Title of Project: Emergency Department Overcrowding and Quality of Acute Asthma Care for Children

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1. **Structured Abstract**

1.1. Purpose: To assess the association between emergency department (ED) crowding and quality of care for children.
1.2. Scope: We studied children seen for acute asthma and for fractures at a children's hospital ED.
1.3. Methods: We studied three processes-of-care for each population. Quality measures represented timeliness (1-hour receipt of process), effectiveness (receipt/non-receipt), and equity (language, identified-primary-care-provider, insurance). Primary independent variables were crowding measures from adult studies. We used adjusted crowding-quality models to select crowding measures most consistently associated with timeliness and effectiveness. We then measured the impact of crowding on timeliness, effectiveness, and equity. For timeliness and effectiveness, we measured the adjusted relative risk between 75^{th} and 25^{th} percentiles of each crowding measure. For equity measures, we tested their role as moderators of the crowding-quality models.
1.4. Results: The asthma population included 927 patients, and the fracture population included 1,229. Two crowding measures had a consistently inverse association with quality across both populations: total patient-care hours and number arriving in prior 6 hours. Using these two crowding measures, patients were 22-60% less likely to receive the indicated process within 1 hour at the 75th than at the 25th percentile of crowding. In the asthma population, timeliness and effectiveness measures showed an inverse, dose-related association with crowding—an effect not moderated by equity measures. Patients were 52-74% less likely to receive timely care and 9-14% less likely to receive effective care at the 75th than at the 25th percentile.
1.5. Key Words: Crowding, Quality of Healthcare, Hospital Emergency Service

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2. **Purpose**

The primary aim of this study was to measure the association of the quality of emergency department (ED) care for children with ED crowding. We explored this objective in two conditions: acute asthma and fracture-related pain. The three objectives addressed in pursuing this aim were as follows:

2.1. Select quality measures for the two conditions, based on criteria from national guidelines and prior studies, and extract these measures from the electronic medical record (EMR).
2.2. From nine crowding measures used in adult ED studies, select those most relevant to pediatric ED populations through their association with quality of clinical care for asthma and fracture-related pain.
2.3. Across four domains of quality—safety, effectiveness, timeliness, and equity—measure the dose-response effect of ED crowding on quality by comparing quality among crowding percentiles.

As the PI sought additional research collaboration in this area, the PI also became involved in a related project through the Child Health Corporation of America's research group. The objectives for that project were:

2.4. Determine how children's hospitals acutely react to inpatient crowding.
2.5. Quantify the effect of smoothing occupancy on inpatient crowding at children's hospitals.

2.6. Describe the emergency department resource burden of the spring 2009 H1N1 influenza pandemic at US children's hospitals by quantifying observed-to-expected utilization.

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3. **Scope**

3.1. Background

3.1.1. Objectives 2.1 – 2.3

Studies of ED crowding in adult populations have compared crowding measures, often using the association with quality of care as the basis for comparison.[1-12] Although the Institute of Medicine (IOM) report, *Emergency Care for Children,* identifies the impact of ED crowding on pediatric patients as a key research priority,[13] no prior studies have compared crowding measures in an ED population of children.

Because most recent studies of crowding use quality measures as the basis for comparison,[7] a factor contributing to the lack of pediatric studies comparing crowding measures is the paucity of quality measures relevant to children in the ED setting.[14-16] The Institute of Medicine's (IOM) report on quality defines quality of care by six dimensions: safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity.[17] A recent review of quality dimensions and ED crowding showed inverse associations (decreased quality associated with increased crowding) across all dimensions studied.[1] Our investigation addressed the issue of relevant quality measures tailored specifically for the ED setting. We used national guidelines and prior studies to develop measures of quality for two ED conditions common among children: acute asthma and fracture-related pain.

3.1.2. Objectives 2.4 – 2.5

Hospital crowding is a significant concern for healthcare professionals, health system administrators, policymakers, and patients due to several negative consequences, including poorer patient outcomes and increased provider stress. External factors that cause crowding, such as access to ambulatory and specialty care and seasonal variations in disease incidence, are usually beyond the control of an individual hospital. Yet, a significant portion of demand for beds is from predictable, scheduled elective admissions – and even admissions from the ED have highly predictable patterns. Internal factors for crowding include a hospital's physical plant, staffing, and efficiency in using resources to impact patient flow. Among these internal factors, some are difficult for a hospital to change quickly, such as capacity (licensed number of beds) and staffing. Therefore, how hospitals use given capacity becomes an important predictor of crowding, delays, errors, and diversions (and related potential for lost revenue from patients who go, and referring physicians who look, elsewhere).

3.1.3. Objective 2.6

Unlike seasonal influenza outbreaks,[2,3] almost half of patients hospitalized in the first wave of the 2009 H1N1 pandemic were children.[2,3] Due to mild virulence[4] and the predominance in children, a disproportionate numeric burden was experienced in emergency department (ED) settings treating large numbers of children.[5-7] Although the pandemic disproportionately affected children and outpatient settings, only two papers—each reporting pediatric utilization at two EDs in a single city—reviewed ED utilization.[6,7]

3.2. Context

The first three objectives (2.1 – 2.3) were achieved using the EMR of the ED at the Children's Hospital of Denver. The three additional objectives (2.4 – 2.6) were achieved using the Pediatric Health Information System (PHIS), a national administrative database containing resource-utilization data from 41 freestanding, tertiary-care children's hospitals.

3.3. Settings

For objectives 2.1-2.3, study variables were extracted from the EMR of the Children's Hospital of Denver ED, a tertiary-care ED located in an academic children's hospital. The ED has 48 individual patient rooms, and the 12-month census during the study period was 56,900. For objectives 2.4-2.6, study variables were extracted from the PHIS, which includes data from 39 hospitals (23 with ED data) located in noncompeting markets of 23 states plus the District of Columbia and accounts for 20% of all general, tertiary-care children's hospitals.

3.4. Participants

3.4.1. Objectives 2.1-2.3

Quality measures used in the ED crowding-quality analyses of adults include both general (e.g., mortality) and condition-specific (e.g., time-to-fibrinolysis) metrics. Because general measures such as mortality (<1% in the study ED) and left-without-being-seen rates (1-2%) are relatively rare ED phenomenon for children, condition-specific measures are more relevant. To reduce the chances that our findings would also be single-condition specific, we chose to use two unrelated conditions: asthma exacerbations and acute, fracture-related pain. These were selected based on the prevalence of the condition, the clinical importance of timely care, and the existence of applicable clinical practice guidelines (CPG) that help define evidence-based quality of care metrics.

Asthma is among the most common reasons children seek ED care, resulting in 750,000 ED visits annually nationwide.[18] A treatment algorithm for acute asthma is detailed in the National Asthma Education and Prevention Program (NAEPP).[19] Inclusion criteria for the asthma population were ages 2-21 years with a primary ICD-9 code for acute asthma. Because of known practice pattern variations in distinguishing asthma from the viral respiratory infections common among children <2 years old, we excluded these younger children from our asthma population.[34]

Long-bone fractures are also among the most common reasons children seek ED care, resulting in 598,000[20] ED visits per year nationwide. Pain management guidelines and standards have been issued by The Joint Commission[21] and the American Academy of Pediatrics.[22] Inclusion criteria for the fracture population were ages 0-21 years with any ICD-9 code for an isolated long-bone fracture. Exclusion criteria for the fracture population included any ICD-9 code indicating major trauma, a second fracture, or child maltreatment. Among patients with pain, we chose to focus on those with acute, isolated, long-bone fractures so as to avoid patients with complex analgesia needs, such as hypotensive patients with multi-system trauma.

