Emergency Department Crowding and Time to Care in Patients With Acute Stroke

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Background and Purpose—Emergency department (ED) crowding occurs when demands for ED care exceed the supply of available resources. Prior studies have shown that ED crowding is associated with a delay in provision of critical ED services, but the impact of ED crowding on acute stroke care has not been extensively studied.

Methods—We conducted a retrospective study of patients who presented to the ED with acute stroke symptoms (ischemic stroke, transient ischemic attack, intracerebral hemorrhage) at 2 hospitals. All patients with active stroke symptoms who presented within 3 hours were included and a random sample of patients with symptoms >3 hours was used for comparison. The association between ED crowding measures (waiting room number, ED occupancy, number of admitted patients, and total patient hours) and time to head CT order, completion, and interpretation, and time to administration of thrombolysis was determined.

Results—Of 253 patients presenting with acute stroke symptoms ≤3 hours from symptom onset, 52 (21%) received thrombolysis. A random comparison group of 253 patients with symptoms >3 hours was identified. There was no significant association between ED crowding and delays in CT timing or thrombolysis in patients with symptoms ≤3 hours. Several measures of ED crowding were associated with prolonged times to CT order and completion in patients with symptoms >3 hours.

Conclusions—ED crowding was not associated with care delays in thrombolysis-eligible patients with stroke. However, those with symptoms >3 hours do experience CT delays at higher levels of ED crowding. **(*Stroke*. 2011;42:1074-1080.)**

Key Words: crowing ■ emergency ■ overcrowding ■ quality ■ stroke ■ time to care

Treatment is time-sensitive for patients with ischemic stroke presenting within the first few hours after symptom onset. Along with supportive care, primary goals of emergency department (ED) care include the rapid assessment of eligibility for and administration of thrombolytic therapy.[1] Determination of thrombolysis eligibility involves several steps, including the performance and interpretation of head CT, history and physical examination, assessment of inclusion/exclusion criteria, and rapid coordination of ED physicians, neurologists, and radiologists. Current guidelines for adults with ischemic stroke from the American Stroke Association and American Heart Association recommend that CT completion occur within 25 minutes, CT interpretation within 45 minutes, and administration of intravenous tissue plasminogen activator within 60 minutes in eligible patients.[2]

Rapid coordination of ED services for patients with stroke is challenging because of competing demands in the ED, delays in specialist availability, prehospital transport, and recognition.[3–7] ED crowding occurs when demands for care exceed resource supply, and this may play a role in delays in stroke care.[8] ED crowding delays critical ED services, including time to antibiotics in pneumonia, time to analgesia in severe pain, and time to CT readings in abdominal pain.[9–13] However, ED crowding has less dramatic effects on patients identified early as severely ill such as in acute myocardial infarction.[14] Patients with stroke eligible for thrombolysis represent a group in which ED care is time-critical and rapid mobilization of resources should be prioritized. The presence of a concurrent trauma alert activation (a competing resource) was not associated with delays in CT for patients with stroke.[15] No studies have directly tested the association between ED crowding and care timing in acute stroke. We studied this relationship in patients who presented with active symptoms <3 hours from symptom onset and those presenting ≥3 hours in 2 hospitals.

Methods

A retrospective study of patients with stroke was performed in 2 urban hospitals (January 1, 2005, to July 30, 2008). One hospital was

Received July 15, 2010; final revision received September 24, 2010; accepted October 13, 2010.

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***Stroke* is available at http://stroke.ahajournals.org** **DOI: 10.1161/STROKEAHA.110.586610**

Table 1. Demographic Characteristics of Patients Presenting to the ED With Symptoms of Stroke to 2 Hospitals (n=506)

