The Association between Emergency Department Crowding and Hospital Performance on Antibiotic Timing for Pneumonia and Percutaneous Intervention for Myocardial Infarction

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Abstract

Background: Antibiotics within four hours of arrival for patients with pneumonia and percutaneous intervention (PCI) within two hours for patients with acute myocardial infarction (AMI) are standard measures of emergency department (ED) quality.

Objectives: To assess the institutional-level association between measures of ED crowding and process measures for pneumonia and AMI.

Methods: The authors used summary data from 24 academic hospitals in the University Health Consortium. Analysis included the 2004 ED cycle time survey and performance data from January to December 2004 regarding the Joint Commission for Accreditation of Healthcare Organizations' PN-5b (initial antibiotic administration within four hours) for pneumonia and AMI-8a (PCI received within 120 minutes). Spearman correlation coefficients were used to determine associations between crowding and performance measures.

Results: Across all institutions, 59% (range 43%–77%) of pneumonia patients received antibiotics within four hours, and 57% (range 22%–95%) of AMI patients received PCI within two hours. An increase in overall ED length of stay (−0.44, $p = 0.04$) and for admitted patients (−0.37, $p = 0.08$) was associated with a decrease in the proportion of pneumonia patients receiving antibiotics within four hours. An increase in chest x-ray turnaround time (−0.83, $p < 0.001$) and an increase in the left-without-being-seen rate (−0.51, $p = 0.01$) were also associated with a decrease in the proportion of pneumonia patients receiving antibiotics within four hours. No measures of crowding exhibited an association with time to PCI for AMI patients.

Conclusions: Administrative measures of ED crowding showed an association with poorer performance on pneumonia quality of care measures but not with AMI quality of care measures. Hospitals might consider improving ED throughput, reducing boarding times for admitted patients, and reducing chest x-ray turnaround times to improve pneumonia care.

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Emergency department (ED) crowding is a national problem.[1,2] It is estimated that about a third of EDs experience crowding on a daily basis.[3] ED crowding has been associated with lower community socioeconomic status as well as reduced levels of physician and nursing staff coverage.[4] Although studies have clearly demonstrated that ED crowding reduces patient and ED staff satisfaction,[5,6] there is limited evidence that crowding objectively affects overall quality of care.[7,8] Moreover, there are few controlled studies that demonstrate that crowding affects actual patient outcomes or

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standard measures of quality as defined by the Joint Commission for Accreditation for Healthcare Organizations (JCAHO), the Centers for Medicare & Medicaid Services (CMS), or the Institute for Healthcare Improvement. Finally, although there are many available measures of ED crowding, identifying a linkage between specific measures of ED crowding and quality of care would help identify those measures that are most useful for continued monitoring.

Quality of care is commonly defined by the performance of process measures that have been clearly shown to reduce patient morbidity and mortality for specific illnesses.[9] Because the ED stay is often a relatively small percentage of the overall time of an inpatient visit, it is difficult to directly draw a causal relationship between ED crowding and mortality. Instead, more proximate care measures that are tied to mortality may better illustrate the crowding/quality relationship. One notable study by Schull et al. drew a link between ambulance diversion, a surrogate measure of crowding, and timing of thrombolysis in a hospital system for patients with acute myocardial infarction.[10] In this study, high hospital network traffic was associated with a small, but statistically significant, reduction in door-to-needle times for patients with acute myocardial infarction (AMI).

As of 2005, CMS and JCAHO have published eight core quality measures that affect all EDs.[11] Two of the eight core measures, antibiotic administration within four hours of hospital arrival for patients with pneumonia, and percutaneous intervention (PCI) within two hours of arrival for patients with AMI, require rapid mobilization of resources and have been associated with improved mortality.[12–14] Because of the relatively short time window allowed for time to PCI and time to antibiotics for pneumonia, as well as the variability among these measures, we thought these processes might be adversely affected when the ED is crowded.

