

# Effect of Emergency Department Crowding on Time to Antibiotics in Patients Admitted With Community-Acquired Pneumonia

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**Study objective:** We hypothesize that emergency department (ED) volume and increased patient complexity are associated with lower quality of care, as measured by time to antibiotics for patients being admitted with community-acquired pneumonia.

**Methods:** This was a cross-sectional study at a university tertiary care hospital ED. Community-acquired pneumonia patients admitted from the ED and discharged between January 2004 and June 2005 were reviewed by our institution for The Joint Commission's antibiotic timing core measure. Medical records were abstracted for patient age, sex, race, mode of transport, arrival time, triage acuity, inpatient level of care, and arrival-to-antibiotic-administration times. Controlling for patient characteristics, multivariate logistic regression determined association of antibiotic administration within 4 hours of arrival, with total ED volume at the time of the community-acquired pneumonia patient's arrival, and with number of ED patients requiring admission at the time of arrival.

**Results:** Four hundred eighty-six patients were eligible for the study; antibiotic administration time was available for 405. Sixty-one percent of patients received antibiotics within 4 hours. Antibiotic administration within 4 hours was less likely with a greater number of patients (odds ratio 0.96 per additional patient; 95% confidence interval 0.93 to 0.99) and a greater number of patients ultimately admitted (odds ratio 0.93 per patient; 95% confidence interval 0.88 to 0.99) in the ED. The effect of additional patients was present below total ED capacity.

**Conclusion:** As ED volume increases, ED patients with community-acquired pneumonia are less likely to receive timely antibiotic therapy. The effect of additional patients appears to occur even at volumes below the maximum bed capacity. Measures to ensure that quality targets are met in the ED should consider the impact of ED volume. [Ann Emerg Med. 2007;xx:xxx.]

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## INTRODUCTION

### Background

Emergency department (ED) crowding has been postulated as a potential cause of poor quality patient care.<sup>1</sup> Several reports in the lay press have claimed that EDs are often unsafe because of crowding.<sup>2-8</sup> According to The Joint Commission (TJC), more than half of all "sentinel event" cases of morbidity and mortality as a result of delays in treatment occur in EDs, with ED crowding cited as a contributing factor in 31%.<sup>9</sup> To date,

however, there have been limited published scientific data to support this statement.<sup>10-16</sup>

There were more than 16 million admissions to US hospitals initiated in EDs in 2003, representing 55% of all admissions, excluding pregnancy and childbirth.<sup>17</sup> The most frequent reason for admission from an ED was pneumonia, with 935,000 admissions (5.7% of admissions through an ED). Community-acquired pneumonia was one of the initial areas identified by TJC as a hospital core measure for quality of care, with a target of 8 hours. A large retrospective study using a 1998 to 1999 Centers for Medicare & Medicaid Services (CMS) data

**Editor's Capsule Summary***What is already known on this topic*

Emergency department (ED) crowding has been associated with adverse patient care events and postulated to adversely affect quality. It is unknown whether quality is affected at patient volumes less than capacity.

*What question this study addressed*

Does ED patient volume affect compliance with the 4-hour target for initial antibiotic administration in individuals with community-acquired pneumonia?

*What this study adds to our knowledge*

Compliance with the 4-hour target decreased as patient numbers increased, even at volumes less than maximal ED patient capacity.

*How this might change clinical practice*

Methods to facilitate compliance with quality measures should include the impact of ED patient volume.

set found that administration of antibiotics to patients 65 years or older, admitted with pneumonia within 4 hours of hospital arrival, was associated with improved in-hospital and 30-day mortality.<sup>18</sup> Subsequently, CMS and TJC revised their core measure to create a target of receiving initial antibiotics within 4 hours of hospital arrival.

**Importance**

EDs are being closely scrutinized for their ability to meet the 4-hour antibiotic target, as well as other quality benchmarks, yet the impact of their volume is often not recognized. Demonstrating a relationship between volume and quality of care is important in bringing resources to bear on solving the crowding issue, as well as improving the ability to meet quality benchmarks. Additionally, if ED volume affects performance on measures of quality of care, EDs may need to revise their operations to meet the growing challenge of delivering time-sensitive treatments for trauma, sepsis, stroke, and acute coronary syndrome patients.

**Goals of This Investigation**

The purpose of this study is to determine whether there is an association between ED volume and timing of antibiotic administration in patients admitted to the hospital through the ED with community-acquired pneumonia. We hypothesize that antibiotic delay is associated with higher ED volume and, in particular, a higher volume of ED patients requiring hospital admission.

**MATERIALS AND METHODS****Study Design**

This is a cross-sectional study of patients who were admitted through a university tertiary care hospital ED and discharged

from an inpatient hospitalization for pneumonia between January 1, 2004, and June 30, 2005. We analyzed the effect of each additional patient present in the ED at the community-acquired pneumonia patient's arrival on the odds of the community-acquired pneumonia patient receiving antibiotics within 4 hours.

**Setting**

The ED has an annual census of 39,000 patients, with 29 beds, and is staffed by emergency medicine, internal medicine, pediatric, and psychiatry residents, as well as nurse practitioners and physician assistants. All patient care is supervised 24 hours a day by board certified emergency physicians. Our institution adheres to a strict nurse-to-patient ratio, as mandated by state law, and staffing allows us to cover all patient rooms.

