The Effect of Emergency Department Crowding on Clinically Oriented Outcomes

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Abstract

Background: An Institute of Medicine (IOM) report defines six domains of quality of care: safety, patient-centeredness, timeliness, efficiency, effectiveness, and equity. The effect of emergency department (ED) crowding on these domains of quality has not been comprehensively evaluated.

Objectives: The objective was to review the medical literature addressing the effects of ED crowding on clinically oriented outcomes (COOs).

Methods: We reviewed the English-language literature for the years 1989–2007 for case series, cohort studies, and clinical trials addressing crowding's effects on COOs. Keywords searched included ''ED crowding,'' ''ED overcrowding,'' ''mortality,'' ''time to treatment,'' ''patient satisfaction,'' ''quality of care,'' and others.

Results: A total of 369 articles were identified, of which 41 were kept for inclusion. Study quality was modest; most articles reflected observational work performed at a single institution. There were no randomized controlled trials. ED crowding is associated with an increased risk of in-hospital mortality, longer times to treatment for patients with pneumonia or acute pain, and a higher probability of leaving the ED against medical advice or without being seen. Crowding is not associated with delays in reperfusion for patients with ST-elevation myocardial infarction. Insufficient data were available to draw conclusions on crowding's effects on patient satisfaction and other quality endpoints.

Conclusions: A growing body of data suggests that ED crowding is associated both with objective clinical endpoints, such as mortality, as well as clinically important processes of care, such as time to treatment for patients with time-sensitive conditions such as pneumonia. At least two domains of quality of care, safety and timeliness, are compromised by ED crowding.

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Emergency department (ED) crowding was first described nearly 20 years ago.[1,2] Reviews of crowding's history and causes are available.[3] The Input-Throughput-Output conceptual model[4] has become a widely accepted paradigm to understand the various causes of crowding. Modern conceptions of

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crowding suggest that crowding in the ED reflects broader hospital crowding and inefficiencies in bed and resource management. A 2003 report from the Government Accountability Office (GAO) and a 2006 report by the Institute of Medicine (IOM) note that bottlenecks in output, such as the inability to transfer admitted patients to inpatient beds, are a leading cause of crowding.[5,6]

The 2006 IOM reports represented a comprehensive, landmark look at the past, present, and future of out-of-hospital, hospital-based, and pediatric emergency care in the United States. In response to these reports, in 2007 the Board of Directors of the Society for Academic Emergency Medicine (SAEM) convened a task force to examine the effects of ED crowding on patient-oriented outcomes and emergency medicine education. Task force members were appointed by the chair and chosen for their history of scholarship in the field. Members were not chosen to represent specific professional organizations. This article represents the task force's examination of crowding's effects on clinically oriented outcomes (COOs).

The task force subcommittee charged with studying patient outcomes convened three times: in person at the May 2007 SAEM annual meeting, by conference call in September 2007, and again in person at the October 2007 Scientific Assembly of the American College of Emergency Physicians.

Because the IOM report on emergency care discussed quality of ED care using a framework contained in its 2001 report,[7] this subcommittee chose to summarize the literature on crowding and patient outcomes using the same framework. This consists of six quality of care domains: safety, timeliness, patient-centeredness, efficiency, effectiveness, and equity. High-quality care, according to the IOM, performs well in all six domains. Our analysis, therefore, reviews the evidence of the clinical effects of crowding on the six domains. Another recent review of crowding addressed causes and solutions, as well as effects.[8]

METHODS

We queried the Medline, Cochrane, and PsycNET search engines, limited to English-language articles, for the years 1989–2007 for case series, cohort studies, and clinical trials addressing crowding's effects on COOs. Keywords searched included ''emergency department crowding,'' ''emergency department overcrowding,'' ''mortality,'' ''time to treatment,'' ''patient satisfaction,'' and ''quality of care.'' Abstracts of all articles were reviewed by the first author and at least one other author. Articles were retained for analysis if they represented cohort studies (prospective or retrospective) or clinical trials with quantitative data and addressed a clinically relevant endpoint that fits within one of the IOM quality domains. Clinically relevant endpoints included mortality, morbidity, treatment delays, patient satisfaction, and process measures such as walkouts, length of stay (LOS), and diversion. Reviews and editorials were omitted. We did not prespecify a definition of crowding, insofar as multiple measures are in use, and no consensus yet exists on a quantitative definition of crowding. A formal abstraction tool was not used; agreement on inclusion or exclusion was by consensus of the two reviewers.