3.4.2. Objectives 2.4-2.6

Analyses for objectives 2.4 and 2.5 included all patient admissions to children's hospitals in PHIS at any of 39 participating hospitals during calendar year 2006 (objective 2.4) or 2007 (objective 2.5). Due to variation across hospitals in the presence of birthing, neonatal intensive care, and designated behavioral health units, these beds and associated patients were excluded.

Analyses for objective 2.6 included all ED visits during April-July 2009 at all of the 23 PHIS hospitals with ED data. Data from 2004-2008 were also included to project "expected" values for each utilization metric.

3.5. Incidence, Prevalence

3.5.1. Objectives 2.1-2.3

Over the study period, 927 patients were included in the asthma population, and 1,229 patients were included in the fracture population.

3.5.2. Objectives 2.4-2.6

For objective 2.4, a total of 510,616 admissions met inclusion criteria For objective 2.5, 14,235 hospital bed-days were included. The analysis for objective 2.6 included 390,983 ED visits during the 14-week study period.

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4. **Methods**

4.1. Study Design

4.1.1. Objectives 2.1-2.3

We performed a cross-sectional study with data collection via retrospective extraction from an EMR involving two groups of pediatric patients treated in the study ED from November 1, 2007, to October 31, 2008: an asthma population and a fracture-related pain population.

4.1.2. Objectives 2.4-2.6

We performed a series of retrospective studies with data from PHIS involving two groups of patients: inpatients (objectives 2.4 and 2.5) and ED patients (objective 2.6).

4.2. Data Sources/Collection

4.2.1. Objectives 2.1-2.3

All data extractions from the ED EMR were performed using Crystal Reports XI (Business Objects, San Jose, CA) to query data in EpicCare® (Epic Systems Corporation, Verona, WI), a computerized patient tracking and charting system.

4.2.2. Objectives 2.4-2.6

Data were obtained from the Pediatric Health Information System (PHIS), which includes ED and inpatient data from 41 non-profit tertiary-care children's hospitals in the US, with 23 hospitals that had ED data available continuously from 2004-09. The Child Health Corporation of America (Shawnee Mission, KS) and participating hospitals jointly validated data quality and reliability.[15]

4.3. Interventions

Not applicable.

4.4. Measures

4.4.1. Objective 2.1

We developed quality measures for three IOM quality dimensions based on their availability in the EMR. Of the three remaining dimensions, we omitted *patient-centeredness* due to the absence of patient-level measures at the study ED, and we omitted *efficiency* due to the difficulty of differentiating "good" from "bad" quality for the most commonly used ED measure, length-of-stay.[1] We excluded our one safety measure, unplanned transfer from the inpatient floor to the intensive care unit (ICU) after ED admission, based on insufficient numbers to model this measure.

For each population, we selected three processes to serve as the basis for quality measures. These processes were selected based on their availability (including timestamps) in the EMR, their inclusion in the relevant clinical practice guideline (CPG), and their use in prior studies. [23-35]

For the asthma population, the three processes were the initial asthma score, inhaled beta-agonist, and systemic corticosteroid ("steroid"). For the fracture population, the three processes were the initial pain score, analgesic, and opioid analgesic, selected based on a prior study of crowding and fracture pain analgesia.[8] To define when a process was indicated, for each process, we defined a relevant, at-risk subpopulation, using methods derived from a multi-center adult ED study of the quality of asthma care.[36]

For each of the three processes of care studied, we defined poor *timeliness* as a delay of ≥1 hour from the patient's ED arrival. The 1-hour threshold was selected for the asthma population based on NAEPP guidelines and a Cochrane review. [37,38] We tested an additional timeliness measure, the number of asthma study patients who left without being seen (LWBS), based on its prior inclusion in the crowding-quality literature. [39,40]

We also included the measure "return to the ED within 72 hours," based on use in prior studies.[16,26,41] We explored including two other measures—percent with negative chest radiograph" [16,19,42] and unplanned transfer from the inpatient floor to the intensive care unit (ICU) after ED admission[43-45]—but had insufficient variation to model these measures.

We selected *equity* variables to reflect both preferred language and access to care. As race and ethnicity are missing for most patients in the dataset, we used the variable "preferred language," routinely recorded for all patients at triage. A study of quality of acute asthma care and race/ethnicity found no difference in acute asthma severity and ED management,[25] although studies of language and non-asthma ED care have found increased resource utilization for patients with limited English-language proficiency.[46,47]

For access variables, we included presence of a primary care provider (PCP) as well as two insurance variables indicating the presence of any insurance and the presence of public insurance, such as Medicaid. Prior literature on equity and crowding has shown crowding to more common in EDs located in poorer neighborhoods[48] and in EDs used disproportionately by uninsured persons.[49]

4.4.2. Objective 2.2

4.4.2.1. Crowding Measures

We selected nine crowding measures based on their use in prior literature,[6,8] simplicity, ease of measure in the EMR, and distribution across the categories of the input-throughput-output model (the standard framework for understanding components of the healthcare system that contribute to or are affected by ED crowding).[10,50,51] Crowding measures were calculated based on the time of ED arrival for each patient included in the asthma or fracture population ("index patient").

We included two global measures of crowding:

- *Total patient-care hours:* the sum of the ED length-of-stay (LOS) in hours for all of the patients in the ED at the time of arrival of the index patient
- *ED occupancy*: the proportion of the total number of registered ED patients to the number of ED beds at the time of arrival of the index patient

We also included two input measures of crowding:

- *Number waiting to see attending:* a count of the number of ED patients not yet assigned to a billing provider at the time of arrival of the index patient

- *Number arriving in 6 hours:* a count of the number of newly registered patients in the 6-hour period before the time of arrival of the index patient

The two throughput measures calculated the mean ED LOS in minutes for two subgroups assigned by disposition:

- *Mean ED LOS of patients discharged:* the mean ED LOS for patients who were discharged from the ED in the 6 hours before the time of arrival of the index patient
- *Mean ED LOS for patients admitted:* the mean ED LOS for admitted patients who were transferred to inpatient beds in the 6 hours before the time of arrival of the index patient

We included three output measures of crowding:

- *Number discharged in 6 hours:* the number of patients discharged from the ED in the 6 hours before the time of arrival of the index patient
- *Number admitted in 6 hours:* the number transferred to inpatient beds in the 6 hours before the time of arrival of the index patient
- *Hospital occupancy*: the percent occupancy for the whole hospital at the time of arrival of the index patient

4.4.2.2. Other Variables

Demographic variables included age, gender, preferred language, and insurance. We coded insurance as two dichotomous variables: the presence of any insurance and the presence of publicly funded insurance, such as Medicaid.