Variable	≤3 Hours (n=253)	>3 Hours (n=253)
Age, years, mean±SD	64±17	65±15
Female, no. (%)	131 (52%)	150 (59%)
Black, no. (%)	180 (71%)	192 (76%)
ED ICD-9 diagnosis, no. (%)		
Ischemic	179 (71%)	145 (57%)
Intracerebral hemorrhage	40 (16%)	24 (9%)
Transient Ischemic Attack	34 (13%)	84 (33%)
GCS, mean±SD	13.6±2.8	14.2±2.4
mNIHSS, median (IQR)	5 (1–10)	1 (0–4)
EMS arrival	170 (67%)	104 (41%)
Triage level		
1 (most urgent)	158 (63%)	70 (28%)
2	77 (30%)	144 (57%)
3	15 (6%)	39 (15%)
4 (least urgent)	3 (1%)	0
Intubated	24 (10%)	12 (5%)
Comorbid conditions		
Cancer	29 (12%)	39 (15%)
Congestive heart failure	58 (23%)	49 (19%)
Hypertension	200 (79%)	210 (83%)
Diabetes	80 (32%)	88 (35%)
Prior stroke	64 (25%)	67 (26%)
Triage to CT order, minutes, median (IQR)	7 (2–21)	38 (10–83)
Triage to CT completion, minutes, median (IQR)	30 (18–59)	102 (48–164)
CT completion in 25 minutes	109 (43%)	28 (11%)
Triage to CT interpretation, minutes, median (IQR)	76 (47–122)	151 (89–235)
CT interpretation in 45 minutes, no. (%)	60 (24%)	16 (6%)
Patients receiving tPA, no.	52	0
Triage to tPA, minutes, median (IQR)	73 (48–101)	. . .
tPA within 60 minutes	21 (40%)	. . .

ICD indicates International Classification of Diseases, 9th Revision; GCS, Glasgow Coma Scale; EMS, emergency medical services; tPA, tissue plasminogen activator.

a comprehensive stroke center with a stroke team (24-hour availability) with 57 000 annual ED visits.[16] When patients with stroke are identified as thrombolysis-eligible (arriving with active symptoms and within 3 hours of symptom onset), ED physicians immediately page the stroke team who typically responds within minutes. The CT scanner is adjacent to the ED on the same floor. The second hospital was an affiliated community ED with 30 000 annual ED visits that was not a stroke center and does not have either in-house neurologists or a stroke team. The stroke team from the academic hospital can be consulted by phone, but the stroke team does not come to the ED. The CT scanner is 3 floors above the ED requiring elevator transport and a CT is standard care for patients with stroke symptoms. Both hospitals have in-house CT technicians (24-hour availability) and patients with stroke who arrived during the study period after 3 hours from symptom onset or without active symptoms were not explicitly prioritized for a CT scan. Both hospitals have cardiac catheterization laboratories to treat patients with ST-segment elevation myocardial infarction and the academic site is a Level I trauma center.

Table 2. Crowding Levels That Patients With Stroke Were Exposed to in 2 Hospital EDs (n=506)

Average Crowding Scores	Academic Tertiary Care Hospital (n=398)	Community Teaching Hospital (n=108)
Admitted no., patients, median (IQR)	10 (7–13)	5 (3–6)
Occupancy, median percent (IQR)	78% (63–85%)	79% (58–89%)
Patient-hours, median (IQR)	129 (89–168)	48 (29–75.5)
Waiting room, no. of patients, median (IQR)	11 (6–18)	4 (0–7)

Table 3. Timing to CT and Compliance With ASA/AHA Standardized Measures in Patients With Stroke Presenting to 2 Hospitals (n=506)

Symptom Onset ≤3 Hours (n=253)	Academic Tertiary Care Hospital (n=199)	Community Teaching Hospital (n=54)
Time to CT order, minutes, median (IQR)	7 (2–17)	8 (2–39)
Time to CT completion, minutes, median (IQR)	26 (15–51)	60 (32–109)
Time to CT read, minutes, median (IQR)	67 (45–111)	109 (72–179)
CT completed ≤25 minutes, no. (%)	96 (48%)	13 (24%)
CT read ≤45 minutes, no. (%)	51 (26%)	9 (17%)
Time to CT order, minutes, median (IQR)	35 (9–79)	52 (21–95)
Time to CT completion, minutes, median (IQR)	91 (38–164)	111 (74–174)
Time to CT read, minutes, median (IQR)	142 (73–236)	181 (123–232)
Patients Who Received Thrombolysis (n=52)	**Academic Tertiary Care Hospital (n=49)**	**Community Teaching Hospital (n=3)**
Thrombolysis ≤60 minutes, no. (%)	20 (41%)	1 (33%)

ASA/AHA indicates American Stroke Association/American Heart Association.