**Selection of Participants**

As part of ongoing quality assurance and TJC core measure reporting at our institution, an outside vendor (University HealthSystems Consortium) reviews medical records of inpatients eligible for TJC core measure PN-5b.<sup>19</sup> Patients eligible for this measure are adult (>18 years) patients, including those transferred from a long-term care facility, who were discharged from the hospital with a primary diagnosis (determined by *International Classification of Diseases, Ninth Revision* coding) of community-acquired pneumonia or secondary diagnosis of community-acquired pneumonia (if the primary diagnosis was sepsis or respiratory failure). University HealthSystems Consortium reviewed charts of all patients meeting the eligibility criteria from January 1, 2004, through December 31, 2004, in accordance with TJC reporting requirements. Thereafter, the TJC reporting requirements were revised, and University HealthSystems Consortium selected a random sample of 75 patients per calendar quarter, using a computerized random-number generator (SAS, version 9.1; SAS Institute, Inc., Cary, NC). Eligibility criteria (as defined by TJC) remained unchanged. University HealthSystems Consortium then excluded patients in accordance with TJC core measure PN-5b exclusion criteria<sup>19</sup> if they did not have a working diagnosis of pneumonia at or before admission, were younger than 18 years, had received antibiotics within the 24 hours before their ED presentation, were treated in-hospital with comfort care only, did not receive antibiotics during the hospitalization, were transferred from another acute care hospital (including another ED), or received their first dose of antibiotics more than 36 hours from arrival. Charts of all remaining patients were reviewed for antibiotic timing and the results reported to our institution. From this group of patients, we selected all patients who had been admitted to the hospital from the ED to perform the present study. Patients were excluded from this study if the antibiotic administration time was not available from the chart.

## Data Collection and Processing

The ED maintains an administrative database of each patient visit that includes patient demographics (obtained from the hospital registration system) and descriptors of the ED visit and disposition (entered by clerical staff at the end of each visit). For each community-acquired pneumonia patient in the sample, patient age, sex, self-determined race and ethnicity, mode of transport (ambulance or self), triage acuity (1 to 4; 1=emergency), and level of care to which the patient was admitted (ICU or not) were obtained from this database. Time of arrival, as recorded in the intake log, time of registration, and triage time were recorded for each patient. Because some of our patients (walk-ins) are recorded in the log before being registered or triaged, and some patients are triaged immediately (eg, ambulance patients and those with emergent chief complaints), the time of arrival was considered the earliest of these 3 times, according to TJC standards.

We abstracted date and time of antibiotic administration from the ED chart for each subject by using a structured form. For those cases in which data were missing (either because of a missing chart or lack of a legible documented time), we made 3 attempts to obtain the information before reporting the data as unavailable. Data abstraction was performed by 2 abstractors (C.A.M. and C.F.), who were blinded to the ED volume data.

The ED database permits calculation of the hourly volume of the ED on any previous date. The hourly volume can also be determined for the number of patients in the department with a specific disposition. From this database, we determined the total number of patients and the number of patients who were ultimately admitted to the hospital, who were already present in the ED when each community-acquired pneumonia patient arrived. The community-acquired pneumonia patient was included as a patient present in the ED. Patients who ultimately left without being seen were also included in the total volume during the time they were physically present in the ED. These patients were included because they create workload for the nursing staff and some patients are already in rooms before they leave. All data were entered into an electronic spreadsheet (Microsoft Excel 97; Microsoft Corporation, Redmond, WA).

## Methods of Measurement

Demographic and presenting characteristics were tabulated. We compared demographic and presenting characteristics of patients for whom we could not establish time to antibiotic administration with those for whom we could. We calculated time from ED arrival to antibiotic administration and dichotomized patients into those who did and did not receive antibiotics within 4 hours, according to the TJC/CMS standard. We determined the number of patients in the department at each community-acquired pneumonia patient's arrival.

## Outcomes Measures

We dichotomized patients into those who did and did not receive antibiotics within 4 hours, according to TJC/CMS standard.

## Primary Data Analysis

We used multivariate logistic regression to determine the association of total ED volume with antibiotic delivery within 4 hours, controlling for community-acquired pneumonia patient demographic and clinical characteristics. To assess whether the number of admitted patients in the ED (as opposed to total ED volume) influenced time to antibiotics in community-acquired pneumonia patients, we repeated the multivariate analysis with 2 separate variables for ED volume: number of patients present who were ultimately admitted to the hospital and number of patients who were discharged. Predictor variables used in the model were selected a priori according to our clinical experience, suggesting these factors might affect how quickly a patient might be treated: mode of transport, triage acuity, age, shift of arrival, level of care to which they were admitted. We also included race, ethnicity, and sex because of concerns of disparities in health care delivery or atypical presentations. To assess for an impact of potential heightened suspicion for pneumonia by ED providers during the winter, we performed a multivariate analysis that included season as a predictor. Patients who had missing values for predictor variables were excluded from the multivariate analysis.

We chose not to include ED length of stay as a predictor variable, because a prolonged length of stay could be a cause of antibiotic delay (eg, a patient with an atypical presentation who requires multiple tests to confirm a diagnosis of pneumonia) or a result of crowding (a delay to getting into a room, obtaining a chest radiograph, or ordering or administration of antibiotics when the ED is very busy or is holding boarders). Conversely, a short length of stay could result in prolonged antibiotic time if, for example, an unstable patient is thought to have another illness, is quickly moved to the floor, and then is discovered to have pneumonia (eg, a patient presenting with chest pain, rapidly admitted for cardiac catheterization and later found to have pneumonia). Or a short length of stay could be due to lack of crowding and the ability to be treated by a provider quickly. Thus, the interpretation of the results for this variable would be difficult. Moreover, the potential contributors to the length of stay were assessed by using triage acuity, age, arrival mode, ICU placement, and volume as predictor variables.