History elements included second-hand smoke exposure—routinely recorded at triage—and a variable for presence of a primary care provider. Exam variables included the two condition-specific scores—asthma score and pain score. Because the scores were used to define subpopulations, they were not included as severity adjusters in the models.

For both populations, the primary severity adjusters were triage level and ambulance arrival. For asthma patients, we also included the initial room-air pulse oximetry value. We included an indicator of evening time of arrival to adjust for the independent contribution of time of day to quality of care.[72]

4.4.3. Objective 2.3

We used the EMR to retrospectively assign the following overall ED crowding indicators at each asthma patient's ED arrival time: ED occupancy and the number of patients waiting to see an attending provider. These were chosen from a published list of potential crowding indicators[10] and were included because they were significant variables in previous studies on the impact of ED crowding on quality of care.[6,8] The other variables collected are the same as for objective 2.2, described in section 4.3.2.3.

4.4.4. Objective 2.4

Hospital capacity was defined using PHIS data on the number of active beds (excluding perinatal and behavioral) at each hospital for 2006. Midnight census was used to calculate occupancy (percent of bed capacity occupied) for each day of 2006, and all analyses were at the hospital level. The dependent variables – potential responses to high occupancy – were also calculated independently for each day of 2006 and included:

- Number of medical elective admissions
- Number of surgical elective admissions
- Number of short-stay admissions (length of stay ≤1 day)

- Number of low-severity admissions from ED (lowest quartile of APR-DRG severity classification)
- Observed-to-expected length of stay for ambulatory-care sensitive conditions (ACSC) (conditions for which ambulatory care may reduce, though not eliminate, the need for hospital admission)
- Observed-to-expected length of stay for non-ACSC
- Number of inbound transfers from another acute care hospital
- Number of outbound transfers to another acute care hospital

Two approaches were used to determine a hospital's acute response to high occupancy. First, normative threshold levels of midnight occupancy were set at 85%, 90%, and 95% of each hospital's capacity. A generalized linear model was built independently for each threshold and each dependent variable using, as a predictor, the prior day's midnight occupancy interacted with an indicator variable. These models measured each hospital's direction and magnitude of the eight responses throughout the 24-hour period after the prior day's midnight occupancy threshold level was exceeded.

Second, to assess how each hospital responded relative to its own occupancy experience over the course of the year, we categorized each day into the following percentiles of midnight census for each hospital: a) <90th, b) 90th to <95th, c) 95th to <98th, and d) 98th to 100th. Again, direction and magnitude of response were measured.

4.4.5. Objective 2.5

Occupancy was calculated as described above for objective 2.4. *Maximum occupancy in a week* referred to the highest occupancy level achieved in a 7-day period (Monday-Sunday). *Weekly smoothing* referred to our retrospective method of setting each hospital's daily occupancy at the mean value for each week (repeated weekly). We presented our findings using a set of occupancy thresholds—85%, 90%, 95%, and 100%.

4.4.6. Objective 2.6

For each utilization, severity, and quality outcome measure, we derived the expected value for the 2009 study period using the same methods described for derivation of the expected ED influenza-like-illness (ILI) weekly visits. For the weeks of the spring 2009 H1N1 influenza pandemic, we measured the observed value for each variable and calculated the observed-to-expected proportion.

Utilization variables were aggregated across hospitals. For the hospital-level analysis, we reported ILI visits, as these were most indicative of influenza-attributable visits, and all ED visits, as these conveyed the total burden placed on the ED. We also described the use of viral testing and administration of anti-influenza medications.

We assessed ED quality of care using ED revisits within 7 days, both for all ED patients and for the subset of ED ILI patients.[34,35] Revisits were included for any cause and were reported weekly using expected 2009 weekly revisit rates as a comparison.

4.5. Limitations

4.5.1. Objectives 2.1 – 2.3

A primary limitation of this study is that it was performed at one ED, affecting the generalizability of findings. A second limitation is that the EMR's active patient-tracking system may have resulted in discrepancies between the EMR event time and the actual event time. It is likely that this discrepancy is present more often when the ED is crowded, leading to overestimation of the association between crowding and delay of care.

A third limitation is that we may have over- or under-included patients in the way we defined each subgroup. This may have altered the receipt/nonreceipt proportions—an increase in subgroup size would increase the proportion who did not receive a process—but should not have affected the proportion with delayed care. A fourth limitation is that our retrospective analysis may have been confounded by inadequate adjustment for severity of illness.[52] Finally, although the absolute impact of crowding on the process of care in this population was large, there is limited evidence for a link between processes and outcomes of ED care.

4.5.2. Objectives 2.4 – 2.5

A primary limitation is that the use of administrative data precluded us from modeling all possible responses for each hospital. For example, hospitals have different staffing models and those with high provider-to-patient ratios may be better able to accommodate fluctuations in census. For this reason, our approach may underestimate each hospital's ability to respond to high levels of occupancy. Furthermore, some hospitals may simply be equipped to handle high occupancy without compromising quality of care or access. Second, we assumed a fixed number of beds for the whole year, an approach that may not accurately reflect actual available bed count on specific days. This limitation was minimized by counting all beds for each hospital as available for all the days of the year, so hospitals with a high census when all available beds are included would have an even higher percent occupancy if some of those beds were not actually usable beds. Third, midnight census, the only universally available measure, was used to determine occupancy rather than peak census. Midnight census provides a standard snapshot, but is rarely close to peak census. In order to account for these limitations, we analyzed the data using different thresholds of high midnight occupancy.

4.5.3. Objective 2.6

A primary limitation was that only children's hospitals were included. The experience at these hospitals may not be representative of experiences in other settings, such as emergency departments in general hospitals that also provide emergent care to children. Second, we used the upper 90% confidence interval of the expected patient volume to define the surge period. As no data exist to support (or refute) this definition, there is potential to underestimate or overestimate both the duration and magnitude of the surge. We considered higher and lower surge thresholds to explore the potential impact of our specific surge definition on our conclusions; alternate definitions of the surge threshold did not meaningfully alter our results. Finally, our use of a discharge diagnosis-based definition of ILI rather than virologic confirmation of influenza illness meant that some patients in our study may not have had influenza. This latter limitation would cause us to overestimate the resource burden attributed to the spring H1N1 influenza pandemic.

5. **Results**

5.1. Principal Findings

Our results indicate that key measures of crowding include *total patient-care hours* and *number arriving in 6 hours* —one global measure of crowding and one input measure. We demonstrated an association between ED crowding and the quality of the delivery of asthma care in a large, academic ED. We found that crowding exerts a "dose-related" effect on the three processes used to measure the timeliness and effectiveness of ED asthma care and can raise the risk of lower-quality care by a factor of 3.8 for 1-hour steroid administration and a factor of 1.2 for receipt of indicated asthma score, based on interquartile risk ratio.

5.2. Outcomes

5.2.1. Objective 2.1

We found high levels of receipt—above 80%—for all three processes for the asthma population, as well as one fracture-population process: pain score. For the remaining two fracture-population processes, we found low levels of receipt: among patients for whom any analgesia was indicated (pain score $\geq$ 1), 31.6% received any analgesia medication; among the subset of these for whom opioid analgesia was indicated (pain score $\geq$ 4), 32.2% received an opioid. Of the five processes, we found rates of timely receipt ranging from 23% (steroid) to 64% (beta-agonist).