Endpoints were chosen based on their clinical relevance (e.g., mortality) or broad acceptance as relevant measures of ED care quality (e.g., patients who leave without being seen). Some measures may fit under more than one quality domain (e.g., time to antibiotic for patients with pneumonia may address both safety and timeliness of care); we arbitrarily assigned each measure to a single quality domain. In general, endpoints fall into three broad categories: mortality, time to treatment, and other.

RESULTS

A total of 369 articles were identified, of which 41 were kept for inclusion. These articles were largely single-institution observational cohort studies; none were randomized controlled trials. Several reflected data pooled from multiple EDs, usually in a common geographic area. Hence, the strength of the evidence is modest at best. Data from the studies are summarized in Table 1[9–29] and reviewed in detail under Discussion.

DISCUSSION

The next six sections address each quality domain and are followed by a research agenda, review of findings, limitations, and conclusions.

Safety and Effectiveness

The IOM defines safe care as ''avoiding injuries to patients from the care that is intended to help them''[7] and effective care as ''providing services based on scientific knowledge to all who could benefit and refraining from providing services to those not likely to benefit (avoiding underuse and overuse).''[7] These concepts overlap in the context of effects of ED crowding and are discussed together here.

Crowding and Mortality. Investigators from Australia, Spain, and the United States have addressed the question of whether patients experience higher mortality rates when presenting during periods of ED crowding. A retrospective, single-center Australian study attempted to quantify the association between ED crowding and 10-day mortality.[9] ED occupancy was measured in 8-hour intervals coinciding with staffing shifts and was calculated as the total number of patient care hours during the shift divided by 8 hours. Based on this measure, the peak 25% of shifts were considered ''crowded'' and were compared with the remaining shifts. The groups were well matched for baseline characteristics including season, age, shift, and referral source. The relative risk of mortality at 10 days was 1.34 (95% confidence interval [CI] = 1.04 to 1.72) when comparing crowded versus noncrowded shifts. Another Australian study found that hospital and ED crowding were associated with an increased 2-, 7-, and 30-day mortality with statistically significant hazard ratios of 1.3, 1.3, and 1.2, respectively.[10] The adverse effect on mortality occurred when midnight hospital occupancy exceeded the 99th percentile distribution or when >20%

Table 1
Review of Selected Studies Examining Effect of Crowding on COOs*

IOM Quality Domain	Main Outcome	Study	Effect of ED Crowding on Main Outcome
Safety and effectiveness	Mortality	Richardson[9]	In a single ED, RR of mortality at 10 days was 1.34 (95% CI = 1.04 to 1.72).
		Sprivulis[10]	In three hospitals, hazard ratios for mortality at 2, 7, and 30 days were 1.3, 1.3, and 1.2 for patients admitted during periods of greater ED and hospital occupancy.
		Miro[11]	In a single ED, weekly visit volume and ED mortality rate correlated (p = 0.01).
		Chalfin[12]	In a consortium of 120 hospital ICUs, in-hospital mortality when transferred to ICU > 6 hours was 17.4% vs. 12.9% for transferred < 6 hours (OR = 0.71; 95% CI = 0.56 to 0.89).
	Walkouts	Baker[13]	At a single public hospital ED, 11% of 186 patients who left without being seen were hospitalized within the next week; three required emergency surgery.
		Stock[14]	In a logistic model using data from 30 EDs, waiting time, fraction of patients uninsured, and teaching status had independent positive associations with patients who left without being seen.
Timeliness	Time to antibiotic	Pines[15]	Of 694 patients admitted with pneumonia at a single ED, 69% received antibiotics within 4 hours when waiting room occupancy and ED LOS were in the lowest quartile vs. 28% during the highest quartiles for both measures of crowding.
		Fee[16]	Of 405 patients admitted with pneumonia at a single ED, antibiotic administration within 4 hours was less likely with a greater number of patients (OR = 0.96 per additional patient; 95% CI = 0.93 to 0.99) and a greater number of patients ultimately admitted (OR = 0.93 per patient; 95% CI = 0.88 to 0.99) in the ED.
		Pines[17]	In 24 hospitals, ED LOS was inversely associated with probability of receiving antibiotics for pneumonia within 24 hours (Spearman $\rho = -0.44$, p = 0.04).
	Time to thrombolysis	Schull[18]	In the 25-ED region of Toronto, Ontario, Canada, high crowding as measured by total out-of-hospital time (associated with the proportion of EDs on diversion) was 2.1 minutes longer than during noncrowding (p = 0.004).
		Schull[19]	In Toronto, median door-to-needle times were 40, 45, and 47 minutes in conditions of no, moderate, and high network crowding, respectively (p < 0.001). Moderate and high crowding conditions were associated with longer median door-to-needle time (3.0 minutes, 95% CI = 0.1 to 6.0) and 5.8 minutes (95% CI = 2.7 to 9.0), respectively.
	Time to analgesic	Pines[20]	Of 13,758 patients with severe pain at a single ED, a multivariate logistic model showed that analgesic nonadministration was independently associated with waiting room number (OR = 1.03 for each additional waiting patient; 95% CI = 1.02 to 1.03) and occupancy rate (OR = 1.01 for each 10% increase in occupancy; 95% CI = 0.99 to 1.04).
		Hwang[21]	In a single ED, occupancy >120% was associated with lower likelihood of documentation of pain score (OR = 0.46; 95% CI = 0.21 to 0.98), but no difference in administration of analgesia to older patients with hip fracture (OR = 2.02; 95% CI = 0.89 to 4.62).
Patient-centeredness	Satisfaction	Sun[22]	Not feeling informed about prolonged waits was associated with greater dissatisfaction (OR = 0.48; 95% CI = 0.39 to 0.57).