Our objective was to assess the association between hospital-level measures of ED crowding and antibiotic timing in pneumonia or time to PCI in acute myocardial infarction. We hypothesized that selected measures of crowding, particularly those that affect patient flow, would be negatively associated with hospital time to antibiotics and time to PCI.

METHODS

Study Design

We performed a cross-sectional study linking two existing data sources: the University Health Consortium (UHC), a 2004 survey on ED cycle times, and data from the Health and Human Services on mandatory reported performance measures in 2004, specifically 1) the percentage of patients admitted with pneumonia who received antibiotics in four hours from hospital arrival and, 2) the percentage of patients with ST-segment elevation or new left bundle branch block AMI who received PCI within two hours of hospital arrival. This study was presented to the institutional review board at the University of Pennsylvania and determined to be exempt from institutional review board review.

Data Sources

The UHC administers the ED cycle time survey every two years to their member hospitals. Survey participation was voluntary and the 2004 cycle time survey was administered to approximately 60 member hospitals from June to September. Surveys were filled out by the ED administrative director. Twenty-four hospitals responded to the 2004 survey. Included in the UHC survey were specific information on ED volume, staffing levels (physician and nonphysician full-time equivalents), lengths of stay for admitted and discharged patients, intensive care unit admission rates, bed turnover rates, documentation levels, diversion hours, and turnaround times for laboratory studies and chest radiographs (CXR). ED lengths of stay (admitted, overall, and for discharged patients) represented the average value over the previous year. The diversion hours, ED visits, staffing, and treatment spaces represent actual values over the prior year. Cycle time measures, such as bed turnover rates and times to admission, were derived from survey participants based on a random sample of 30 individual patients at each institution. The turnaround time for CXR was also based on a random sample of 30 patients and is defined as the time from x-ray order to x-ray completion by the radiology technician; it does not include the time that it takes for a radiologist to provide an interpretation.

Permission was received from the UHC to use this dataset for analysis. We linked the results of this survey with data regarding individual hospital performance on antibiotic timing for pneumonia and PCI timing in AMI aggregate data that were made public by CMS. The data from the UHC survey and the data from the performance measures are reported for the same time period (2004).

The performance measures were derived from the January 2004 to December 2004 reported performance on JCAHO AMI-8a (PCI received within 120 minutes of hospital arrival) and PN-5b (initial antibiotic administration within four hours of hospital arrival), for the 24 hospitals that participated in the UHC survey. These data are reported every three months by nongovernment acute care hospitals in the U.S. Hospitals are not required to report data, but they receive an incentive payment from CMS according to Section 501(b) of the Medicare Prescription Drug, Improvement, and Modernization Act of 2003 for reporting data. Charts are screened by the individual hospitals for inclusion using ICD-9 criteria and then chosen for inclusion using chart review. Data are compiled by the nonprofit company Quality Net Exchange (www.qnetexchange.org), which performs periodic data audits on the charts to ensure data quality. These data are available publicly (www.hospitalcompare.hhs.gov) and were accessed in November 2005. As part of this database, hospitals report their performance on measures AMI-8a and PN-5b. For patients with acute myocardial infarction, inclusion criteria are patients with an ICD-9 principal diagnosis of acute myocardial infarction and an ICD-9 for PCI, along with ST segment elevation or new left bundle branch block on the electrocardiogram performed closest to hospital arrival, and PCI performed within the first 24 hours of arrival.[15] For pneumonia, included patients are those 18 years and older who are admitted with a working diagnosis of pneumonia and who received antibiotics within 36 hours of arrival. The data include both ED-evaluated patients and direct admissions. For reporting purposes, data excluded patients who were provided comfort measures only,

transferred from another acute care hospital, received antibiotics within the 24 hours prior to arrival, or were involved in clinical trials.[16]

Data Analysis

All analyses were conducted at the hospital level. Summary statistics across all crowding and performance measures are reported with sample means and ranges. Spearman correlation coefficients were calculated to determine associations between hospital cycle times, staffing levels, and measures of crowding with the performance of four-hour antibiotic administration and performance of the two-hour time to PCI. Spearman coefficients range from −1 to +1 and provide a measure of how two variable correlated, with −1 being perfectly negatively correlated and +1 being perfectly positively correlated; *t* tests, chi-square tests and analysis of variance were used to determine differences between hospitals that responded to the survey and nonresponding hospitals. Stata 9.0 (College Station, TX, 2005) was used for all analyses. A p-value of ≤ 0.05 was considered significant.