5.2.2. Objective 2.2.

Across the 45 models combining each of the nine crowding variables and each of five quality measures, patients in the two populations were 0.26 (95% confidence interval (0.17, 0.38)) to 1.52 (1.17, 2.09) times as likely to receive the indicated care process within 1 hour when each crowding measure was at the 75th than at the 25th percentile. Of the 45 adjusted risk ratios, 27 showed inverse associations, two showed positive associations, and 16 showed no significant association.

Two “key” crowding measures showed consistent, dose-related, inverse association with quality of care across all five measures: *total patient-care hours* and *number arriving in 6 hours*. The crowding measures with the lowest interquartile risk ratio varied by population; the key crowding measures selected represented a compromise across the two clinical conditions. Across the 10 models combining one of the two key crowding variables with one of the five quality measures, patients in the two populations were 0.40 (0.27, 0.55) to 0.78 (0.71, 0.85) times as likely to receive the indicated care process within 1 hour when each crowding measure was at the 75th than at the 25th percentile. All 10 adjusted risk ratios were significant.

5.2.3. Objective 2.3

We expressed the relationship between quality and crowding in terms of the ratio in risk between the 75th and 25th percentiles of crowding for each process measure. In modeling the association between the two crowding measures and the adjusted risk for the two effectiveness and three timeliness measures, we found a dose-related effect, with a significant overall ratio (25th to 75th percentile) in all 10 models.

The relative risks were of greater magnitude in the timeliness measures than in the effectiveness measures. Patients were 0.26 (0.17, 0.39) to 0.48 (0.34, 0.63) times as likely to receive timely care when each crowding measure was at the more-crowded, 75th, percentile than at the less-crowded, 25th, percentile. They were 0.86 (0.80, 0.92) to 0.91 (0.86, 0.95) times as likely to receive effective care at the 75th than at the 25th percentile.

We found no direct effect of the four equity variables (with the two insurance variables combined) on the timeliness/effectiveness measures. None of the equity variables are moderators of the association between the timeliness/effectiveness measures and crowding measures. The sole exception was that having no PCP was associated with an increased adjusted risk of receiving a steroid in the first hour, based on ED occupancy percentile.

5.2.3.1. Objective 2.4

In total, the hospitals were frequently at high occupancy at midnight: of the 14,235 hospital midnights included, 7.8% were at 85-89% occupancy, 4.9% were at 90-94% occupancy, 3.2% were at 95-99% occupancy, and 5.5% were at >100% occupancy

Overall, hospital response to high occupancy was rare and of small magnitude. In looking at each of the eight separate responses, whether compared to normative standards of high occupancy or within-hospital percentiles, less than half the hospitals lowered the number of elective admissions, short admissions, or low-severity admissions; reduced observed-to-expected LOS; or altered transfers.

5.2.3.2. Objective 2.5

Overall, hospital mean midnight occupancy ranged from 70.9% to 108.1% on weekdays and 65.7% to 94.9% on weekends. Uniformly, weekday occupancy exceeded weekend occupancy, with a median difference of 8.2% points (IQR: 7.2%-9.5% points). There was a wide range of median hospital weekday-weekend occupancy differences across hospitals. The overall difference was less in winter months (median difference, 7.7% points; IQR: 6.3%-8.8% points) than in summer months (median difference, 8.6% points; IQR: 7.4%-9.8% points; Wilcoxon sign rank test, $p<0.001$).

Thirty-five hospitals (89.7%) exceeded the 85% occupancy threshold on at least 20% of weekdays, and 29 (74.4%) exceeded the 95% occupancy threshold. Across all hospitals, the median difference in weekly maximum and weekly mean occupancy was 6.6% points (IQR: 6.2%-7.4% points).

Smoothing reduced the number of hospitals at each threshold except the 85% threshold. Expressed as a linear relationship, the reduction in weekday peak occupancy (y) based on a hospital's median difference in weekly maximum and weekly mean occupancy (x) was $y = 2.69 + 0.48x$. A hospital with a 10% point difference between weekday and weekend occupancy could reduce weekday peak by 7.5% points.

Application of the smoothing algorithm increased the number of patients exposed to the lower thresholds (85% and 90%) but decreased the number of patients exposed to >95% occupancy. For example, smoothing at the 85% threshold led to 596 more patients per hospital being exposed to this level of hospital occupancy, but smoothing at the 95% threshold resulted in 630 fewer patients per hospital being exposed to that threshold.

5.2.3.3. Objective 2.6

For individual hospitals, the median peak in observed-to-expected proportion of weekly ED visits was 1.30 (IQR: 1.19, 1.40). This increased to a median of 1.56 (IQR: 1.27, 2.07) when only ED ILI visits were included. Compared with the percent expected, the percentage admitted from the ED to non-ICU beds and to ICU beds were 30% and 56% lower, respectively. The lower overall acuity was also reflected in other utilization; there was less overall diagnostic testing (including fewer chest radiographs) and less treatment with antibacterials, bronchodilators, and systemic corticosteroids. Despite the high surge volumes, there was a decrease in rate of return to the ED within 7 days.

Higher-than-expected ED ILI visits were seen for children 2-17 years—highest in the 9-17 year olds—and in females, Latinos, the insured, and those with asthma. Lower-than-expected ED ILI visits were seen for children younger than 2 years of age, the uninsured, those with immune deficiencies and cardiovascular disease, and those in the Middle Atlantic region. No factors were associated with higher-than-expected ED-to-inpatient admission rates.

5.3. Discussion

5.3.1. Objective 2.2.

Our results indicate that key measures of crowding include *total patient-care hours* and *number arriving in 6 hours* —one global measure of crowding and one input measure. This differs from adult-population ED literature, which suggests that output measures of crowding (primarily boarding burden—the number of patients staying in the ED while awaiting an inpatient bed) are most related to quality.[4,53] One possible reason for this difference may be the unavailability of a boarding burden measure in the present study. Our surrogate variable, inpatient occupancy, may reflect beds that appear open but are not available for ED admissions because they are reserved for elective admissions. Inpatient occupancy was inversely associated with quality in the asthma population but could not be considered a key crowding measure, as there was no similar association in the fracture population.

We modeled nine crowding measures and five quality measures across two populations of children seen in the ED. Of these 45 models, 27 (60%) showed an inverse association between crowding and quality, with interquartile ratios as 0.26 (an almost four-fold effect). This confirms previous studies[6,8,23,48,49,54-64] that reported an ED crowding-quality association in adult populations.