Patients were identified through a medical records search. A query was constructed for admitted ED patients with an ED principle diagnosis of ischemic stroke, intracranial hemorrhage, or transient ischemic attack (International Classification of Diseases, 9th Revision 433, 434, 431, 435.9, 436). A list of thrombolytic-treated patients was obtained from the academic center stroke registry to determine if all thrombolytic patients were identified.

Physician and nursing notes in the ED record were reviewed by a trained abstractor (senior-level ED resident) for inclusion. An initial cohort was constructed of patients with active symptoms and onset <3 hours from ED arrival. Patients were excluded if symptom onset was indeterminate, patients were transferred, or trauma was suspected. A second cohort with symptom onset ≥3 hours was used as a comparator that was chosen at random from all patients with symptom onset ≥3 hours. An equal number of patients was chosen for the comparison group in each hospital to permit similar power to test study hypotheses.

Arrival time was obtained from the earliest ED registration: either the triage time or intake time (both automatically time-stamped). CT order time, completion time, read time, and time of administration of reperfusion therapy were also determined from chart review. CT order time is time-stamped when ordered by a physician. CT completion and read times were obtained from time stamps on radiology documentation. Both values are reliable and were available in 100% of records. Time of reperfusion therapy was extracted from

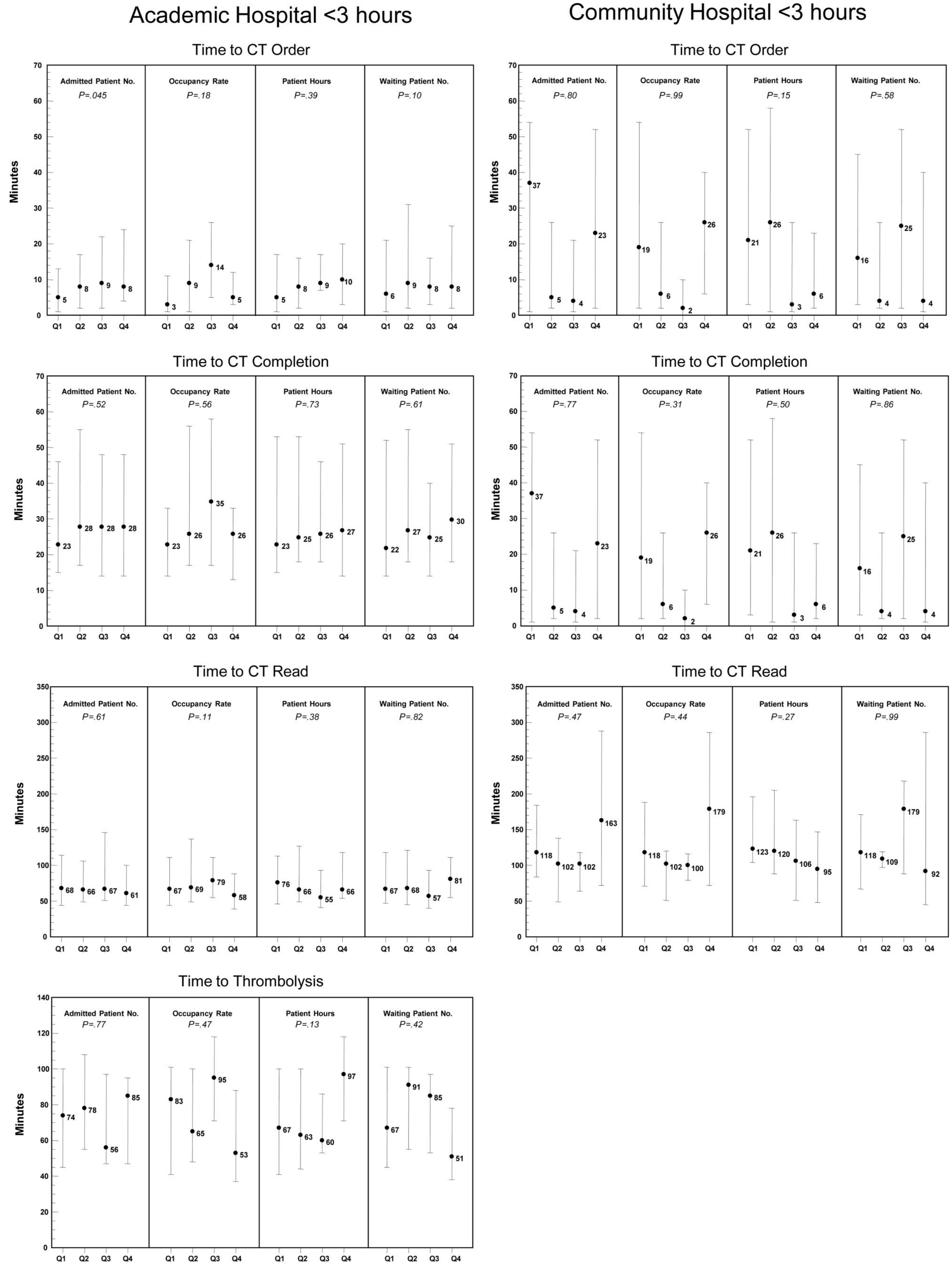

Figure 1. The relationship between ED crowding measures in quartiles and CT timing in patients with stroke potentially eligible for and receiving thrombolysis in 2 hospitals (n=253). Error bars represent 95% confidence intervals.