## Sensitivity Analyses

We assessed the multivariate model using the Hosmer-Lemeshow test. We checked for influential observations by examining the impact of deleting the most influential observation on the estimated volume effect. We also specifically assessed possible interaction of crowding with the early (January to September 2004) versus late (October 2004 to June 2005) period to detect any impact of an internal educational campaign to improve compliance with the 4-hour antibiotic goal. Additionally, we assessed possible interaction of crowding with high triage acuity to determine

whether ED volume had a greater effect on patients with lower triage acuities.

The multivariate model assumed a linear effect of each additional patient present in the ED on arrival of the community-acquired pneumonia patient. However, our clinical experience suggested that there would be a threshold effect whereby additional patients did not affect the odds of antibiotic delivery until a certain ED volume was reached. Therefore, we tested additional models that assumed no effect until 10, 15, 20, 25, or 30 patients had been reached, with a linear effect thereafter. We used the  $-2$  times the log likelihood value as a summary of how well the models fit the data, with smaller numbers indicating a better fit.

Analyses were conducted using Stata software (version 7; StataCorp, College Station, TX) and SAS (version 9.1). Results are expressed as odds ratios (ORs) with 95% confidence intervals (CIs). *P* values are 2-tailed.

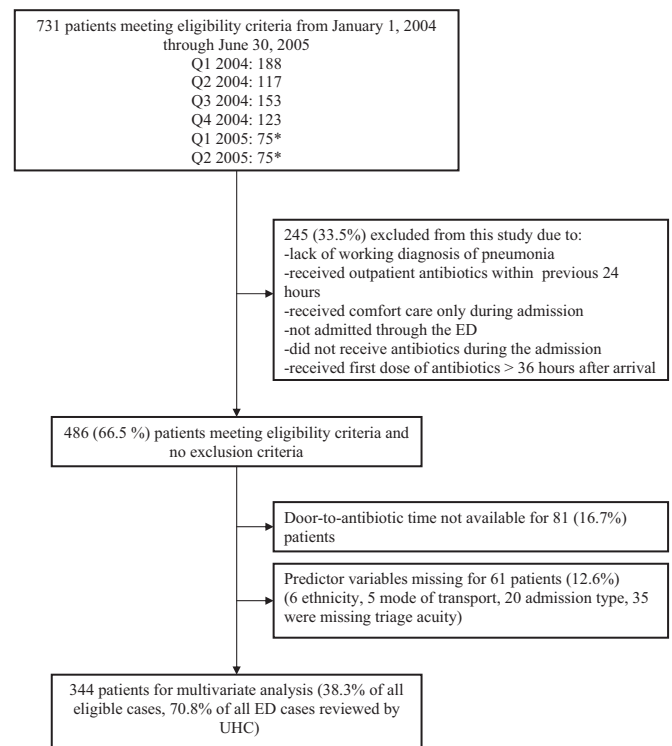
We use the 4-hour antibiotic administration target as a measure of quality of care. We chose to study volume, rather than crowding per se, because multiple definitions of crowding exist but there is no agreed-on standard, and, to some extent, the definitions depend on what impact is being considered.<sup>12,13,20-23</sup> We also recognize that even a small number of patients who require a large number of resources could result in delayed care for others.<sup>14</sup> Finally, we wanted to be certain we did not miss an effect on quality of care that occurred below a level at which providers would consider an ED crowded. Therefore, rather than using a specific volume cutoff for when the ED is “crowded,” we determined whether the ability to care for patients would deteriorate as the number of patients in the ED increased, whether there was any threshold number of patients at which the deterioration would occur, and whether the association of volume with care delivery would be greater with the subset of patients who were ultimately admitted to the hospital. The latter group represents more complex patients and therefore high resource users.

This study was approved by the Committee on Human Research at our institution.

## RESULTS

### Characteristics of Study Subjects

A total of 898 patients were discharged from our hospital with a primary or secondary diagnosis of community-acquired pneumonia during the study period (Figure 1). Seven hundred thirty-one patient visits met eligibility criteria for measure PN-5b and were chosen for review. Four hundred eighty-six (66.5%) had no PN-5b exclusion criteria and were admitted through the ED. Antibiotic delivery time was unavailable for 81 patients from this group, leaving a final sample of 405 for review (45% of all community-acquired pneumonia cases at our hospital, 55% of all cases chosen for review, 83.3% of eligible ED cases that had been reviewed by University HealthSystems Consortium). The mean age was 68.4 years, 53.1% were men, 50.4% were white, 21.1% had emergency acuity, 12.7% were



**Figure 1.** Case selection.

\*Number of charts selected for review per quarter was reduced to 75 in quarter 1 2005, in accordance with a change in TJC/CMS reporting requirements. In quarter 1 and quarter 2 2005, these 75 charts were randomly selected from the total meeting eligibility criteria (213 in quarter 1 2005 and 104 in quarter 2 2005).

admitted to an ICU, and mean length of stay was 8.9 hours (Table 1). Patients for whom we could not determine time to antibiotics were similar to the study group, with the exception of being younger (Table 1).

### Main Results

Sixty-one percent of study patients received antibiotics within 4 hours; 92.4%, within 8 hours. Table 2 shows the characteristics of individuals who received antibiotics within the 4-hour target and those who did not.