RESULTS

Emergency Department Description

The mean number of ED visits for the 24 hospitals in the UHC survey was 50,537 per year (range 31,739–81,621), and mean number of treatment spaces was 38 (23–59). Average hospital-level ED length of stay (LOS) for admitted patients averaged 6.1 hours (3.5–11.1), and for discharged patients was 3.9 hours (2–4.9). The left-without-being-seen rate was 3.3% (0.6%–14.4%). Turnaround time (TAT) for CXR was 48 minutes (22–102). Other hospital characteristics and crowding measures are listed in Table 1.

Table 1
Administrative and Crowding Measures for 24 Academic Hospitals in the University Health Consortium Survey

Measures	*n**	Mean	Range
ED visits	22	50,538	31,739–81,621
Treatment spaces	24	37.9	23–59
Full-time physician FTE	24	29.1	9–82
Full-time non-physician FTEs	23	81.1	3–164
Left-without-being-seen	23	3.3%	0.6%–14.4%
Unscheduled 72-hour returns	21	3.1%	1%–5%
ED length of stay–overall	23	4.1 hrs	2.3–5.7
ED length of stay–admitted	24	6.1 hrs	3.5–11.1
ED length of stay–discharged	24	3.4 hrs	2–4.9
Admission rate	24	23.7%	14%–39%
Visits per bed	22	1,339	962–1,900
Turnaround time for CBC results	15	38.1 min	13–62
Turnaround time for CXR performance	11	48.3 min	22–102
ED diversion hours	17	407 hrs	0–2081
Registered nurse percentage (as percentage of non-MD FTE)	24	61.5%	48.7%–73.0%
Emergency medicine residency program	23	61.0%	

ED = emergency department; FTE = full time equivalent; CXR = chest x-ray; CBC = complete blood count; MD = physician.
* Denotes the number of hospitals out of 24 who reported the data.

Table 2
Joint Commission on Accreditation of Healthcare Organizations Core Measures Affecting 24 University Health Consortium Emergency Departments

	n	Mean (%)	Range
Acute myocardial infarction			
Aspirin at arrival (within 24 hrs)	24	97.2	93%–100%
Beta blockers at arrival (within 24 hrs)	24	93.3	82%–100%
Percutaneous intervention (within 2 hrs)	20	57.5	22%–95%
Thrombolytic administration (within 0.5 hr)*	0	N/A	N/A
Pneumonia			
Time to antibiotics (within 4 hrs)	24	58.8	43%–77%
Most appropriate initial antibiotic	21	77.7	58%–91%
Blood culture before first antibiotic	23	77.0	46%–94%
Oxygenation assessment	24	99.3	96%–100%

* Each hospital had less than three observations. Data are from January to December 2004; *n* is the number of hospitals reporting data.

Pneumonia Quality of Care

The hospital-level average performance on antibiotic administration for pneumonia care, which is defined as the percentage of patients with pneumonia who received antibiotics within four hours of hospital arrival, was 59% (range 43%–77%) (Table 2). Table 3 shows differences between hospitals that responded to the UHC survey compared with those that did not. Table 4 shows the association between potentially intervenable versus non-intervenable measures of ED crowding and performance on antibiotic timing and PCI timing. Figure 1 shows

Table 3
University Health Consortium 2004 Emergency Department (ED) Cycle Time Survey

	Respondents (*n* = 24)	Nonrespondents (*n* = 36)	p-value
Annual ED visits (mean)	50,538	62,951	0.04
Geographic region			0.12
Northeast	2 (8%)	12 (33%)	
Midwest	8 (33%)	8 (22%)	
South	9 (37%)	8 (22%)	
West	5 (21%)	8 (22%)	
ED residency Primary teaching site	16 (67%)	27 (75%)	0.48