Table 4. Relative Risk of Delay in Time to CT Completion and Interpretation in an Academic Tertiary Care Hospital Based on 4 Measures of ED Crowding (n=199)*

	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Time to CT Completion >25 Minutes				
Admitted patient no.	Reference (1.0)	0.8 (0.5–1.1)	0.8 (0.5–1.1)	0.8 (0.6–1.2)
Occupancy rate	Reference (1.0)	0.9 (0.6–1.2)	0.9 (0.7–1.3)	0.8 (0.6–1.2)
Patient-hours	Reference (1.0)	0.9 (0.7–1.3)	0.8 (0.5–1.2)	0.8 (0.5–1.2)
Waiting room no.	Reference (1.0)	0.8 (0.6–1.2)	0.9 (0.6–1.3)	0.8 (0.5–1.2)
Time to CT Interpretation >45 Minutes				
Admitted patient no.	Reference (1.0)	0.8 (0.5–1.4)	0.7 (0.4–1.5)	1.3 (0.7–2.3)
Occupancy rate	Reference (1.0)	0.8 (0.5–1.5)	0.7 (0.4–1.5)	1.4 (0.7–2.5)
Patient-hours	Reference (1.0)	0.8 (0.4–1.8)	1.2 (0.5–2.4)	0.9 (0.4–1.8)
Waiting room no.	Reference (1.0)	1.2 (0.6–2.5)	1.5 (0.7–2.8)	0.8 (0.4–2.0)

*Values represent adjusted ratios for the risk of delay compared to the lowest level of crowding (Quartile 1). Adjusted models control for the time of day, mNIHSS, whether the patient was intubated in the ED, and triage class. Using $P<0.0125$ as significant, none of the resulting risk ratios are significantly different from Quartile 1.

ED nursing notes, neurology notes, ED physician notes, or from the completion time in the electronic record when no other time was documented. Patient-level and ED-level variables were downloaded from the electronic medical record, including demographics, arrival mode (ambulance versus ambulatory), time of day, triage class, and ED intubation. The modified National Institute of Health Stroke Scale (mNIHSS) was calculated from the documented neurological examination.[17] Other comorbid conditions were abstracted from a review of ED and hospital records. Blinded interrater agreement was performed in 5% of the charts by a second trained abstractor (junior-level ED resident). The interrater agreement κ for abstracted variables was 1.0, except for the mNIHSS, which was 0.96.