The multivariate analysis included 344 patients, representing 84.9% of ED cases with antibiotic time available and 70.8% of all eligible ED cases reviewed by University HealthSystems Consortium. The 61 patients excluded from the multivariate analysis were missing 1 or more variables: ethnicity (6), mode of transport (20), admission type (20), triage acuity (35).

Higher ED volume was independently associated with a lower likelihood that a community-acquired pneumonia patient would receive antibiotics within 4 hours (OR 0.96 per additional patient in the ED; 95% CI 0.93 to 0.99) (Table 3). Thus, for each additional patient present in the ED at a community-acquired pneumonia patient's arrival, the odds of receiving antibiotics within 4 hours decreased by 4%. The

**Table 1.** Study participants and those excluded because of lack of antibiotic-timing data.

Variable	Study Group (n=405)	Time to Antibiotic Not Available (n=81)
Male, %	53.1	46.9
Age, y (mean±SD)	68.4±19.0	64.0±18.3
<b>Race, %</b>		
White	50.4	53.2
Asian/Pacific Islander	26.2	20.3
Black	11.6	13.9
Other	11.9	12.7
<b>Ethnicity, %</b>		
Non-Hispanic	91.7	88.6
Hispanic	8.3	11.4
<b>Triage Acuity, %</b>		
1 (Emergency)	21.1	11.5
2	61.4	73.1
3	7.0	15.4
Arrived by ambulance, %	32.0	33.8
<b>Admission type, %</b>		
Medical-surgical floor	34.8	31.6
Telemetry/stepdown	52.5	45.6
ICU	12.7	22.8
<b>Shift of arrival, %*</b>		
Day	38.3	44.4
Evening	44.7	39.5
Night	17.0	16.0
Total ED patients on arrival (mean±SD) <sup>†</sup>	24.3±9.0	23.0±9.5
Admitted ED patients on arrival (mean±SD) <sup>†</sup>	9.1±4.3	8.8±4.3
ED length of stay (h, mean±SD)	8.9±5.3	8.4±6.4

\*Day shift is 7 AM to 3 PM; evening, 3 PM to 11 PM; night, 11 PM to 7 AM.

<sup>†</sup>Patients on arrival means patients present in the ED when the community-acquired pneumonia patient arrived and includes the community-acquired pneumonia patient. Arrival time is the earliest of greeting, triage, or registration time of the community-acquired pneumonia patient.

number of patients already present in the ED who were ultimately admitted appeared to have a slightly stronger effect (OR 0.93 per patient; 95% CI 0.88 to 0.99) than the number ultimately discharged (OR 0.97; 95% CI 0.93 to 1.02), but the difference was not statistically significant ( $P=.29$ ). A higher triage acuity and admission to the ICU were independently associated with antibiotic administration in less than 4 hours. Season of admission (OR 2.91, 95% CI 0.56 to 14.97 for spring versus fall; OR 1.58, 95% CI 0.29 to 8.57 for summer versus fall; and OR 2.71, 95% CI 0.69 to 10.64 for winter versus fall) and later study period (OR 0.94, 95% CI 0.58 to 1.52) did not appear to substantially improve the model and were not included in the final model.

### Sensitivity Analyses

The Hosmer-Lemeshow test did not provide strong evidence of violations in our multivariate model ( $P=.13$ ). In addition, there appeared to be no overly influential observations that substantially distorted our results. Deleting the single observation with the greatest influence on the estimated volume

effect in our final multivariate model had essentially no impact on the results shown. The interaction of ED volume with high triage acuity or with early versus late study period did not reach statistical significance. We found similar estimates of the volume effect, dropping 1 predictor at a time from the multivariate model. Thus, the volume effect appeared important in univariate analysis, an inclusive multivariate model, and more parsimonious multivariate models.

None of the additional multivariate models that tested for thresholds of 10, 15, 20, and 25 patients in the ED at arrival of the community-acquired pneumonia patient fit the data substantially better than the linear model. We found modest evidence against the assumption that antibiotic delivery deteriorated only after a threshold of 30 patients (greater than our 29-bed capacity) is passed. These data suggest that if there is a threshold at which the crowding effect begins in our ED, it occurs below 30 patients, ie, below our maximal capacity.

Figure 2 shows a scatterplot of raw proportions of community-acquired pneumonia patients who received antibiotics within 4 hours versus the number of ED patients who were present on arrival of the community-acquired pneumonia patient (Figure E1, a scatterplot of time to antibiotic versus ED volume, is available online at <http://www.annemergmed.com>). A univariate linear logistic regression model of the log odds of receiving antibiotics within 4 hours versus the number of patients (and percent of our ED bed capacity) in the ED at the arrival of a community-acquired pneumonia patient shows the negative impact of concurrent ED patients on the probability of antibiotic administration within 4 hours. The univariate logistic regression model estimates that if a community-acquired pneumonia patient arrived when there were 10 other patients in the ED, the probability of receiving antibiotics within 4 hours would be 72.5%, 64.6% if 20 ED patients, 55.8% if 30 ED patients (maximum bed capacity for our ED), and 46.4% if there were 40 ED patients present on their arrival.

### LIMITATIONS

This is a cross-sectional, single-center study, and the findings may not apply to other settings. The study sample included every admitted pneumonia patient from January through December 2004 and a random sample thereafter. Although this was a mixed sample of randomly selected patients for some quarters and all patients for others, we do not see how this might have biased our results in one particular direction. Door to antibiotic time was unavailable in 16.7% of the ED cohort. However, we do not believe that the inclusion of these patients in our final analysis would have changed the results of our analysis, because they were similar in characteristics other than age, and age did not appear to be a strong predictor of delayed antibiotics in our logistic regression analysis. Some patients with antibiotic times were missing predictor variables and were excluded from the multivariate analysis; however, the results of the multivariate are similar to those of the univariate (in which all patients were included).