With the exception of pain-score assessment, a significant proportion of patients with asthma and with fracture-related pain either did not receive or had delayed receipt of an indicated process. The greatest delays were in administration of steroids and opioids, the two processes requiring a physician order. Our findings regarding the quality of care for the asthma population are difficult to compare to prior literature due to heterogeneity both in the quality measures used and in the definition of the subpopulations for which processes were indicated.[24,28] The rates of poor quality care in the fracture pain population are comparable to those noted in prior studies of ED analgesia for children.[29,30]

5.3.2. Objective 2.3.

We demonstrate an association between ED crowding and the quality of the delivery of asthma care in a large, academic ED. We found that crowding exerts a “dose-related” effect on the three processes used to measure the timeliness and effectiveness of ED asthma care and can raise the risk of lower-quality care by a factor of 3.8 for 1-hour steroid administration and a factor of 1.2 for receipt of indicated asthma score, based on interquartile risk ratio. These findings were robust in multivariable analysis after adjusting for other known risk factors for variations in quality of asthma care.[65-67] This confirms previous studies,[6,8,23,48,49,54-64] which reported an ED crowding-quality association in adult populations.

We modeled nine quality measures across three IOM dimensions. Of these nine measures, only the timeliness and effectiveness measures showed a significant association with crowding, with all significant associations indicative of an inverse relationship. Of these, the measures that had the largest effect size were timeliness measures, with lesser effects in the effectiveness measures. Prior studies including both types of measures have also found greater effect of crowding on timeliness than on effectiveness of care.[8,23]

Despite the smaller effect size of crowding on the two effectiveness measures, this finding is more novel than the finding that crowding impacts timeliness of care. At the 75th percentile of crowding, patients had a 12-13% lower chance of receiving an indicated asthma score and a 9-12% lower chance of receiving an indicated steroid, than at the 25th percentile of crowding.

We also found that equity measures had no impact on quality of care across varying degrees of crowding. Although non-ED studies have shown disparities in asthma care based on ethnicity and insurance, [65-67] our finding is consistent with prior ED studies of both race/ethnicity[25] and insurance,[27] which found no effect on the quality of acute asthma care for children in the ED.

5.3.3. Objective 2.4

In this study, we found that less than half of children's hospitals employed at least one of eight potential responses to high occupancy and that the magnitude was relatively small compared to overall occupancy. We also found considerable variability in the types of strategies used both within and across hospitals. These findings suggest that hospitals should engage in local review of patient flow and high-occupancy times in order to maximize patient safety, quality of care, and hospital efficiency.

As a whole, PHIS hospitals were often at high occupancy, with 21% of all midnights above 85% and 13.4% above 90% occupancy in 2006. Prior studies show that patient safety, quality, and efficiency can be adversely impacted by occupancy above 85-90%.[8, 9 10, 11] To ensure safe, high-quality, and effective delivery of care – as well as optimal patient/family experiences, avoidance of rejected transports and referrals, lessened ED crowding, decreased staff stress, and ability to deliver on educational missions – hospitals should consider implementing initiatives to better analyze and manage patient flow.

5.3.4. Objective 2.5

We found frequent high levels of occupancy. Consistently, weekend occupancy was lower than weekday occupancy, with a median difference of 8.2% points. This difference indicates that weekend capacity is available to offset high-weekday occupancy. Though hospitals at the lower end of the occupancy thresholds (85%, 90%) would not reduce frequency or severity of occupancy at this level by very much, those at the higher end (95%, 100%) would reduce the number of days operating at very high levels of occupancy and the number of patients exposed to such levels. In this study, if all 39 hospitals each smoothed their occupancy as we did (allowing weeks to differ), 39,607 patients could be protected from exposure to 95% occupancy, and 50,079 patients, from 100% occupancy. We found that hospitals in the range of size of PHIS hospitals with a difference of 10% points between weekday and weekend occupancy could reduce weekly peak occupancy by 7.4% points. This provides an opportunity for hospitals to avoid days with occupancy at or above 95-100%.

5.3.5. Objective 2.6

Fourteen (61%) of 23 hospitals experienced a surge in ED volume. For hospitals experiencing a surge, the resource burden was substantial: ED visits were 24% higher than expected during surge weeks and, during peak weeks, were 30% higher than expected. The overall acuity remained low, with only a small minority of patients requiring hospitalization (5.0% of children presenting with ILI to the EDs), with far lower than expected rates of ICU and non-ICU admission and positive pressure ventilation. This finding is consistent with reported local experiences.[5-7] No patient characteristics were associated with higher than expected rates of ED-to-inpatient admission.

5.4. Conclusions

5.4.1. Objectives 2.1 – 2.3

This is the first study to compare crowding measures with regard to their association with the quality of emergent care for children. Our analysis comparing crowding metrics found that the key metrics are global and input measures, indicating that crowding is multifactorial and cannot be mitigated by ED providers simply working harder. Our analysis of crowding and three dimensions of quality of ED care for children with acute asthma found that both timeliness and effectiveness of care were inversely associated with crowding and that equity of care was not associated with crowding.

5.4.2. Objectives 2.4 – 2.5

Our study revealed that children's hospitals are frequently crowded, and hospital responses to high occupancy are rare and of small magnitude. Hospitals are consistently more crowded on weekdays but have unused weekend capacity that can be used to smooth occupancy over all days of the week. This provides hospitals facing challenges with patient flow on weekdays an opportunity to decrease the frequency and severity of high occupancy and reduce the number of patients exposed to it. There may be good clinical and business cases for targeting high occupancy or turnover as a "never event," like other patient safety goals. If so, hospitals should work to better measure patient flow, limit or eliminate high-occupancy times, and reduce variability through appropriate proactive operations management and timely reactive responses.

5.4.3. Objective 2.6

During the spring wave of the 2009 H1N1 influenza pandemic, pediatric EDs nationwide experienced a marked increase in visits, but only a minority of patients with ILI required hospitalization, and even fewer required intensive care. The data provided in this study can be used for future pandemic planning at hospital and community levels.

5.5. Significance

5.5.1. Objectives 2.1 – 2.3

The IOM and the Robert Wood Johnson Foundation have identified the impact of ED crowding on children as a research priority.[13,68] Our investigation addresses this priority by modeling the crowding-quality association in an ED population of children with acute asthma and with fracture-related pain.

5.5.2. Objectives 2.4 – 2.5

Given that studies in adults hospitals have found increases in sentinel events and medical errors associated with crowding, our finding that more than 20% of hospital midnights were above 85% occupancy raises serious concerns about adverse effects on patient safety and quality of care in the pediatric inpatient population. Strategies to smooth—or otherwise reduce—inpatient crowding are consistent with larger goals to improve the safety, efficiency, patient-centeredness, and value of the healthcare system. To the extent that acute responses to high occupancy fail to decrease crowding – or compromise access and satisfaction – hospitals need to consider proactive approaches such as smoothing fluctuations in elective admissions.

5.5.3. Objective 2.6

Our study highlights the importance and integral role that children's hospitals play in providing surge-level care for children within their respective regions. The large influx of low-acuity patients challenged a system whose mainstays of preparedness focus on stockpiling supplies for the critically ill or injured as opposed to having broadly distributed surge capacity to meet differing levels of need. This finding is helpful for future surges and health policy, as it highlights the need for a better-integrated delivery system that can appropriately match capacity to demand and acuity.