Table 4
Associations of Emergency Department (ED) Crowding Measures with Antibiotic Timing for Pneumonia (4-hr Antibiotics) and Time to Percutaneous Intervention (2-hr PCI) for Myocardial Infarction

		Spearman Correlation Coefficient (r) and p-value	
	n	4-hr Antibiotics	2-hr PCI
Potentially intervenable crowding measures			
ED length of stay–overall	23	−0.44 (0.04)	0.36 (0.88)
ED length of stay–admitted	24	−0.37 (0.08)	0.01 (0.98)
ED length of stay–discharged	24	−0.63 (0.18)	−0.05 (0.85)
Turnaround time for CXR performance	11	−0.83 (0.001)	−0.35 (0.36)
Nondirectly intervenable crowding measures			
ED visits	22	−0.58 (0.004)	−0.01 (0.97)
Left-without-being-seen %	22	−0.51 (0.01)	−0.11 (0.67)
Unscheduled 72-hr returns	12	−0.10 (0.83)	0.08 (0.56)
Visits per bed	18	0.09 (0.70)	−0.23 (0.35)
ED diversion hours	17	−0.29 (0.26)	−0.01 (0.97)

n = number of observations, CXR = chest x-ray.

hospital-level scatterplots of crowding measures and performance measures. An increase in overall ED LOS (−0.44, p = 0.04), and in the LOS for admitted patients (−0.37, p = 0.08) was associated with a trend toward a decrease in the percentage of patients receiving antibiotics within four hours for patients with pneumonia, whereas increased ED LOS for discharged patients was not significantly associated with the performance measure (p = 0.18). An increase in TAT for CXR was associated with a significant decrease in the percentage of patients receiving antibiotics within four hours (p < 0.001). An increase in the percentage of patients who left without being seen was significantly associated with a significant decrease in the percentage of patients receiving antibiotics within four hours (p = 0.01).

Myocardial Infarction Quality of Care

The hospital-level average percentage of patients who received PCI within two hours of arrival was 57% (range 22%–95%). There were no ED crowding measures that were significantly associated with the percentage of patients with AMI who received PCI within two hours.

DISCUSSION

In this study, poorer performance on antibiotic timing for patients with pneumonia was significantly associated with measures of ED crowding, but PCI timing for patients with acute myocardial infarction was not associated with crowding. Schull and colleagues found a significant dose-dependent difference between low-to-medium and high network traffic as measured by ambulance diversion and time to thrombolysis for AMI; however, the absolute difference in time to thrombolysis was relatively small—about 5 minutes.[10] Given our study results, it may be that mobilization of resources to treat patients with AMI may be much less dependent on the state of operational crowding in the ED. When patients

