training levels. Senior EM residents (PGY-2 and -3) had a shorter PTD time than PGY-1 EM residents. However, when PTD was compared under different crowding statuses of the study ED, no significant differences were found among residents regardless of their EM training experience (Table 3). Furthermore, when evaluating patient total ED LOS, we found that increased levels of

ED crowding yielded prolonged patient LOS regardless of resident training level (Table 4).

We further evaluate EM residents of different genders. Our results showed male residents saw relatively more new patients per hour (Table 2), with shorter PTD and total patient LOS (Tables 3 and 4) than female residents. Regardless of resident genders, we found that there were more new patients per hour and prolonged PTD and LOS found when the ED was at higher crowding statuses.

Most patients seen by residents were categorized as ESI-1 to ESI-3, with the most being ESI-3 patients (Table 5). No significant differences occurred in terms of median PTD as a function of different levels of acuity; therefore, patient ESI was not considered for resident proficiency measurements (Table 6).

We evaluated the dynamic changes of resident efficiency during the academic year (from July to June of next year) under the different ED crowding statuses. Figure 2 shows the dynamic changes of number of new patients per resident per hour during the academic year. The number of new patients per hour seen by PGY-1 residents increased significantly with an increase in experience regardless of ED crowding statuses (Figure 2). However, such changes did not duplicate among

Table 2
A Comparison of Number of New Patients Seen Hourly by Residents of Different Training Levels Under ED of Different Crowding Statuses

	Number of New Patients Per Hour Seen by Residents				Maximal Changes
	Not Crowded	Crowded	Overcrowded	Overall	
PGY-1 EM residents					
Median (IQR)	2 (1–2)	2 (1–2)	2 (1–2)	2 (1–2)	0.20
Mean ($\pm$ SD)	1.75 ($\pm$ 0.86)	1.90 ($\pm$ 0.91)	1.95 ($\pm$ 0.96)	1.86 ($\pm$ 0.91)	
Total number of patients	12,288	8,360	9,580	30,228	
PGY-2 EM residents					
Median (IQR)	2 (1–3)	2 (2–3)	2 (2–3)	2 (2–3)	0.31
Mean ($\pm$ SD)	2.40 ($\pm$ 1.26)	2.65 ($\pm$ 1.34)	2.71 ($\pm$ 1.42)	2.57 ($\pm$ 1.34)	
Total number of patients	23,330	16,950	19,240	59,520	
PGY-3 EM residents					
Median (IQR)	2 (2–3)	3 (2–3)	3 (2–4)	2 (2–3)	0.29
Mean ($\pm$ SD)	2.47 (1.31)	2.73 (1.38)	2.76 (1.36)	2.64 (1.35)	
Total number of patients	24,265	17,406	19,501	61,172	
All EM male residents					
Median (IQR)	2 (1–3)	2 (2–3)	2 (2–3)	2 (2–3)	0.30
Mean ($\pm$ SD)	2.31 ($\pm$ 1.25)	2.56 ($\pm$ 1.33)	2.61 ($\pm$ 1.36)	2.48 ($\pm$ 1.32)	
Total number of patients	37,795	27,407	31,047	96,249	
All EM female residents					
Median (IQR)	2 (1–3)	2 (2–3)	2 (2–3)	2 (1–3)	0.26
Mean ($\pm$ SD)	2.27 ($\pm$ 1.22)	2.49 ($\pm$ 1.30)	2.53 ($\pm$ 1.33)	2.41 ($\pm$ 1.29)	
Total number of patients	22,088	15,309	17,274	54,671	

IQR = interquartile range.

Table 3

A Comparison of PTD Time of Patients Seen by Residents of Different Training Levels Under ED of Different Crowding Statuses