Validated measures of ED crowding were assigned at ED arrival and calculated based on tracking system queries (EMTrac; University of Pennsylvania, Philadelphia, PA).[9–13,18,19] These queries were performed using Microsoft Access (Microsoft Corporation, Redmond, WA) and permit the precise reconstruction of state at the time of ED arrival. These measures include waiting room number, ED occupancy, admitted patient number, and total patient-hours. These measures signify a "crowding" exposure at triage after which subsequent outcomes may be measured to test associations between crowding and quality. The outcomes were time to CT order, read, and interpretation. Among candidates for thrombolysis, outcomes were time to CT completion ≤25 minutes and interpretation ≤45 minutes and time to reperfusion therapy ≤60 minutes in patients receiving thrombolysis.[2]

Statistical Analysis

Data are presented as means±SD, frequencies, or medians with interquartile ranges (IQRs) for nonparametric time data. Mann–Whitney *U* tests were used to assess differences in crowding levels and CT timing between the 2 EDs. A Fisher exact test assessed differences in American Stroke Association/American Heart Association measures in thrombolysis-eligible patients. For these analyses, a probability value of <0.05 was used.

Because crowding levels were different at the 2 hospitals, each crowding measure was divided into quartiles within each hospital. We then assessed differences in CT timing among crowding quartiles using Cochrane-Armitage test for trend. To account for multiple comparisons, a Bonferroni correction was used; a probability value of <0.0125 was significant.

Multivariable analysis was then performed at the academic hospital to assess the adjusted effects of crowding and delays in CT completion (>25 minutes) and CT interpretation (>45 minutes) in <3-hour patients. For this analysis, the primary independent variables were crowding quartiles for each hospital. To calculate relative risk, a generalized linear model with a log link, Gaussian error, and robust estimates of the SEs of the model coefficients were used. This model controlled for triage class as a continuous variable (1 to 4), mNIHSS, ED intubation, time of day, and mode of arrival. Model goodness of fit was tested and there was sufficient power.[20] For this analysis, a probability value of <0.0125 was significant. There was insufficient power to perform multivariable analysis in thrombolysis patients or in the thrombolysis-eligible patients at the community hospital. Stata 10 (Stata Corporation, College Station, TX) was used.

Results

A total of 1342 patients was admitted with cerebral ischemia, intracerebral hemorrhage, or transient ischemic attack over the study period. Among these, 253 patients presented to the ED <3 hours from symptom onset with active symptoms. Of those, 52 (21%) received thrombolysis. Patients arriving <3 hours from symptoms had lower Glasgow Coma Score (13.6 versus 14.2; $P=0.01$), higher mNIHSS (5 versus 1; $P<0.001$), were more likely intubated (10% versus 5%; $P=0.03$), and more likely to arrive by ambulance (67% versus 41%; $P<0.001$). They also had shorter times from triage to CT order (8 versus 38 minutes; $P<0.001$), CT completion (30 versus 102 minutes; $P<0.001$), and CT interpretation (76 versus 151 minutes; $P<0.001$; Table 1). For the combined cohorts, crowding levels were significantly higher at the academic hospital (Table 2).

Within the <3-hour cohort, the academic hospital had shorter times to CT completion (26 versus 60 minutes; $P<0.001$) and CT read (67 versus 109 minutes; $P<0.001$). For the >3-hour cohort, the academic hospital had shorter times to CT completion (91 versus 111 minutes; $P=0.02$) and CT read (142 versus 181; $P=0.03$). With regard to American Stroke Association/American Heart Association measures in thrombolysis-eligible patients, the academic hospital performed better for CT completion within 25 minutes (48% versus 24%; $P<0.001$) and CT read within 45 minutes (25% versus 17%; $P=0.03$; Table 3).