**Table 2.** Likelihood of receiving antibiotics within 4 hours by patient characteristic.

Variable	<4 h, No. (%)	OR	95% CI
Age (per 10 y)		1.12	1.00–1.24
<b>Sex</b>			
Female (reference)	115/190 (60.5)	1.00	
Male	134/215 (62.3)	1.08	0.72–1.61
<b>Race</b>			
White (reference)	125/204 (61.3)	1.00	
Asian/Pacific Islander	70/106 (66.0)	1.23	0.75–2.01
Black	26/47 (55.3)	0.78	0.41–1.48
Other	28/48 (58.3)	0.88	0.47–1.68
<b>Ethnicity</b>			
Non-Hispanic (ref)	226/366 (61.7)	1.00	
Hispanic	18/33 (54.5)	0.74	0.36–1.52
<b>Mode of transport</b>			
Self (reference)	163/272 (59.9)	1.00	
Ambulance	85/128 (66.4)	1.32	0.85–2.05
<b>Admission type</b>			
Non-ICU* (ref)	193/336 (57.4)	1.00	
ICU	43/49 (87.8)	5.31	2.20–12.82
<b>Triage acuity</b>			
3 (Reference)	26/65 (40.0)	1.00	
2	137/227 (60.4)	2.28	1.30–4.01
1 (Emergency)	65/78 (83.3)	7.50	3.46–16.28
<b>Shift<sup>†</sup></b>			
Day (reference)	90/155 (58.1)	1.00	
Evening	107/181 (59.1)	1.04	0.68–1.61
Night	52/69 (75.4)	2.21	1.17–4.16
Total patients in ED on arrival (per additional patient) <sup>‡</sup>		0.97	0.94–0.99
Patients ultimately admitted in ED on arrival <sup>‡</sup>		0.94	0.89–0.98
Patients ultimately discharged in ED on arrival (per additional patient) <sup>‡</sup>		0.96	0.93–0.99
Number of ED patients ultimately admitted to ICU on arrival (per additional patient)*		0.94	0.73–1.20

\*Non-ICU=medical-surgical, telemetry or stepdown.

<sup>†</sup>Day shift is 7 AM to 3 PM; evening, 3 PM to 11 PM; night, 11 PM to 7 AM.

<sup>‡</sup>Patients on arrival means patients present in the ED when the community-acquired pneumonia patient arrived and includes the community-acquired pneumonia patient. Arrival time is the earliest of greeting, triage, or registration time of the community-acquired pneumonia patient.

Charts were reviewed by 2 abstractors (C.A.M. and C.F.), who were not blinded to the study hypothesis, which could have introduced bias. We believe this is unlikely, however, because the abstractors were blinded to the ED volume data. Additionally, abstractors did not assess the same charts. Thus, we did not conduct an independent audit of charts to determine the accuracy of the abstraction process or variability between the abstractors.

Finally, the dichotomization of time to antibiotics, although occasioned by current regulatory and quality standards, limits our ability to determine the effect of crowding on time to antibiotics. Using a more sophisticated model of time to antibiotics, for example, using ordinal logistic or linear regression, might have been more sensitive.

## DISCUSSION

In this study, we found that a greater number of patients in the ED is associated with delayed administration of antibiotics for ED patients with community-acquired pneumonia, which was apparent on univariate analysis and remained similar when controlled for other factors in a multivariate model. We also

found that having more admitted patients in the ED was associated with delayed antibiotic administration. Although we found that patients with a more urgent triage acuity and those admitted to an ICU were more likely to receive antibiotics within 4 hours, higher-acuity patients appeared to also be affected by a greater volume. Our results strengthen concerns about the ability of EDs to deliver quality care under crowded conditions.

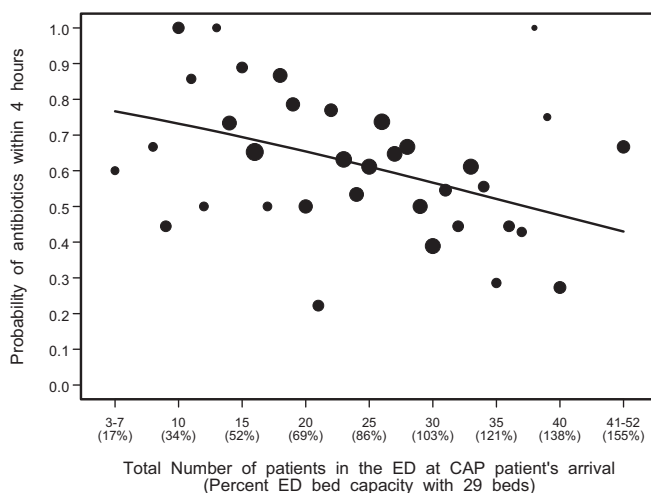
There is no universally accepted definition of crowding. ED crowding has been defined as the percentage of local hospitals within a common network that were on ambulance diversion,<sup>12,13</sup> time required for a patient brought by emergency medical services (EMS) to be placed in an ED bed,<sup>20</sup> time required to get an admitted patient to an inpatient bed,<sup>21</sup> and total number of patients in the ED or a percentage of ED bed capacity.<sup>22,23</sup> Others have referred to crowding with less concrete measures, such as the need to use hallway space as treatment areas or a subjective sense of crowding.<sup>11</sup> We chose to use ED volume as a measure of crowding because a previous study at our institution showed a correlation between total ED volume and rates of patients leaving without being seen.<sup>22</sup>