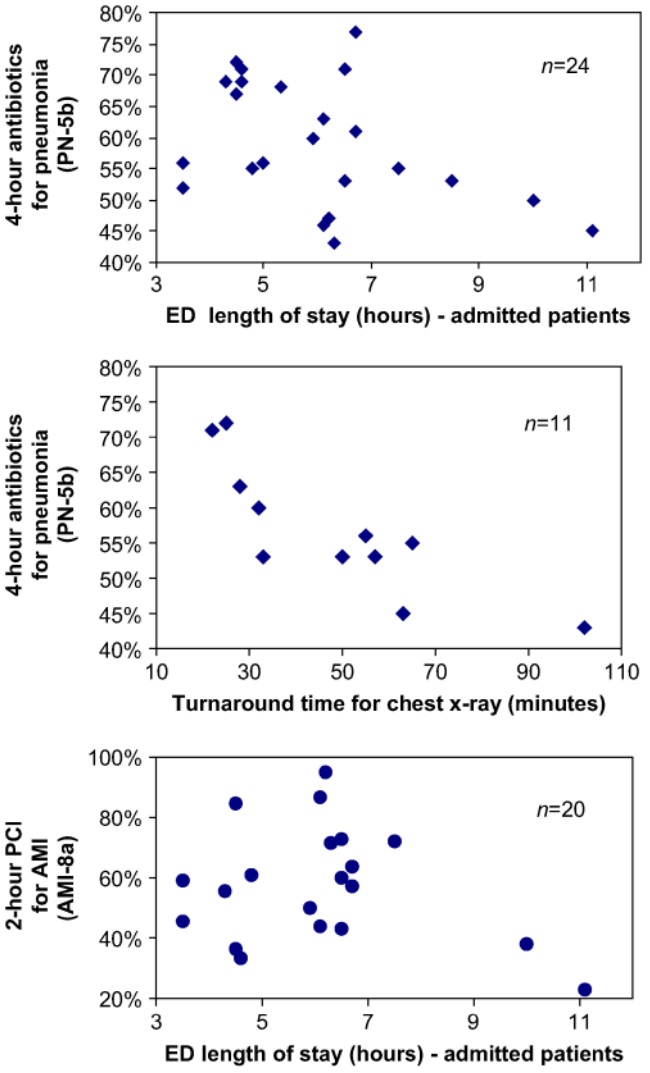

Figure 1. Hospital-level scatterplots of crowding measures and performance measures.

arrive at an ED with a clear diagnosis of ST-segment elevation myocardial infarction that requires an immediate life-saving intervention such as PCI, all available and sometimes unavailable resources rapidly shift to treat the patient.

By contrast, antibiotic timing in pneumonia might be much more sensitive to operational changes and crowding in the ED. Many process steps are required to diagnose pneumonia, whereas the typical diagnosis of ST-segment elevation AMI involves only the performance and interpretation of an electrocardiogram (ECG). Patients with pneumonia, particularly elders,[17] can present with atypical symptoms and may not present with a clear diagnosis. A diagnosis of pneumonia may be found after a wide search for a diagnosis, which may include an ED CXR, chest CT, or abdominal CT, and may continue even after the patient is admitted to the hospital.

When the ED is crowded, process times tend to increase, and queues for scarce resources lengthen. The ability of providers in the ED to deliver appropriate and timely care for patients without apparent signs of a time-sensitive illness can be compromised. Fishman and

colleagues showed that the presence of trauma alert activations significantly affect the mortality rate for patients treated concurrently with suspected acute coronary syndrome.[18] In patients with suspected acute coronary syndrome (in contrast to AMI), ED evaluation involves multiple steps, often consisting of serial ECGs, laboratory testing including cardiac markers, chest radiography, hospital admission, and occasionally cardiac stress testing.

The variability in AMI care may be more dependent on the availability of the cardiac catheterization laboratory or the ability to administer immediate thrombolytics when PCI is unavailable. Most of the institutions in this study had three or fewer thrombolysis events in 2004, indicating that failure to perform PCI at these academic hospitals may have been a function of a failure to quickly mobilize the cardiac catheterization laboratory, or a failure to recognize early that the patient needed urgent revascularization.

It is notable that the overall success rate of antibiotic timing in pneumonia and PCI timing in AMI are both relatively low, at less than 60%. The best-performing hospital was 77% on antibiotic timing for pneumonia, indicating either that the best-performing hospital is delivering suboptimal care, or that the optimal target for this performance measure is less than 100%, because some patients cannot reasonably be diagnosed and treated within four hours. Certain patients may still be at risk for delayed diagnosis and treatment, even in the best of circumstances (i.e., no crowding). In particular, patients who present in nonobvious ways or need multiple steps to diagnose (CT scans or serial CXRs) may be at risk for delayed treatment because diagnostic pathways require time intervals longer than the times allowed by JCAHO and CMS.