Table 1
(Continued)

IOM Quality Domain	Main Outcome	Study	Effect of ED Crowding on Main Outcome
		Yancer[23]	72% reduction in diversion improved patient satisfaction scores.
Efficiency	LOS	Krochmal[24]	ED LOS for admission >24 hours was associated with 10% increase in hospital LOS.
		Liew[25]	ED LOS and hospital LOS were <4 hours, 3.73 days; 4–8 hours, 5.65 days; 8–12 hours, 6.60 days; > 12 hours, 7.20 days ($p < 0.001$). The corresponding excess hospital LOSs were 0.39, 1.30, 1.96, and 2.35 days ($p < 0.001$).
		Bayley[26]	In a single ED, 817 chest pain patients were admitted 904 times. ED LOS was not associated with total hospital LOS or other variables, but annual opportunity costs in lost hospital revenue for chest pain patients was $168,300 ($204 per patient waiting >3 hours for a hospital bed).
		Bernstein[27]	In a single ED, inpatient LOS for patients admitted during increasing quartiles of ED crowding was 5.00, 5.67, 5.81, and 5.85 days, exclusive of ED LOS ($p < 0.001$).
Equitability	Healthcare disparities	Lambe[28]	Waiting time to see ED provider was longer at hospitals in poorer neighborhoods: for every $10,000 decline in per-capita income, patients waited 10.1 minutes longer (95% CI = 1.8 to 18.4 minutes; $p = 0.02$).
		Burt[29]	Bivariate correlation was found between proportion of uninsured using ED and waiting time to see provider = 0.19 ($p < 0.01$) in 2000 NHAMCS database.

CI = confidence interval; ED = emergency department; ICU = intensive care unit; IOM = Institute of Medicine; LOS = length of stay; NHAMCS = National Hospital Ambulatory Medical Care Survey; OR = odds ratio; RR = relative risk.
*Sections are organized using IOM-defined domains of quality.

or more of ED bays were occupied by patients waiting for >8 hours for an inpatient bed.

Mortality rates among current ED patients have also been found to correlate with crowding.[11,30] In a 4-year study of data from a single ED, investigators from Barcelona, Spain, demonstrated a weak but positive correlation between the weekly number of ED visits and mortality rates in the ED ($r = 0.18$, $p = 0.01$). The same authors also stratified the weekly number of ED visits into moderate, intermediate, and high groups and demonstrated that the mortality rate of ED patients was greater during the high volume weeks.[11] These two studies suffer from the fact that crowding was measured as the number of ED visits over the course of an entire week; this is an inordinately long time interval that does not account for consistent differences between consecutive 4- or 8-hour periods. In the United States, patients admitted to the intensive care unit (ICU) suffer higher hospital mortality rates when their ED boarding times exceed 6 hours after the decision to admit.[12] Excessive ED boarding times were associated with an adjusted odds ratio (OR) of 0.71 (95% CI = 0.56 to 0.89) in a multivariate logistic regression model for overall in-hospital survival. However, the two groups were not specifically matched for disease category, resulting in a significantly higher percentage of sepsis patients in the ''delayed'' group and higher percentages of multiple trauma, respiratory, and coronary artery disease patients in the ''nondelayed'' group.