5.6. Implications

5.6.1. Objectives 2.1 – 2.3

Areas for additional study include reassessment of the equity models after implementation of healthcare reform and evaluation of the effects of interventions designed to mitigate the impact of ED crowding on quality of care.[63,64]

5.6.2. Objectives 2.4-2.5

Future studies could examine predictors of quality of care at children's hospitals as related to dynamic organizational factors, such as crowding, as well as workload and workforce.

5.6.3. Objective 2.6

Areas for additional study include comparing the spring 2009 H1N1 surge with the second wave in fall 2009 as well as with prior seasonal influenza seasons and projecting the resource burden if the H1N1 virus had been more virulent.

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6. List of Publications and Products

6.1. Abstracts

6.1.1. Sills MR, Mitchell MS, Pratte K, Ranade D, Liu G, Kahn MG, Fairclough DL. **Overcrowding and time to first systemic corticosteroid medication for patients presenting to a pediatric emergency department for acute asthma exacerbations.** Pediatric Academic Societies' Annual Meeting, Honolulu, May 2008. PAS2008:63:3786.22.

6.1.2. Mitchell MS, Sills MR, Pratte K, Ranade D, Liu G, Kahn MG, Fairclough DL. **Overcrowding and time to first pain score and narcotic medication for patients presenting to a pediatric emergency department for acute, isolated long-bone fractures.** Pediatric Academic Societies' Annual Meeting, Honolulu, May 2008. PAS2008:63:3786.11.

6.1.3. Sills MR, Ranade D, Kahn MG, Fairclough DL. **Overcrowding and time to four time-related outcome measures for patients presenting to a pediatric emergency department for acute asthma exacerbations.** Agency for Healthcare Research and Quality 2008 Conference: Promoting Quality, Partnering for Change. Bethesda, September 2008.

6.1.4. Sills MR, Ranade D, Kahn MG, Fairclough DL. **Overcrowding and time-related outcome measures for patients presenting to a pediatric emergency department for acute long-bone fracture pain and acute asthma exacerbations.** American College of Emergency Physicians Scientific Assembly. Chicago, 2008.

6.1.5. Sills MR, Ranade D, Kahn MG, Fairclough DL. **Crowding and time-related outcome measures for patients presenting to a pediatric emergency department for acute long-bone fracture pain.** Pediatric Academic Societies' Annual Meeting, Baltimore, May 2009. PAS2009:65: 4331.123.

6.1.6. Sills MR, Ranade D, Kahn MG, Fairclough DL. **Crowding and time-related outcome measures for patients presenting to a pediatric emergency department for acute asthma exacerbations.** Pediatric Academic Societies' Annual Meeting, Baltimore, May 2009. PAS2009:65: 2814.118.

6.1.7. Fieldston ES, Hall M, Sills MR et al. **Do Children's Hospitals Respond to Predictable Fluctuations in Patient Volume?** Pediatric Academic Societies' Annual Meeting, Baltimore, May 2009. PAS2009:65: 5514.253.

6.1.8. Fieldston E, Hall M, Sills MR, Slonim A, Myers A, Cannon C, Pati S, Shah SS. **Children's hospitals do not acutely react to high occupancy.** Academy Health Annual Research Meeting, Chicago, June 2009.

- 6.1.9. Sills MR, Ranade D, Kahn MG, Fairclough DL. **Emergency department crowding is associated with decreased quality of care for children with acute asthma.** Pediatric Academic Societies' Annual Meeting, Vancouver, BC, May 2010.
- 6.1.10. Sills MR, Hall M, Simon HK, Fieldston ES, Walter N, Levin JE, Brogan TV, Hain PD, Goodman DM, Fritch-Levens DD, Fagbuyi DB, Mundorff MB, Libby AM, Anderson HO, Padula WV, Shah SS. **Resource burden at children's hospitals experiencing surge volumes during the spring 2009 H1N1 influenza pandemic.** Pediatric Academic Societies' Annual Meeting, Vancouver, BC, May 2010.
- 6.1.11. Fieldston E, Hall M, Shah SS, Hain PD, Sills MR, Slonim A, Myers A, Cannon C, Pati S. **Addressing Children's Hospital Crowding by Smoothing Occupancy.** Pediatric Academic Societies' Annual Meeting, Vancouver, BC, May 2010.
- 6.1.12. Fieldston E, Hall M, Shah SS, Hain PD, Sills MR, Slonim A, Myers A, Cannon C, Pati S. **Addressing Children's Hospital Crowding by Smoothing Occupancy**. Academy Health Annual Research Meeting, Boston, June, 2010.
- 6.1.13. Sills MR, Ranade D, Kahn MG, Fairclough DL. **Emergency department crowding is associated with decreased quality of care for children with acute asthma.** American Public Health Association's Annual Meeting, Denver, November, 2010.
- 6.1.14. Sills MR, Hall M, Simon HK, Fieldston ES, Walter N, Levin JE, Brogan TV, Hain PD, Goodman DM, Fritch-Levens DD, Fagbuyi DB, Mundorff MB, Libby AM, Anderson HO, Padula WV, Shah SS. **Resource burden at children's hospitals experiencing surge volumes during the spring 2009 H1N1 influenza pandemic.** American Public Health Association's Annual Meeting, Denver, November, 2010.

6.2. Manuscripts Published

- 6.2.1. Fieldston ES, Hall M, Sills MR, Slonim AD, Myers AL, Cannon C, Pati S, Shah SS.. **Children's hospitals do not acutely respond to high occupancy..** Pediatrics. 2010 May;125(5):974-81. PMID: 20403931

6.3. Manuscripts Accepted

- 6.3.1. Sills MR, Ranade D, Fairclough DL, Kahn MG. **Emergency department crowding is associated with decreased quality of care for children with acute asthma.** Accepted at *Annals of Emergency Medicine*.
- 6.3.2. Sills MR, Ranade D, Fairclough DL, Kahn MG. **Selecting Crowding Measures for Pediatric Emergency Department Populations.** Accepted at *Pediatric Emergency Care*.

6.4. Manuscripts in Review

- *6.4.1.* Fieldston E, Hall M, Shah SS, Hain PD, Sills MR, Slonim A, Myers A, Cannon C, Pati S. **Addressing Children's Hospital Crowding by Smoothing Occupancy.** In revise-resubmit at *Journal of Hospital Medicine.*
- 6.4.2. Sills MR, Hall M, Simon HK, Fieldston ES, Walter N, Levin JE, Brogan TV, Hain PD, Goodman DM, Fritch-Levens DD, Fagbuyi DB, Mundorff MB, Libby AM, Anderson HO, Padula WV, Shah SS. **Resource burden at children's hospitals experiencing surge volumes during the spring 2009 H1N1 influenza pandemic.** In revise-resubmit at *Academic Emergency Medicine.*

6.5. Manuscripts in Preparation

- 6.5.1. Sills MR, Ranade D, Fairclough DL, Kahn MG. **Emergency department crowding is associated with decreased quality of care for children with fracture-related pain.**

6.5.2. Sills MR, Hall M, Simon HK, Fieldston ES, Walter N, Brogan TV, Hain PD, Goodman DM, Fritch-Levens DD, Fagbuyi DB, Mundorff MB, Shah SS. **Limited resource capacity at children's hospitals: evaluation of the H1N1 pandemic and implications for preparedness**