	PTD Time Seen by Residents (Hours)				Maximal Changes
	Not Crowded	Crowded	Overcrowded	Overall	
PGY-1 EM residents					
Median (IQR)	2.7 (1.7–3.9)	2.8 (1.8–4.1)	2.9 (1.9–4.1)	2.8 (1.8–4.0)	0.2
Mean (±SD)	3.0 (1.8)	3.1 (1.8)	3.2 (1.9)	3.1 (1.8)	
Total number of patients	12040	8175	9373	29588	
PGY-2 EM residents					
Median (IQR)	2.5 (1.6–3.7)	2.6 (1.6–3.8)	2.6 (1.6–3.9)	2.6 (1.6–3.8)	0.1
Mean (±SD)	2.8 (2.0)	2.9 (1.8)	2.9 (2.6)	2.9 (2.2)	
Total number of patients	22841	16617	18876	58334	
PGY-3 EM residents					
Median (IQR)	2.5 (1.5–3.7)	2.6 (1.6–3.8)	2.6 (1.6–3.8)	2.6 (1.6–3.8)	0.1
Mean (±SD)	2.8 (1.8)	2.9 (1.8)	2.9 (1.9)	2.8 (1.9)	
Total number of patients	23,875	17,116	19,212	60,203	
All EM male residents					
Median (IQR)	2.5 (1.5–3.7)	2.6 (1.6–3.8)	2.6 (1.6–3.8)	2.5 (1.5–3.8)	0.1
Mean (±SD)	2.8 (1.8)	2.8 (1.8)	2.9 (1.9)	2.8 (1.8)	
Total number of patients	37,136	26,937	30,554	94,627	
All EM female residents					
Median (IQR)	2.7 (1.7–3.9)	2.8 (1.8–4.1)	2.9 (1.8–4.1)	2.8 (1.8–4.0)	0.1
Mean (±SD)	3.0 (2.0)	3.1 (1.8)	3.1 (2.7)	3.0 (2.2)	
Total number of patients	21,620	14,971	16,907	53,498	

IQR = interquartile range; PTD time = provider-to-disposition time.

Table 4

A Comparison of Total LOS of Patients Seen by Residents of Different Training Levels Under Emergency Department of Different Crowding Statuses

	Patient Total ED LOS Time Seen by Residents (Hours)				Maximal Changes
	Not Crowded	Crowded	Overcrowded	Overall	
PGY-1 EM residents					
Median (IQR)	4.2 (2.8–5.9)	4.6 (3.2–6.5)	5.0 (3.5–7.4)	4.6 (3.1–6.5)	1.4
Mean (±SD)	4.7 (±4.0)	5.3 (±4.0)	6.1 (±4.3)	5.3 (±4.1)	
Total number of patients	12,284	8,343	9,559	30,186	
PGY-2 EM residents					
Median (IQR)	4.1 (2.8–5.8)	4.5 (3.1–6.3)	4.9 (3.3–7.0)	4.4 (3.0–6.3)	1.1
Mean (±SD)	4.7 (±3.3)	5.1 (±3.4)	5.8 (±4.5)	5.2 (±3.7)	
Total number of patients	23318	16910	19197	59425	
PGY-3 EM residents					
Median (IQR)	4.0 (2.7–5.7)	4.5 (3.1–6.3)	4.7 (3.2–6.8)	4.4 (3.0–6.2)	1.1
Mean (±SD)	4.6 (±3.0)	5.2 (±3.6)	5.7 (±4.3)	5.1 (±3.7)	
Total number of patients	24,257	17,394	19,493	61,144	
All EM male residents					
Median (IQR)	4.1 (2.7–5.7)	4.4 (3.1–6.3)	4.8 (3.2–6.9)	4.4 (3.0–6.3)	1.1
Mean (±SD)	4.6 (±3.4)	5.1 (±3.7)	5.7 (±4.1)	5.1 (±3.7)	
Total number of patients	37,779	27,357	30,997	96,133	
All EM female residents					
Median (IQR)	4.2 (2.8–5.9)	4.6 (3.-6.5)	5.0 (3.4–7.2)	4.5 (3.1–6.5)	1.3
Mean (±SD)	4.7 (±3.3)	5.3 (±3.4)	6.0 (±4.7)	5.3 (±3.9)	
Total number of patients	22,080	15,290	17,252	54,622	

IQR = interquartile range; LOS = length of stay.

Table 5
Different ESI Comparisons Among Patients Seen by Residents

	Patients Seen by Residents*
ESI-1	7,701 (5)
ESI-2	57,544 (38)
ESI-3	76,220 (51)
ESI-4	8,274 (6)
ESI-5	855 (0.6)

Data are reported as *n* (%).

ESI = Emergency Severity Index; PTD time = provider-to-disposition time.