These observational studies indicate that ED crowding may be associated with higher mortality rates, both during the initial ED visit and up to 30 days later. They suggest a possible relationship between mortality and crowding, but should be interpreted cautiously because confounding due to variations in severity of illness among patients presenting on crowded versus noncrowded intervals may be difficult to control for and is defined in variable terms. Moreover, none of these series take into account other elements, such as nursing and physician staffing.

Leaving without Being Seen. Several authors have sought to explain the reasons why patients leave before being seen by a provider. Not surprisingly, almost half of the group cite ''fed up with waiting'' as the major reason for leaving, occasionally with serious consequences.[31] Waiting times as long as 6 hours have been associated with higher rates of ''leaving without being seen.''[13,14]

Return Patients to the ED. Patients may make unscheduled return visits to the ED as a result of the worsening of their initial medical condition, inadequate initial care provided in the ED, or incomplete inpatient

care or premature discharge. The evidence addressing whether patients seen during crowded conditions return to the ED more often than patients seen during less crowded times yields mixed results. Looking at a composite outcome of 72-hour returns, radiology overreadings, and quality improvement cases, Bernstein et al.[32] found that patients with these endpoints were more likely to have initially been examined in the ED during periods of crowding ($p = 0.03$). A more recent study by the same author, from a different institution, did not find an association between crowding on the first ED visit and probability of admission during a return visit within 72 hours.[33] Thus, the relationship between crowding and subsequent likelihood of returning to the ED for admission remains unclear.

There is evidence that patients who return to the ED having been recently discharged from inpatient services may exacerbate crowding by two mechanisms: by the visit itself as well as by consuming more resources than the average ED patient.[34] Baer et al.[34] found that, in a single ED, patients discharged from an inpatient unit within 7 days of the ED visit constituted 3% of all visits, but had longer lengths of ED stay (6.58 hours vs. 5.22 hours), a higher admission rate (47% vs. 19%), and higher charges ($1,415 vs. $391, all $p < 0.001$). Given that the ED patient population consists of patients both discharged and admitted to the hospital, it would appear to make sense a priori that recently admitted patients might be sicker and may consume more resources than the average ED patient.

Preventable Medical Errors and Other Adverse Outcomes. ED crowding may contribute to medical errors and adverse events. However, the existing evidence is largely anecdotal and inconclusive. Trzeciak and Rivers[35] conducted a literature review encompassing 1990–2002 to describe the effect of ED crowding on patient safety and public health. The study was largely based on anecdotal reports, self-reports of adverse events, and sentinel event analyses,[36–38] but one key conclusion was that "... overcrowding in ED treatment areas threatens public health by compromising patient safety and jeopardizing the reliability of the entire US emergency care system."[35]

Liu et al.[39] reported on inpatients who were boarded in the ED, evaluating the frequency of errors and adverse events for these patients. Of all boarded patients, 28% had some error or adverse event in the course of boarding. It is not clear how this rate compares to all other hospital patients. In interpreting these findings, ED boarding is a contributing factor to crowding, but is not solely responsible for the problem. In summary, anecdotal evidence exists to link ED crowding with adverse events and error, but these relationships requires further investigation.

Timeliness

The IOM defines timely care as "reducing waits and sometimes harmful delays for both those who receive and those who give care."[7] There is growing evidence of the association between ED crowding and delays in timely patient care. While some delays in ED care may be considered an inconvenience and result in reduced patient satisfaction, delays in care for time-sensitive conditions such as pneumonia, acute myocardial infarction (AMI), stroke, sepsis, those requiring emergent surgery (e.g., appendicitis, bowel obstruction), severe trauma, and ambulance delays may result in poorer patient care outcomes. Two processes that commonly occur in the ED using time to care guidelines, delivery of antibiotics within 4–6 hours for patients admitted with pneumonia, and transfer of patients identified with AMI to cardiac catheterization within 90–120 minutes or thrombolysis within 30 minutes have been accepted as standard measures of quality patient care.[40]