**Table 3.** Likelihood of receiving antibiotics within 4 hours by characteristic (multivariate regression) (n=344).

Variable	OR	95% CI
Age per decade	1.05	0.92–1.20
<b>Sex</b>		
Female (reference)	1.00	
Male	1.08	0.67–1.74
<b>Race</b>		
White (reference)	1.00	
Asian/Pacific Islander	1.04	0.58–1.87
Black	0.77	0.37–1.60
Other	1.04	0.41–2.66
<b>Ethnicity</b>		
Non-Hispanic (reference)	1.00	
Hispanic	0.76	0.25–2.32
<b>Mode of transport</b>		
Self (reference)	1.00	
Ambulance	0.95	0.54–1.68
<b>Admission type</b>		
Non-ICU* (reference)	1.00	
ICU	4.36	1.56–12.16
<b>Triage acuity</b>		
3 (Reference)	1.00	
2	2.33	1.26–4.30
1 (Emergency)	5.15	2.18–12.13
<b>Shift<sup>†</sup></b>		
Day (reference)	1.00	
Evening	1.33	0.73–2.43
Night	1.99	0.94–4.17
Total patients in ED on arrival (per additional patient) <sup>‡§</sup>	0.96	0.93–0.99
Total patients ultimately admitted in ED on arrival (per additional patient) <sup>‡§</sup>	0.93	0.88–0.99
Total patients ultimately discharged in ED on arrival (per additional patient) <sup>‡§</sup>	0.97	0.93–1.02

\*Non-ICU includes medical/surgical floor, telemetry, and stepdown.  
<sup>†</sup>Day shift is 7 AM to 3 PM; evening, 3 PM to 11 PM; night, 11 PM to 7 AM.  
<sup>‡</sup>Patients on arrival means patients present in the ED when the community-acquired pneumonia patient arrived and includes the community-acquired pneumonia patient. Arrival time is the earliest of greeting, triage, or registration time of the community-acquired pneumonia patient.  
<sup>§</sup>Analysis containing total patients was run separately from the model, including admitted and discharged patients (see text).

Our basic model assumed a linear relationship between number of patients and antibiotic delivery time, but our clinical perception was that antibiotic delivery would not be affected by small numbers of patients in the ED. We tested the theory that ED volume might have no effect until a threshold is exceeded. We examined several possible thresholds and found that overall fit to the data was comparable across several possibilities, including that of no threshold (ie, linear relationship). Thus, we have little evidence for or against a threshold, and a larger study would be needed to determine whether and where such a threshold exists. However, if there is a threshold in our ED, it appears to be below 30 patients, that is, at or below our total number of beds. This finding, as well as the possibility of a linear relationship (ie, that each additional patient has an impact on quality of care), suggests that EDs cannot be complacent



**Figure 2.** Probability of antibiotic administration within 4 hours versus ED volume. Scatter plot of raw proportion of pneumonia patients who received antibiotics within 4 hours versus number of ED patients at their arrival (points). The diameter of the data point is proportional to the square root of the number of patients represented. The line represents the fitted probability of receiving antibiotics within 4 hours from a univariate linear logistic regression model using number of ED patients at arrival. The equation for the fitted probability of receiving antibiotics within 4 hours is  $probability = 1 / (1 + \exp(- (1.3724 - 0.0368 \times \text{total number of patients in the ED at community-acquired pneumonia patient's arrival})))$ . Percent ED bed capacity is based on our 29-bed capacity. Note that although this is a logistic curve, it looks nearly linear because only a limited range of fitted probabilities is represented. The plot starts at 3 patients because no community-acquired pneumonia patients arrived when the ED volume was less than 3. Patients presenting at both extremes of ED volume are binned because few community-acquired pneumonia patients arrived with these ED volumes. Their data points are positioned at the midpoint of the “binning” interval. CAP, community-acquired pneumonia.

about their ability to meet benchmarks when things are “slow.”

Emergency physicians believe crowding has contributed to delayed diagnoses, treatment delays, reduced quality of care, and poor patient outcomes.<sup>10,11</sup> ED crowding has been postulated as contributing to delayed identification and treatment of time-sensitive conditions such as acute myocardial infarction, acute stroke, acute surgical emergencies, and severe sepsis, and perhaps leading to potentially avoidable mortality.<sup>14,24</sup> However, few studies have demonstrated the effects of ED crowding on quality of care. Schull et al<sup>13</sup> conducted a retrospective observational study to determine the effect of ED crowding, as measured by ambulance diversion status, on out-of-hospital delays for cardiac patients. They showed that increased hospital ambulance diversion status resulted in delays in EMS transport time and total out-of-hospital time. In

another retrospective observational study, Schull et al<sup>12</sup> demonstrated that ED crowding, measured by ambulance diversion status of local hospital networks, is associated with increased median door-to-needle times for patients with suspected acute myocardial infarctions. Hwang et al<sup>15</sup> found that an ED census greater than 120% of bed capacity was significantly associated with lower likelihood of documentation of pain assessment and longer times to pain assessment. In a modified case-crossover study conducted at our institution, Polevoi et al<sup>22</sup> showed an association between total number of patients exceeding maximum ED bed capacity and the rate of patients who left without being seen. This was most significant when ED capacity exceeded 140%. Hobbs et al<sup>23</sup> also demonstrated an association between higher ED volume and the rate of patients who left without being seen. These studies did not address patient outcomes, but other studies indicate that patients who leave without being seen may have significant medical problems.<sup>25</sup> Finally, Pines et al<sup>16</sup> reviewed data from 24 academic EDs and demonstrated an association between administrative measures of ED crowding (increased overall ED length of stay and length of stay for admitted patients, radiograph turnaround times, and left-without-being-seen rate) and a decrease in the proportion of community-acquired pneumonia patients receiving antibiotics within 4 hours.