*Other 381 patients whose ESIs were unknown.

senior EM residents (PGY-2 and -3). Overall, the number of new patients seen hourly increased for residents of all training levels when the ED became crowded. Such changes were minimized when ED became overcrowded. When PTD was measured, it showed that PTD times decreased during the academic year regardless of resident training experience. PTD times significantly shortened for patients who were evaluated by PGY-1 EM residents throughout the entire academic year regardless of ED crowding statuses. However, such significant changes also did not duplicate among senior EM residents (Figure 3).

DISCUSSION

Provider efficiency has been reported in the literature but mainly focused on the attending physicians.¹ This study focused on EM resident efficiency especially addressing efficiency differences among EM residents

Table 6
PTD Time Comparisons Between All Patients Versus ESI-3 Patients

	PTD Time* (All Patients)	PTD (ESI-3 Patients)
EM PGY-1 residents	2.8 (1.8–4.0) 3.1 (±1.8)	2.8 (1.8–4.0) 3.1 (±1.9)
EM PGY-2 residents	2.6 (1.6–3.8) 2.9 (±2.2)	2.7 (1.7–3.8) 2.9 (±1.9)
EM PGY-3 residents	2.6 (1.6–3.8) 2.8 (±1.9)	2.6 (1.7–3.8) 2.9 (±1.8)
Male EM residents	2.5 (1.5–3.8) 2.8 (±1.8)	2.6 (1.7–3.8) 2.9 (±1.8)
Female EM residents	2.8 (1.8–4.0) 3.0 (±2.2)	2.8 (1.8–4.0) 3.1 (±2.0)
All residents	2.6 (1.6–3.8) 2.9 (±2.0)	2.7 (1.7–3.9) 3.0 (±1.9)

Data are reported as median (IQR) and mean (±SD).

IQR = interquartile range; PTD = provider-to-disposition time.

*Time interval documented in the electronic medical record beginning at the time when the patient is initially seen and evaluated by a provider and ending at the time when the disposition decision is made.

under different crowding statuses of an ED. We found that ED crowding did affect resident efficiency, particularly when efficiency was measured by the number of new patients per resident per hour. Such efficiency improved when the ED transitioned from not crowded to crowded conditions. However, no significant changes occurred when ED crowding status changed from crowded to overcrowded conditions. Additionally, although patient total LOS was affected by ED crowding, PTD was not affected significantly. Our study also found that male residents had relatively higher efficiency than female residents. However, there was a similar trend for efficiency at ED of different crowding conditions between the genders. Overall, resident efficiency seemed to be affected during overcrowded ED conditions, but it was little affected when the ED was under crowded status.

More interestingly, both the number of new patients per resident per hour and the PTD time were affected mostly by PGY-1 EM residents whose efficiency improved significantly with more experience gained during their first year of EM training regardless of ED crowding statuses. Since our program does not increase the patient load requirement for EM resident of different training levels, all EM residents are actively seeing new patients for the first 8 hours during their shift. We consider such efficiency changes among PGY-1 EM residents might be related to their steep learning curve of managing patient flow. Unfortunately, in the past, we have not heavily emphasized teaching residents how to properly manage ED flow until reaching their senior level.¹⁸ The results of this study suggest that earlier introduction of an ED administrative curriculum during residency training may be necessary, especially when residents train in an extremely high-volume ED setting. Such administrative curriculum should include teaching EM residents different ED operational strategies to manage patient flow (e.g., provider in triage, vertical flow models, or direct transfer patient to clinic among patients with nonemergency conditions) during their early EM residency training. Therefore, our study findings add some extra value to the current literature pool on how to enhance the administrative management of resident efficiency and provides future guidance on adjusting administrative didactics during EM residency training.¹⁹

There are many ways to determine provider efficiency in the literature.^{1,2} We chose number of new patients per resident per hour as one of the resident efficiency measurements for the following reasons: 1)

Figure 2. Number of new patients per resident per hour seen by residents of different training levels under ED of different crowding statuses. (A) Number of new patients per resident per hour seen by PGY-1 to -3 residents under ED of not crowded status. (B) Number of new patients per hour seen by PGY-1 to -3 residents under ED of crowded status. (C) Number of new patients per hour seen by PGY-1 to -3 residents under ED of overcrowded status.