In both hospitals, there was no association between any ED crowding measure and any outcome for patients with symptoms <3 hours in the unadjusted analysis (Figure 1) or the adjusted analysis (Table 4). For patients in the academic hospital >3 hours from symptom onset, higher levels of crowding were associated with longer times to CT order for all measures except patient-hours. For time to CT completion,

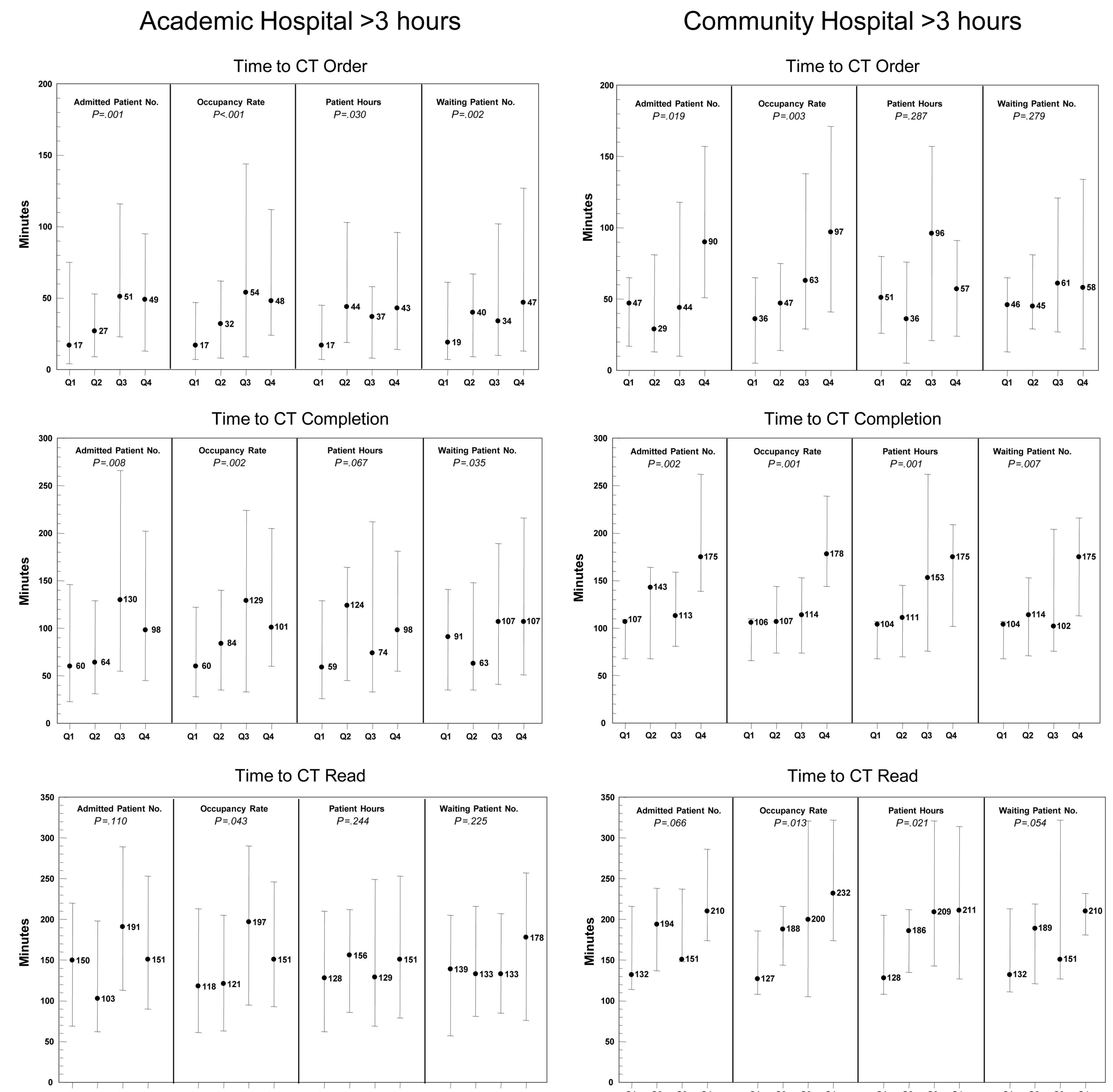

Figure 2. The relationship between ED crowding measures in quartiles and CT timing in patients with stroke not eligible for thrombolysis in 2 hospitals (n=253). Error bars represent 95% confidence intervals.