Even when the volume of patients does not exceed the number of ED beds, the simultaneous arrival of patients requiring time-sensitive treatments can be associated with lower quality of care. This may be because it is not so much the numbers of patients but their resource utilization that can affect care.<sup>14,26</sup> Fishman et al<sup>14</sup> showed that the concurrent presence of a trauma activation patient resulted in increased incidence of 30-day adverse cardiovascular events for patients with potential acute coronary syndromes. The slightly greater effect of admitted versus discharged patients found in our study also suggests an impact of high resource users that may not be reflected in sheer numbers. This effect may be true for some clinical entities and not others or may be institution dependent. Chen et al<sup>27</sup> showed that the concurrent presence of a trauma alert patient does not delay CT imaging of patients with potential stroke.

The group of “ED patients ultimately requiring admission” in our study is not synonymous with boarding of admitted patients. The database from which this number was derived identifies patients by their final disposition. Therefore, the volume of “admitted” patients in the department would include patients who arrived simultaneously with a community-acquired pneumonia patient and who had not yet been treated by a physician, patients in the middle of their evaluation, and boarded admissions. Regardless of the timing, however, these patients would represent those requiring more complex care. Further work is being done to try to identify the impact of “boarders” per se.

Although a 4% decrease in the odds of receiving antibiotics for an additional patient may seem small, the cumulative effect

could result in a substantial impact on the ability to deliver quality of care. As our analysis demonstrated, in an ED with 29 beds and 30 patients present, the odds of timely antibiotic delivery are reduced to 55%. Because these numbers were derived in a single ED, the actual size of the impact per additional patient may be different in other institutions.

Considerable controversy exists about the appropriateness of the TJC/CMS core measures pneumonia guidelines, particularly with respect to the 4-hour antibiotic benchmark.<sup>28-32</sup> No one would argue that delaying antibiotics for a patient with community-acquired pneumonia is beneficial; however, it remains to be seen whether adhering to the 4-hour antibiotic administration benchmark will provide a mortality benefit in the general ED population similar to that observed in the study of Medicare patients.<sup>18</sup> Regardless of the controversy surrounding this core measure, the findings of our study are illustrative of the impact of an increasing number of ED patients on time-sensitive processes of care.

### In Retrospect

We would have liked to further subcategorize the “patients present on arrival of the community-acquired pneumonia patient” by whether or not the additional patients were already admitted to the hospital but awaiting an inpatient bed (“boarders”) because this is a portion of the ED population that could be placed elsewhere, with appropriate hospital planning. However, our database at the time of the study did not contain this information, and we are working on it now to be able to do such an analysis. As noted in the Limitations section, our analysis could have been more sensitive had we looked at the actual time of antibiotic administration rather than the dichotomous outcome. Finally, it would be interesting to see whether provider characteristics play any role with respect to the impact of crowding, a finding that was previously noted to affect the rate of patients leaving without being seen at our institution.<sup>22</sup>

In summary, time to antibiotic administration for community-acquired pneumonia patients is negatively affected by a higher ED volume, and this effect may occur below ED maximal capacity. EDs and hospital administrators need to be aware of the impact that ED volume has on meeting quality-of-care measures.

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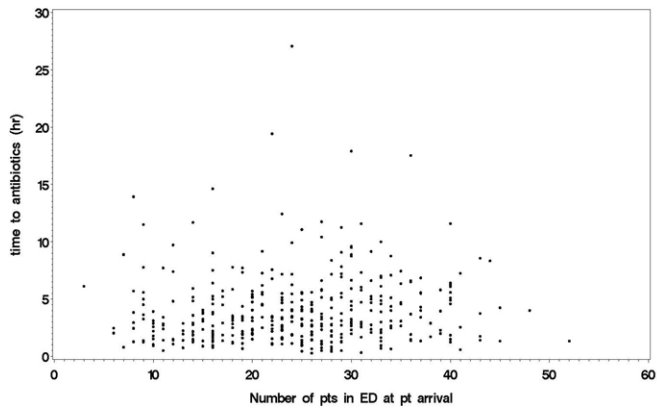
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## REFERENCES