By contrast, the best-performing hospital in this study achieved 95% success on PCI timing. This suggests that this level of quality may be more attainable for AMI. This assumes, however, that ST-segment elevation or new left bundle branch block is present on the first ECG. This is not always the case, as they may develop over the course of the ED stay. Other JCAHO measures, such as aspirin and beta-blockers at arrival for AMI, and oxygenation assessment for pneumonia, were all close to 100% for these hospitals in 2004. By comparison, blood cultures before first antibiotics and selection of appropriate initial antibiotics for pneumonia only occurred a little more than 75% of the time. Whether these measures are considered the standard of care is controversial,[19] but they nonetheless may represent areas for quality improvement.

In 2006 or soon thereafter, CMS and JCAHO will tie antibiotic timing to reimbursement with relatively wide inclusion criteria. After the implementation of so-called *pay for performance*, antibiotic timing might not continue to be an accurate measure of crowding. The financial incentives arising from pay for performance might benefit patients with pneumonia by shortening time to antibiotic administration; however, they might create a potential risk to patients, or promote antibiotic resistance patterns in communities, if they lead to inappropriate use of antibiotics as hospitals try to improve their rates or reach 100% on this measure to maximize reimbursement.

In our opinion, the two crowding measures that we linked to quality of care for pneumonia, turnaround time for CXRs and length of stay for admitted patients, are most directly amenable to process changes. It makes sense that EDs that experience radiology delays as defined by turnaround time for CXRs would experience poorer performance on the ability to rapidly diagnose and treat pneumonia. Poorer pneumonia care was associated with ED length of stay for admitted patients, even after controlling for the effect of radiology delays.

Boarding of inpatients is a common complaint in EDs and is a primary cause of crowding because of some hospitals' inability to adequately respond to fluctuations in demand for inpatient beds.[20] The ED length of stay for admitted patients is a direct indicator of the ability of an individual hospital to prepare inpatient beds for ED patients. It is an indicator of a hospital's administrative efficiency and ability to cope with the demand for rapid surges in capacity. Taken together in multivariable analysis, ED LOS for admitted patients and turnaround time for CXR are two factors that both individually and combined have a high level of explanatory power for variability in pneumonia quality of care, and they are obvious targets for future interventions. Left-without-being-seen rates were also associated with poorer pneumonia care; however, left-without-being-seen rates serve only as a proxy measure for crowding and are not amenable to direct action.[21]

One option is for JCAHO and CMS to consider measuring overall ED length of stay for admitted patients as a reportable quality measure for hospitals. This measure of performance might motivate hospitals to increase the capacity of available beds for ED patients, reduce turnaround times for bed turnover, and reduce the delay associated with transferring patients to ready inpatient beds. It might also provide a disincentive for the deprioritization of low-margin ED patients over those admitted for high-margin procedures such as cardiac, orthopedic, and neurosurgical procedures. Many solutions have been proposed for this problem, such as the *one-bed ahead* strategy, by which a bed is always available for patients from the emergency department.[22] Other solutions that have been proposed include transferring patients from the ED to inpatient halls until beds are available, to provide motivation for the inpatient staff to turn over beds.[23]

LIMITATIONS

As with any study of ecological associations, this study relies on aggregate data on hospital performance measures and cannot make direct inferences at the individual case level about crowding and hospital performance. Moreover, we could not therefore assess potential confounding by patient-level factors associated with the crowding measures of interest. Also, because of the survey nature of the UHC data, there may be misclassification bias if cycle times were incorrectly reported. There was no independent validation of these data. Another concern is the potential for limited generalizability and selection bias, because only academic medical centers are UHC members (60), and the UHC members are a small fraction of all academic medical centers as represented by the Council of Teaching Hospitals and Health Systems. In addition, our overall sample size was small,

and statistical power for detecting small but important associations was limited.

CONCLUSIONS

Antibiotic timing for patients with pneumonia was significantly associated with ED crowding measures, whereas timing of care for patients with ST-segment elevation AMI was not. As antibiotic timing for pneumonia becomes an important measure for reimbursement, hospitals should consider the potential of improved turnaround times for chest radiographs, improving ED throughput, and reducing boarding times in the ED to achieve the goal of timely antibiotic treatment for pneumonia.

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