occupancy and the number admitted patients were associated with prolonged times. There was no association between ED crowding and time to CT read. In the community hospital, higher levels of occupancy were associated with longer CT order times, whereas all measures of crowding predicted longer times to CT completion. No measures of ED crowding were associated with prolonged time to CT read (Figure 2).

Discussion

We found that ED crowding was not associated with care delays for patients with stroke arriving <3 hours from symptom onset. However, several ED crowding measures predicted delays in CT ordering and CT completion in patients outside of the intravenous thrombolysis window. This confirms previous studies reporting that the critically ill patients with stroke and acute myocardial infarction are not affected by competing resource demands.[14,15] However, delays in patients outside of the thrombolysis window may still be clinically significant in some patients, whereas CT results may guide medication use (such as antithrombotic therapy) or neurosurgical procedures.

An important difference comes in comparing the academic hospital, a comprehensive stroke center, with the nonstroke center community hospital. Despite higher crowding levels, the academic hospital performed better on time to CT completion and time to CT read. A few possibilities may explain this. In the academic hospital, the stroke team consists of neurologists who respond to the ED immediately.

Stroke teams may reduce delays because they typically stay at the bedside through the initial ED care.[21–23] Another possible reason may be related to the CT scanner location. The academic hospital has a scanner directly adjacent to the ED, whereas the community hospital requires elevator transport. Another study reported that moving the CT scanner to the ED reduces delays to thrombolysis.[24]

Another important finding was the wide IQR of the time intervals in all patients, in which 1 in 4 patients potentially eligible for thrombolysis experienced a >20-minute delay in CT order and a 60-minute delay in CT completion. Given that pooled analysis of tissue plasminogen activator trials show clear benefit for early treatment, delays in diagnostic testing that slow administration of thrombolytic therapy may have a substantial clinical impact.[25] However, ED crowding did not appear to be an important factor influencing these delays. In another study, hospital-level differences explained differences in time to imaging.[6] Further study is needed to investigate what other factors may lead to subsets of patients experiencing delays. Certainly, clinical issues (eg, airway management) can lead to unavoidable delays, but only 10% of the <3-hour cohort was intubated indicating that other factors likely contribute.

Despite improved compliance with American Stroke Association/American Heart Association guidelines, only half of potentially thrombolysis-eligible patients had their CT completed within 25 minutes of arrival, and 1 in 4 had a radiology read on the CT within 45 minutes. The latter probably underestimates the proportion of patients with a read time within guidelines because CTs are typically viewed by the stroke team immediately. In a recent study of thrombolysis-eligible patients with stroke, only 25% of patients had CTs completed within 25 minutes, and comprehensive stroke centers had significantly shorter times.[26] This indicates there is still considerable room for improvement.

There are several study limitations. We only investigated stroke care in 2 hospitals, reducing the study's generalizability. Our study was retrospective, and the small sample size for patients receiving thrombolysis did not permit multivariable analysis. Because the stroke team may read CTs immediately after completion or radiologists may verbally communicate findings before dictation, CT read times may not accurately represent the time of a clinical decision. Finally, since study completion, the time window for intravenous thrombolysis has expanded to 4.5 hours.[27] It is possible that the perception of a longer window for thrombolysis may further slow time-dependent stroke care.

In summary, several of ED crowding measures were associated with prolonged CT times in patients who presented ≥3 hours after symptom onset. ED crowding was not associated with delays in patients potentially eligible for thrombolysis or in the administration of thrombolytic therapy. Comparing 2 hospitals, stroke care was faster in a comprehensive stroke center than in a community hospital despite more ED crowding.

Acknowledgments

We thank Chris Boedec for his help with this study.

Disclosures

None.

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