Recent studies have demonstrated the association between patient-level exposure to ED crowding and clinically significant delays in care. For patients with community-acquired pneumonia, there are several studies that have associated ED crowding with delays in delivery of antibiotics.[15–17] One was an ecologic study correlating longer ED LOS for admitted patients with the number of patients ultimately admitted who did not receive antibiotics within 4 hours of arrival as recommended by the Joint Commission Core Measure PN-5b.[16] Two other studies have confirmed this association at the patient level and have demonstrated that exposure to ED crowding, when measured by ED LOS and number of waiting room patients, was associated with delays in antibiotic therapy.[15,17] Both studies demonstrated that even at low levels of crowding, there was a lower likelihood of receiving timely antibiotics.

Studies have demonstrated differences in ambulance response times and time to thrombolysis in AMI on the order of less than 10 minutes during times of high systemwide diversion.[18,19] By contrast, when measured at the individual hospital level, there was no association between ED crowding when defined by ED LOS and time to percutaneous intervention for patients with AMI.[17] Another study of critically ill patients involving those with severe sepsis and septic shock did not demonstrate clinically associations between overall levels of ED crowding and time to antibiotics or survival.[41] Prolonged ED LOS, however, has been associated with a higher risk of death in patients admitted to ICUs from the ED. These studies suggest that ED crowding may have variable effects on timeliness of initiation of early therapy for critically ill patients, while longer boarding of patients in EDs prior to ICU transfer may increase mortality.[12]

ED crowding has also been associated with delays in analgesic therapy for patients with severe pain.[20,21,42] One study demonstrated that higher ED patient occupancy and more waiting room patients were associated with delays in analgesia of greater than 1 hour both from triage and from room placement time.[20] Another study demonstrated similar delays of over 1 hour from patient arrival to physician pain assessment, analgesia ordering, and analgesia administration during periods of high ED census, high number of boarders, and high number of nonboarding patients.[42] Finally, a study of hip fracture patients 50 years and older found that they were less likely to receive analgesia during periods of high ED patient census.[21]

Studies have demonstrated little effect of ED crowding on time to diagnosis for patients with appendicitis

or small bowel obstruction.[43] For the latter two studies, patient insurance type and arrival during change of clinician shift were significantly associated with delayed care for these time-sensitive conditions.

A general observation of studies evaluating ED crowding and time to care is that crowding is less likely to affect patients who are identified as critically ill during early ED assessment (i.e., those with acute ST-segment elevation myocardial infarction or septic shock). In these cases, the lack of an association or small effect sizes suggest that such conditions, or the related interventions, may be less sensitive to the negative effects of crowding. Conversely, patients with multistep processes of care, complex care coordination, or those where well-developed protocols (e.g., ST-segment elevation myocardial infarction) to speed care do not exist may be more dramatically affected by ED crowding.

Finally, other time-related outcomes associated with ED crowding include patient waiting times and ambulance diversion. Prolonged patient wait times can result in not only delays to care, but also reduced patient satisfaction and patients leaving without being seen or even eloping during medical evaluation. Studies have demonstrated increased patient waiting times with lower ratios of clinician staff to the number of waiting room patients and ED census.[28,44] While ED census has been found to increase patient waits, the level of complexity of the ED patients may also dictate this association.[45]

Almost half of EDs in the United States reported diverting ambulances at some point during 2002.[46] While ambulance diversion itself has been used as a measure of crowding for some studies, it is in fact an outcome of crowding,[47,48] and several studies have used diversion as an outcome to validate proposed measures of ED crowding.[48–50] Ambulance diversion from hospitals not only causes delays in transport and care for patients with acute emergencies, but also results in lost revenue for hospitals[23,26,51,52] and may be associated with adverse outcomes.[53–55] ED crowding has been associated with longer ambulance transport times and longer response times for patients with chest pain.[18] One study showed that one in eight patient transports by paramedics were delayed (some over an hour) waiting for an open ED gurney to receive the patient.[56] A study from Canada found that each admitted patient boarding in the ED caused an additional 6 minutes of ambulance diversion,[57] with similar findings reported from Australia.[58] By comparison, increasing the number of ICU beds has been shown to reduce hospital time spent on diversion.[59] Diversion's effects on harder clinical endpoints such as mortality and in-hospital complications require further study.