Reference List

1. Bernstein SL, Aronsky D, Duseja R, Epstein S, Handel D, Hwang U, et al. The effect of emergency department crowding on clinically oriented outcomes. *Acad Emerg Med.* 2009;16:1-10.
2. Hoot NR, Aronsky D. Systematic review of emergency department crowding: causes, effects, and solutions. *Ann Emerg Med.* 2008;52:126-136.
3. Hwang U, Concato J. Care in the emergency department: how crowded is overcrowded? *Acad Emerg Med.* 2004;11:1097-1101.
4. Khare RK, Powell ES, Reinhardt G, Lucenti M. Adding more beds to the emergency department or reducing admitted patient boarding times: which has a more significant influence on emergency department congestion? *Ann Emerg Med.* 2009;53:575-585.
5. Moskop JC, Sklar DP, Geiderman JM, Schears RM, Bookman KJ. Emergency department crowding, part 1--concept, causes, and moral consequences. *Ann Emerg Med.* 2009;53:605-611.
6. Pines JM, Localio AR, Hollander JE, Baxt WG, Lee H, Phillips C, et al. The impact of emergency department crowding measures on time to antibiotics for patients with community-acquired pneumonia. *Ann Emerg Med.* 2007;50:510-516.
7. Pines JM. Moving closer to an operational definition for ED crowding. *Acad Emerg Med.* 2007;14:382-383.
8. Pines JM, Hollander JE. Emergency department crowding is associated with poor care for patients with severe pain. *Ann Emerg Med.* 2008;51:1-5.
9. Pines JM, Yealy DM. Advancing the Science of Emergency Department Crowding: Measurement and Solutions. *Ann Emerg Med.* 2009.
10. Solberg LI, Asplin BR, Weinick RM, Magid DJ. Emergency department crowding: consensus development of potential measures. *Ann Emerg Med.* 2003;42:824-834.
11. United States Government Accountability Office. Hospital Emergency Departments Crowding Continues To Occur, And Some Patients Wait Longer Than Recommended Time Frames. Washington, DC: GAO; 2009. Report No.: GAO-09-347. [Accessed 7/20/2009].
12. Weiss SJ, Ernst AA, Nick TG. Comparison of the National Emergency Department Overcrowding Scale and the Emergency Department Work Index for quantifying emergency department crowding. *Acad Emerg Med.* 2006;13:513-518.
13. Institute of Medicine. Emergency care for children: Growing pains. Washington: National Academies Press; 2007. Available at http://www.nap.edu/catalog.php?record_id=11655 [Accessed 9/4/2009].
14. Bordley WC. Outcomes research and emergency medical services for children: domains, challenges, and opportunities. *Ambul Pediatr.* 2002;2:306-310.
15. Clancy CM, Dougherty D, Walker E. The importance of outcomes research in pediatric emergency medicine. *Ambul Pediatr.* 2002;2:293-300.
16. Guttmann A, Razzaq A, Lindsay P, Zagorski B, Anderson GM. Development of measures of the quality of emergency department care for children using a structured panel process. *Pediatrics.* 2006;118:114-123.
17. Institute of Medicine. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington: National Academies Press; 2001. Available at http://www.nap.edu/catalog.php?record_id=10027 [Accessed 9/4/2009].

18. Akinbami LJ, Moorman JE, Garbe PL, Sondik EJ. Status of childhood asthma in the United States, 1980-2007. *Pediatrics.* 2009;123 Suppl 3:S131-S145.
19. National Asthma Education and Prevention Program, National Heart Blood and Lung Institute. Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma. Bethesda, MD: National Institutes of Health; 2007. Report No.: NIH publication No. 08-4051. Available at http://www.nhlbi.nih.gov/guidelines/asthma/
20. National Center for Health Statistics. National Hospital Ambulatory Medical Care Survey--Emergency Department Visit Data, 2004-2006. National Center for Health Statistics 2008 July 11; Available at: ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Datasets/NHAMCS/ [Accessed 11/29/2008].
21. Joint Commission. Comprehensive Accreditation Manual for Hospitals: Nutritional, Functional, And Pain Assessments And Screens. Joint Commission 2009; Available at: http://www.jointcommission.org/AccreditationPrograms/Hospitals/Standards/09_FAQs/PC/Nutritional_+Functional_Pain_+Assessments.htm [Accessed 9/5/2009].
22. Zempsky WT, Cravero JP. Relief of pain and anxiety in pediatric patients in emergency medical systems. *Pediatrics.* 2004;114:1348-1356.
23. Hwang U, Richardson LD, Sonuyi TO, Morrison RS. The effect of emergency department crowding on the management of pain in older adults with hip fracture. *J Am Geriatr Soc.* 2006;54:270-275.
24. Pollack CV, Jr., Pollack ES, Baren JM, Smith SR, Woodruff PG, Clark S, et al. A prospective multicenter study of patient factors associated with hospital admission from the emergency department among children with acute asthma. *Arch Pediatr Adolesc Med.* 2002;156:934-940.
25. Boudreaux ED, Emond SD, Clark S, Camargo CA, Jr. Race/ethnicity and asthma among children presenting to the emergency department: differences in disease severity and management. *Pediatrics.* 2003;111:e615-e621.
26. Emerman CL, Cydulka RK, Crain EF, Rowe BH, Radeos MS, Camargo CA, Jr. Prospective multicenter study of relapse after treatment for acute asthma among children presenting to the emergency department. *J Pediatr.* 2001;138:318-324.
27. Ferris TG, Crain EF, Oken E, Wang L, Clark S, Camargo CA, Jr. Insurance and quality of care for children with acute asthma. *Ambul Pediatr.* 2001;1:267-274.
28. Scribano PV, Lerer T, Kennedy D, Cloutier MM. Provider adherence to a clinical practice guideline for acute asthma in a pediatric emergency department. *Acad Emerg Med.* 2001;8:1147-1152.
29. Brown JC, Klein EJ, Lewis CW, Johnston BD, Cummings P. Emergency department analgesia for fracture pain. *Ann Emerg Med.* 2003;42:197-205.
30. Selbst SM, Clark M. Analgesic use in the emergency department. *Ann Emerg Med.* 1990;19:1010-1013.
31. Cimpello LB, Khine H, Avner JR. Practice patterns of pediatric versus general emergency physicians for pain management of fractures in pediatric patients. *Pediatr Emerg Care.* 2004;20:228-232.
32. Friedland LR, Kulick RM. Emergency department analgesic use in pediatric trauma victims with fractures. *Ann Emerg Med.* 1994;23:203-207.
33. Alexander J, Manno M. Underuse of analgesia in very young pediatric patients with isolated painful injuries. *Ann Emerg Med.* 2003;41:617-622.
34. Boyd RJ, Stuart P. The efficacy of structured assessment and analgesia provision in the paediatric emergency department. *Emerg Med J.* 2005;22:30-32.
35. Rogovik AL, Rostami M, Hussain S, Goldman RD. Physician pain reminder as an intervention to enhance analgesia for extremity and clavicle injuries in pediatric emergency. *J Pain.* 2007;8:26-32.