- Trzeciak S, Rivers EP. Emergency department overcrowding in the United States: an emerging threat to patient safety and public health. *Emerg Med J.* 2003;20:402-405.
- Gibbs N. Do you want to die? The crisis in emergency care is taking its toll on doctors, nurses, and patients. *Time.* May 28, 1990:58-65.
- Spiegel C, Wielawski I. Two investigations set on overcrowding of emergency room (California State and Los Angeles County investigations of conditions at County-USC Medical Center). *Los Angeles Times.* 1991;111:B3.
- Doherty L. Hospitals turn ambulances away. *Sydney Morning Herald.* November 3, 1998; 3.
- Will G. The trauma in trauma care. *Newsweek.* March 12, 1990: 98.
- Tye L. Officials offer little hope for emergency room diversion. *Boston Globe.* November 14, 2000;Metro/Region section:A12.
- Shute N, Marcus MB. Code blue: crisis in the ER. *US News and World Report.* September 10, 2001:54-61, 64, 66.
- Appleby J. ER conditions critical. *USA Today.* February 4, 2000: News Section:A, 1.
- Joint Commission International Center for Patient Safety. Sentinel event alert, Issue 26, 2002. Available at: <http://www.jcipatientsafety.org/14745/>. Accessed March 16, 2006.
- Lewin Group (for the American Hospital Association). *Emergency Department Overload: A Growing Crisis. The Results of the American Hospital Association Survey of Emergency Department (ED) and Hospital Capacity.* Falls Church, VA: American Hospital Association; 2002.
- Derlet RW, Richards JR. Overcrowding in the nation's emergency departments: complex causes and disturbing effects. *Ann Emerg Med.* 2000;35:63-68.
- Schull MJ, Vermeulen M, Slaughter G, et al. Emergency department crowding and thrombolysis delays in acute myocardial infarction. *Ann Emerg Med.* 2004;44:577-585.
- Schull MJ, Morrison LJ, Vermeulen M, et al. Emergency department overcrowding and ambulance transport delays for patients with chest pain. *CMAJ.* 2003;168:277-283.
- Fishman PE, Shofer FS, Robey JL, et al. The impact of trauma activations on the care of emergency department patients with potential acute coronary syndromes. *Ann Emerg Med.* 2006;48: 347-353.
- Hwang U, Richardson LD, Sonuyi TO, et al. 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.
- Pines JM, Hollander JE, Localio AR, et al. 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.
- Elixhauser A, Owens P. Reasons for being admitted to the hospital through the emergency department, 2003. HCUP Statistical brief #2. February 2006. Rockville, MD: Agency for Healthcare Research and Quality. Available at: <http://www.hcup-us.ahrq.gov/reports/statbriefs/sb2.pdf>. Accessed May 4, 2006.
- Houck P, Bratzler DW, Nsa W, et al. Timing of antibiotic administration and outcomes for Medicare patients hospitalized with community-acquired pneumonia. *Arch Intern Med.* 2004;164: 637-644.
- Joint Commission on Accreditation of Healthcare Organizations. Pneumonia measure information form v1.05 [Joint Commission on Accreditation of Healthcare Organizations Web site]. Available at: [http://www.jointcommission.org/NR/rdonlyres/2F0D758A-13AD-4A8E-9D01-330325A25F3F/0/2zb\\_PN5ab.pdf](http://www.jointcommission.org/NR/rdonlyres/2F0D758A-13AD-4A8E-9D01-330325A25F3F/0/2zb_PN5ab.pdf). Accessed July 10, 2006.
- Eckstein M, Chan LS. The effect of emergency department crowding on paramedic ambulance availability. *Ann Emerg Med.* 2004;43:100-105.
- Andrulis DP, Kellermann A, Hintz EA, et al. Emergency departments and crowding in United States teaching hospitals. *Ann Emerg Med.* 1991;20:980-986.
- Polevoi SK, Quinn JV, Kramer NR. Factors associated with patients who leave without being seen. *Acad Emerg Med.* 2005; 12:232-236.
- Hobbs D, Kunzman SC, Tandberg D, et al. Hospital factors associated with emergency center patients leaving without being seen. *Am J Emerg Med.* 2000;18:767-772.
- Derlet RW. Overcrowding in emergency departments: increased demand and decreased capacity. *Ann Emerg Med.* 2002;39:430-432.
- Bindman AB, Grumbach K, Keane D, et al. Consequences of queuing for care at a public hospital emergency department. *JAMA.* 1991;266:1091-1096.
- Schull MJ, Kiss A, Szalia JP. The effect of low-complexity patients on emergency department waiting times. *Ann Emerg Med.* 2007; 49:257-264.
- Chen EH, Mills AM, Lee BY, et al. The impact of a concurrent trauma alert evaluation on time to head computed tomography in patients with suspected stroke. *Acad Emerg Med.* 2006;13:349-352.
- Moran GJ, Abrahamian FM. Blood cultures for community-acquired pneumonia (can we hit the target without a shotgun?). *Ann Emerg Med.* 2005;46:407-408.
- Walls RM, Resnick J. The Joint Commission on Accreditation of Healthcare Organizations and Center for Medicare and Medicaid Services community-acquired pneumonia initiative (what went wrong?). *Ann Emerg Med.* 2005;46:409-411.
- Fee C, Weber E, Sharpe BA, et al. JCAHO/CMS core measures for community-acquired pneumonia [letter]. *Ann Emerg Med.* 2006;47:505.
- Walls RM, Resnick JB. JCAHO/CMS core measures for community-acquired pneumonia (reply to Fee, #2005-1075) [letter]. *Ann Emerg Med.* 2006;47:506.
- Fee C, Weber EJ. Identification of 90% of patients ultimately diagnosed with community-acquired pneumonia within four hours of emergency department arrival may not be feasible. *Ann Emerg Med.* 2007;41:561-563.

**Editor's Capsule Summary:** *What is already known on this topic:* Emergency department (ED) crowding has been associated with adverse patient care events and postulated to adversely affect quality. It is unknown whether quality is affected at patient volumes less than capacity. *What question this study addressed:* Does ED patient volume affect compliance with the 4-hour target for initial antibiotic administration in individuals with community-acquired pneumonia? *What this study adds to our knowledge:* Compliance with the 4-hour target decreased as patient numbers increased, even at volumes less than maximal ED patient capacity. *How this might change clinical practice:* Methods to facilitate compliance with quality measures should include the impact of ED patient volume.



**Figure E1.** Scatterplot of time to antibiotic administration for pneumonia patients versus number of ED patients at their arrival (points).