Patient-centeredness

The IOM defines patient-centered care as ''providing care that is respectful of and responsive to individual patient preferences, needs, and values and ensuring that patient values guide all decisions.''[7]

Patient Satisfaction. Patient satisfaction is widely used to assess hospital services and is one measure of patient-centeredness. Hospitals use this to gauge patient perceptions and to better understand causes of dissatisfaction at the individual, departmental, and system levels. Satisfaction surveys typically ask about duration of visit, the appearance of the facility, the service provided by healthcare staff and ancillary services, and the overall perception of quality.[60,61]

Prolonged waiting times, whether it is for nonurgent care, for patients who perceive they have an emergency, or prolonged holding while waiting for admission or discharge, are known to decrease patient satisfaction. Inefficient hospital systems that fail to move the patient through the ED visit frequently hear patients and their families stress their dissatisfaction with the ED visit. By instituting a variety of protocols or system efficiencies, and by reducing patient wait times, satisfaction scores improve.[60]

Sun et al.[22] surveyed approximately 2,300 patients and noted that a significant number of patients were dissatisfied when they were not told about the prolonged wait times or actually perceived that they had prolonged wait times. In a follow-up article, they concluded that their patient satisfaction survey replicated their prior finding that satisfaction strongly predicts the patient's willingness to return.[62] Patient perception of wait times, rather than actual LOS or time waiting to be seen by a physician, was the source of dissatisfaction.[22]

In a study by Yancer et al.,[23] process improvement teams implemented a series of hospitalwide initiatives to decrease ambulance diversion, decrease wait times in the ED, improve patient satisfaction scores, and decrease risks to patient safety. The teams focused on reducing crowding by looking at inpatient bed availability. After process redesign, ambulance diversions fell by 72%, average inpatient and ED LOS fell, the number of boarders held in the ED decreased, and ED patient satisfaction scores improved.

Rodi et al.[63] described the Institute for Healthcare Improvement's finding that reducing delays is critical to improving all aspects of emergency care. Turnaround time is a primary driver of satisfaction. Resources can help improve delivery of care. Even at children's hospitals it was noted that prolonged LOS resulted in dissatisfaction and increased number of patients ''left without being seen.''[64]

Garson et al.[65] asked patients whether they had a preference for boarding in an inpatient unit or in the ED setting. The patients' preferences were for an inpatient hallway over the ED. The implication is that transfer of patients to hallway locations would reduce ED LOS, improve safety, and patient satisfaction.

Patient safety is also affected by prolonged LOS and overcrowding. Viccellio[61] reviewed the above article that looked at whether patients preferred boarding in the ED versus boarding on an inpatient floor. He comments that his facility's patient satisfaction improved when patients were boarded on inpatient floors. The patients who were boarded on the inpatient units had a shorter time in moving to an actual inpatient bed than did the patients boarded in the ED.[66] The boarding of admitted patients in the ED may jeopardize their well-being.

Efficiency

The IOM defines efficient care as "avoiding waste, in particular waste of equipment, supplies, ideas, and energy."[7] ED crowding may lead to less efficient care if, for example, delays in the ED lead to complications that require longer hospital stays. Compared to elective admissions, patients who are admitted through the ED are more expensive to care for.[67] Krochmal and Riley[24] found that patients who had to spend at least 24 hours in the ED had inpatient LOS that were about 10% longer than patients who had shorter ED LOS.[24] A study in three Australian hospitals found a similar correlation between ED LOS and inpatient LOS.[25] However, a separate study by Bayley et al.[26] found no association between ED LOS and inpatient LOS. Like outcomes that could be associated with ED crowding, the analyses may be confounded by the fact that sicker patients may be rushed through the ED, but still have long hospital LOS. Thus, the findings to date are likely to underestimate the effects of ED crowding.