36. Tsai CL, Sullivan AF, Gordon JA, Kaushal R, Magid DJ, Blumenthal D, et al. Quality of care for acute asthma in 63 US emergency departments. *J Allergy Clin Immunol.* 2009;123:354-361.
37. Doing the most to ensure the least emergency department asthma visits: asthma experts consider preliminary project findings. *Pediatrics.* 2006;117:S159-S166.
38. Rowe BH, Spooner C, Ducharme FM, Bretzlaff JA, Bota GW. Early emergency department treatment of acute asthma with systemic corticosteroids. *Cochrane Database Syst Rev.* 2001;CD002178.
39. Baker DW, Stevens CD, Brook RH. Patients who leave a public hospital emergency department without being seen by a physician. Causes and consequences. *JAMA.* 1991;266:1085-1090.
40. Stock LM, Bradley GE, Lewis RJ, Baker DW, Sipsey J, Stevens CD. Patients who leave emergency departments without being seen by a physician: magnitude of the problem in Los Angeles County. *Ann Emerg Med.* 1994;23:294-298.
41. Bernstein SL, Verghese V, Leung W, Lunney AT, Perez I. Development and validation of a new index to measure emergency department crowding. *Acad Emerg Med.* 2003;10:938-942.
42. Crain EF, Weiss KB, Fagan MJ. Pediatric asthma care in US emergency departments. Current practice in the context of the National Institutes of Health guidelines. *Arch Pediatr Adolesc Med.* 1995;149:893-901.
43. Frost SA, Alexandrou E, Bogdanovski T, Salamonson Y, Parr MJ, Hillman KM. Unplanned admission to intensive care after emergency hospitalisation: risk factors and development of a nomogram for individualising risk. *Resuscitation.* 2009;80:224-230.
44. Tam V, Frost SA, Hillman KM, Salamonson Y. Using administrative data to develop a nomogram for individualising risk of unplanned admission to intensive care. *Resuscitation.* 2008;79:241-248.
45. Haller G, Myles PS, Wolfe R, Weeks AM, Stoelwinder J, McNeil J. Validity of unplanned admission to an intensive care unit as a measure of patient safety in surgical patients. *Anesthesiology.* 2005;103:1121-1129.
46. Hampers LC, McNulty JE. Professional interpreters and bilingual physicians in a pediatric emergency department: effect on resource utilization. *Arch Pediatr Adolesc Med.* 2002;156:1108-1113.
47. Ramirez D, Engel KG, Tang TS. Language interpreter utilization in the emergency department setting: a clinical review. *J Health Care Poor Underserved.* 2008;19:352-362.
48. Lambe S, Washington DL, Fink A, Laouri M, Liu H, Scura FJ, et al. Waiting times in California's emergency departments. *Ann Emerg Med.* 2003;41:35-44.
49. Burt CW, Arispe IE. Characteristics of emergency departments serving high volumes of safety-net patients: United States, 2000. *Vital Health Stat 13.* 2004;1-16.
50. Asplin BR, Magid DJ, Rhodes KV, Solberg LI, Lurie N, Camargo CA, Jr. A conceptual model of emergency department crowding. *Ann Emerg Med.* 2003;42:173-180.
51. Institute of Medicine. Hospital-Based Emergency Care: At the Breaking Point. Washington: National Academies Press; 2007. Available at http://www.nap.edu/catalog.php?record_id=11621 [Accessed 9/4/2009].
52. Clark S, Costantino T, Rudnitsky G, Camargo CA, Jr. Observational study of intravenous versus oral corticosteroids for acute asthma: an example of confounding by severity. *Acad Emerg Med.* 2005;12:439-445.
53. Rathlev NK, Chessare J, Olshaker J, Obendorfer D, Mehta SD, Rothenhaus T, et al. Time series analysis of variables associated with daily mean emergency department length of stay. *Ann Emerg Med.* 2007;49:265-271.

54. Pines JM, Hollander JE, Localio AR, Metlay JP. The association between emergency department crowding and hospital performance on antibiotic timing for pneumonia and percutaneous intervention for myocardial infarction. *Acad Emerg Med.* 2006;13:873-878.
55. Fee C, Weber EJ, Maak CA, Bacchetti P. Effect of emergency department crowding on time to antibiotics in patients admitted with community-acquired pneumonia. *Ann Emerg Med.* 2007;50:501-9, 509.
56. Schull MJ, Vermeulen M, Slaughter G, Morrison L, Daly P. Emergency department crowding and thrombolysis delays in acute myocardial infarction. *Ann Emerg Med.* 2004;44:577-585.
57. Schull MJ, Morrison LJ, Vermeulen M, Redelmeier DA. Emergency department overcrowding and ambulance transport delays for patients with chest pain. *CMAJ.* 2003;168:277-283.
58. Schull MJ, Morrison LJ, Vermeulen M, Redelmeier DA. Emergency department gridlock and out-of-hospital delays for cardiac patients. *Acad Emerg Med.* 2003;10:709-716.
59. Sun BC, Adams J, Orav EJ, Rucker DW, Brennan TA, Burstin HR. Determinants of patient satisfaction and willingness to return with emergency care. *Ann Emerg Med.* 2000;35:426-434.
60. Yancer DA, Foshee D, Cole H, Beauchamp R, de la PW, Keefe T, et al. Managing capacity to reduce emergency department overcrowding and ambulance diversions. *Jt Comm J Qual Patient Saf.* 2006;32:239-245.
61. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *Med J Aust.* 2006;184:213-216.
62. Sprivulis PC, Da Silva JA, Jacobs IG, Frazer AR, Jelinek GA. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *Med J Aust.* 2006;184:208-212.
63. Chalfin DB, Trzeciak S, Likourezos A, Baumann BM, Dellinger RP. Impact of delayed transfer of critically ill patients from the emergency department to the intensive care unit. *Crit Care Med.* 2007;35:1477-1483.
64. Baer RB, Pasternack JS, Zwemer FL, Jr. Recently discharged inpatients as a source of emergency department overcrowding. *Acad Emerg Med.* 2001;8:1091-1094.
65. Galbraith AA, Smith LA, Bokhour B, Miroshnik IL, Sawicki GS, Glauber JH, et al. Asthma Care Quality for Children With Minority-Serving Providers. *Archives of Pediatrics Adolescent Medicine.* 2010;164:38-45.
66. Lieu TA, Lozano P, Finkelstein JA, Chi FW, Jensvold NG, Capra AM, et al. Racial/Ethnic Variation in Asthma Status and Management Practices Among Children in Managed Medicaid. *Pediatrics.* 2002;109:857-865.
67. Finkelstein JA, Lozano P, Farber HJ, Miroshnik I, Lieu TA. Underuse of Controller Medications Among Medicaid-Insured Children With Asthma. *Archives of Pediatrics Adolescent Medicine.* 2002;156:562-567.
68. DeLia D, Cantor J. Emergency Department Utilization and Capacity. The Robert Wood Johnson Foundation; 2009 Jul 1. Report No.: 17. Available at http://www.rwjf.org/files/research/072109policysynthesis17.emergencyutilization.pdf [Accessed 7/21/2009].