Figure 3. Provider time evaluated by residents of different training levels under ED of different crowding statuses. (A) Provider time evaluated by PGY-1 to -3 residents under ED of not crowded status. (B) Provider time evaluated by PGY-1 to -3 residents under ED of crowded status. (C) Provider time evaluated by PGY-1 to -3 residents under ED of overcrowded status.

it is a simple and easy way to measure; 2) residents tended to see relatively high-acuity patients in the study ED, and therefore the patient acuity seemed to be less biased across different residents; 3) different shift lengths among residents, where PGY-1 residents had 10-hour shifts with the last 2 hours dedicated to “finishing up” and not picking up new patients and senior residents had 9-hour shifts with the last hour dedicated to “finishing up” and not picking up new patients; and 4) crowding was measured hourly at the study ED, which matched well as the number of new patients per provider per hour, since such crowding statuses change dynamically and patient flow may be affected by different levels of crowding at the ED.¹⁶ Under these circumstances, we are also able to analyze differences in resident efficiency under different ED crowding statuses. We measured PTD as another resident proficiency marker since patient LOS can be affected by different ED crowding statuses whereas PTD seemed to not be affected significantly.^{20,21} Additionally, PTD measured the time interval when the provider was actively engaged in evaluating patients, indicating better control in determining provider

efficiency. We believe that using the combinations of new patients per hour and PTD may increase the accuracy of resident efficiency measurements.

More importantly, this study shows the dynamic changes of resident proficiency especially among PGY-1 EM residents, indicating the necessity of earlier training on patient flow/ED administrative management during EM residency training. Such training, including an administrative ED rotation, is usually placed during the PGY-3 academic year.¹⁸ However, this might be too late for the current EM residents to train on how to efficiently manage ED patient flow. Additionally, our results showed no significant changes in resident proficiency for both PGY-2 and PGY-3 EM residents. This could be due to: 1) each team at the study ED included one senior EM resident and one or two junior EM/non-EM residents, where the senior EM residents see all high-acuity time-sensitive patients (e.g., ST-elevation myocardial infarction, sepsis, stroke patients requiring tissue plasminogen activator) regardless of whether they were PGY-2 or -3 EM residents; or 2) resident proficiency might reach a plateau by the end of their first year of

training. However, we are unable to determine such a direct link based on our current findings. Therefore, a large-scale multicenter study specifically designed to externally validate the differences of PGY-2 and -3 resident proficiency is warranted.

LIMITATIONS

Our study has its limitations. First, due to the design of this study, study population selection bias, information loss, and lack of complete variable inclusions occurred that could potentially skew the study findings. Therefore, it is important to have external validation to determine whether our findings can be duplicated in other facilities. Second, resident efficiency can be heavily affected by different levels of patient acuity. EM residents mainly saw high-acuity patients (ESI-1 to -3). Although ESI correlated well with patient severity,^{22,23} our results could still be deviated by considering patient severity more accurately and comprehensively. Third, resident efficiency could be affected by the attending physicians' proficiency since attending physicians supervise residents and make final decisions. However, attending pairing with residents is random during different shifts and such risk would have biased results toward the null. Finally, there are other potential provider efficiency measurements not used or compared in this study including patients per shifts (as mentioned above) and RVU. Since RVUs can be affected by documentation, billing, and coding, and residents and attending physicians have different ways to complete/edit their medical record, with some completing records during their shifts while others completing them after the shift, we are unable to accurately know the time spent on each patient chart, making RVU as a measure resident efficiency possibly biased in our study. However, our study was neither able to measure its accuracy nor able to determine the association between RVU and resident efficiency.

CONCLUSIONS

Resident efficiency improved significantly only during their first year of emergency medicine training. In addition, resident efficiency can be affected by ED crowding. Future studies could be focused on resident efficiency changes with the implementations of administrative curriculum and operational strategy to

enhance resident performance and optimize patient flow under ED of different crowding conditions.

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Supporting Information

The following supporting information is available in the online version of this paper available at <http://onlinelibrary.wiley.com/doi/10.1002/aet2.10327/full>

Data Supplement S1. Explanations of NEDOCS Variables for ED Crowding Calculations.