A more crowded ED has implications for the ability of a hospital to deal with surge capacity. The American College of Emergency Physicians defines surge capacity as the "health care system's ability to manage a sudden or rapidly progressive influx of patients within the currently available resources at a given point in time."[68] National policy for emergency-preparedness calls for hospitals to accommodate surges of 500 new patients per million population in a disaster and 50 patients per million in other mass casualty incidents.[69] The components to handle surge capacity are complex, and the ability of hospitals to handle disaster surge capacity is not well understood, but the decrease in the number of U.S. EDs and growth in patient volume may have diminished hospital surge capacity. According to an American Hospital Association 2007 survey, nearly half of all US EDs routinely function at or over 100% capacity.[70] A study by Kanter and colleagues[71] in 2007 examined New York's hospitals' ability to respond to influx of new patients. It found that even using underoptimistic assumptions, 500 new patients per million age-specific population will often overwhelm existing hospital resources, especially for an incident involving large numbers of children. However, these estimates are often based on administrative data and not functional hospital capacity and hence are likely to underestimate the effects of hospital and ED capacity on the ability to deal with disaster surges.

Equitability

The IOM defines equitable care as that which "does not vary in quality because of personal characteristics such as gender, ethnicity, geographic location, and socioeconomic status."[7] The literature consistently shows that ED crowding is more prevalent among hospital EDs located in large, urban areas.[5,6,46,72] Crowding is also more common among EDs located in poorer neighborhoods,[28] with longer waiting times at safety-net hospital EDs used disproportionately by uninsured persons.[29] Because minorities and persons of lower socioeconomic status are more likely to live in communities where ED crowding occurs, they are disproportionately impacted by ED crowding and any negative consequences that crowding has on other quality care domains.

Developing a Research Agenda

Many challenges in crowding research remain, particularly in the domains of understanding its effects on clinical care, on education of residents and students, and in the design of interventions to mitigate crowding. There has been much progress in the development of crowding metrics, although a universally accepted measure remains elusive.

Additional work is needed to identify adverse clinical outcomes of ED crowding, with emphasis on new study designs, clinical endpoints, and modeling approaches. The effects of crowding on providers' clinical decision-making requires further study, as does crowding's effects on the ability to educate medical students and residents and other providers in training. Newer tools, such as simulation laboratories, may provide opportunities for work in this area.

Identifying interventions or policies to reduce crowding and ambulance diversion, or to mediate their effects, are needed as well. The Urgent Matters national program office of the Robert Wood Johnson Foundation has funded a number of intervention studies.[73,74]

To develop more useful measures of crowding, we suggest two goals: 1) identify an objective, quantifiable measurement framework that represents normal patient flow and 2) standardize measures related to patient flow.[75] Standardizing the definitions[76,77] and developing generalizable patient flow measures[78] would allow comparisons among different interventions, different ED settings, and facilitate multicenter studies.

Measuring patient flow throughout an institution in real time is challenging. Data from clinical information systems will likely support this task. Many EDs are implementing information systems that incorporate electronic patient tracking boards and integrate data from institutional information systems.[79] Current systems are optimized for supporting providers with patient-oriented information, but may facilitate the real-time monitoring and visualization of operational efficiency measures, such as patient flow, provider productivity, or turnaround times of ancillary services. Improvements in information technology will not only support various approaches to measure patient flow, but will likely facilitate the design and testing of interventions to alleviate crowding.

Of note, the National Quality Forum is currently considering creation of quality measures for ED care.[80] Some of these proposed measures indirectly reflect crowding, such as ED LOS and time to admission decision.

LIMITATIONS

We reviewed English-language literature only, because we were not resourced to conduct searches in other languages. Of note, crowding articles from non–English-speaking countries have been published in English-language journals. We did not conduct a formal systematic review, with two reviewers independently

grading each article for the strength of the evidence. In addition, it would have been useful to have conducted a formal risk-of-bias assessment.[81] Most of the articles cited represent single-institution observational cohorts, and no randomized controlled trials were identified. Hence, the strength of the evidence is modest at best. Finally, we did not search the gray literature, again because of resource constraints. We do note that much of the better-known gray literature in crowding includes government reports such as those of the GAO,[5] or the National Hospital Ambulatory Medical Care Survey (NHAMCS) series.[82] Although invaluable, these reports do not represent original studies of clinically relevant endpoints in ED crowding. Nonetheless, it is possible that by not examining the gray literature articles, we excluded articles addressing clinically important outcomes.

CONCLUSIONS

A growing body of evidence exists to document the adverse effects of ED crowding on clinically important outcomes. Future work will continue to document these adverse effects, but will increasingly focus on interventions to prevent or alleviate crowding's impact on quality of care.

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