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Describing wait time bottlenecks for ED patients undergoing head CT☆

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ABSTRACT

Study objectives: Facing increased utilization and subsequent capacity and budget constraints, ED's must better understand bottlenecks and their effect on process flow to improve process efficiency. The primary objective of this study was to identify bottlenecks in obtaining a head CT and investigate patient waiting time based on those bottlenecks.

Methods: This observational study included all patients undergoing a head CT between July 1, 2013 and June 30, 2014 at a large, urban academic ED with over 100,000 visits per year.

The primary study outcome was total cycle time, defined as the elapsed time between patient arrival and head CT preliminary report, divided into four components of workflow.

Results: 8312 patients who had a head CT were included in this study. The median cycle time from patient arrival to head CT preliminary report was 3 h and 13 min with 39 min of waiting time resulting from bottlenecks. In the 4-step model (time from patient arrival to head CT order, time from head CT order to head CT scheduled, time from head CT scheduled to head CT completed, and time from head CT completed to head CT preliminary report), each process was the bottleneck 30%, <1%, 27%, and 42% of the time, respectively.

Conclusion: Demand capacity mismatch in head CT scanning has a significant impact on patient waiting times. This study suggests opportunities to improve wait times through future research to understand the causes of delays in CT ordering, CT completion and timeliness of radiology reports.

1. Introduction

1.1. Background

Facing increased utilization and subsequent capacity and budget constraints, many emergency departments (EDs) are actively seeking new ways to streamline processes. However, this remains challenging, as most ED processes require coordinating a number of different functions [1]. In addition, while some ED processes can be completed in parallel, many must be completed in series (i.e., the prior step must be completed before moving to the next step). According to the "theory of constraints", a process is only as fast as its slowest step, known as the bottleneck. Better understanding of bottlenecks, and their effect on process flow, can allow emergency physicians to improve patient throughput and decrease wait times [2,3].

Owing to large variations in patient volume and acuity, and subsequent resource demand and utilization, the ED is a unique place to examine bottlenecks. Several studies have investigated methods of identifying bottlenecks in the ED and allocating resources to minimize wait times and optimize resource use [3,4]. Importantly, mean and median wait times are not the only metrics with significant effects on the system, and for certain ED testing processes, outlier wait times have been shown to have a substantial impact on patient length of stay (LOS) [5].

Streamlining patient flow offers several potential benefits. First, faster testing and treatment may lead to the ability to treat patients sooner and provide care of higher quality. Second, treating patients more quickly allows for more-rapid disposition decisions, potentially decreasing ED LOS. Third, for a given level of patient demand, shorter LOS correlates with smaller effective ED census, subsequently decreasing crowding. Such reductions in crowding allow limited resources such as bed space, nursing time, and physician time to be allocated to patients in need. This has been shown to improve patient safety and

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improve timely medication administration [6,7]. Fourth, wait times can also negatively impact patient experience [7,8]. Finally, extended boarding in the ED negatively impacts hospital financial performance [8]. Improving patient flow and throughput thus has the potential to provide benefits to patients, providers, and hospitals alike.

1.2. Importance

Matching resource allocation more closely to resource demand reduces throughput time. In a system with significant variability, like the ED, it is likely that the bottleneck is not the same for every patient, and the existence of shifting bottlenecks has the potential to play a critical role in systems engineering solutions. However, the concept of shifting bottlenecks has not been well studied in the ED.

Computed Tomography (CT) scans of the head offer an instructive case study in understanding ED bottlenecks and variation. Head trauma and headache result in over 2.1 million ED visits annually; 14% of these visits include neuroimaging [9]. Head CTs are ordered for as many as 1 in 10 patients presenting to the ED [10]. In addition, the process of performing a head CT requires numerous coordinated steps between multiple role groups, including emergency physicians, radiologists, nurses, transport, and radiology technicians. Adding to the complexity, multiple patient, staff, and systems factors can impact the turnaround time of this process.

1.3. Objectives

The primary objective of this study was to identify bottlenecks in obtaining an ED head CT and investigate waiting time based on those bottlenecks.

2. Materials and methods

2.1. Study design, participants and setting

This retrospective observational study, approved by the Institutional Review Board, included all patients undergoing head CT between July 1, 2013 and June 30, 2014. The study setting was a large, urban academic ED with over 100,000 visits per year. This facility has 2 dedicated ED CT scanners that operate 24 h per day and primarily serve the ED but are also used for STAT inpatient CT scans.

2.2. Data collection and processing

Radiology logs were used to determine which ED patients had a head CT scan performed. This data was then cross referenced with the ED information system to collect the following time data: patient arrival time, attending assignment time, CT order time, CT completion time, CT preliminary report time (generated by radiologist, often a trainee), CT final report time, and disposition decision (e.g., discharge from ED, admission to hospital) time. We also collected demographic data and the discharge location of the patients.

2.3. Outcome measures

The primary study outcome was total cycle time, defined as the elapsed time between patient arrival and head CT preliminary report, divided into four components of workflow: the time from patient arrival to head CT order, the time from head CT order to head CT scheduled, the time from head CT scheduled to head CT completed, and the time from head CT completed to head CT preliminary report. The disposition time for each patient was also recorded to understand how many patients had a disposition before the head CT preliminary report was available.

2.4. Primary data analysis

Patients with deficient or missing data (i.e., those who had a head CT ordered, scheduled, or completed after dismissal and those with any data that had negative intervals recorded) were excluded. Patients who had long intervals that were unlikely to be accurate (i.e., >6 h between arrival and order, >3 h between ordered and scheduled, >6 h between scheduled and complete, or >8 h between completed and preliminary report) were also removed.

This study compares cycle times, the time to complete a defined process. The overall cycle time of patient arrival to head CT preliminary report time is made up of four components: the time from patient arrival to head CT order, the time from head CT order to head CT scheduled, the time from head CT scheduled to head CT completed, and the time from head CT completed to head CT preliminary report. The sum of the cycle times for a patient moving through each process at the median should be equal to the median cycle time of the overall process. However, in reality patients may move through each of the component processes faster or slower. This lack of coordination, such as moving though one process faster relative to that processes median time and another slower relative to that processes median time creates additional waiting time from capacity mismatch. This study compares the calculated patient arrival to head CT preliminary report time (IE the sum of the medians of each component process cycle time) to the actual patient arrival to head CT preliminary time (the median time it actually took a patient to go through the entire process) to determine the additional waiting time. This entire process was calculated for 25th percentile and 75th percentile as well. We also examined the distribution of the bottleneck, which was defined as the longest interval among the four processes. All analyses were conducted using SAS version 9.4 (SAS Institute, Cary NC) by a PhD biostatistician.

3. Results

The ED summary statistics during the study time frame are depicted in Table 1. A total of 8749 patient encounters had a head CT scan ordered during the study period. Five percent (437/8749) were excluded because of missing/deficient data (1.4%) or unlikely long intervals (3.6%). This left 8312 patients included in the study. The average patient age was 59.6 years (SD 21.0).

Table 2 describes the median, 25th percentile, and 75th percentile times for the four workflow components of the head CT process. The observed median time from patient arrival until a preliminary head CT

Table 1
Summary statistics.

Patient population		8312
Age (mean, std)		59.6 (21)
Male sex (#, %)		4475 (53.8%)
Race (#, %)		
	Asian	276, 3.3%
	African American	620, 7.5%
	Hispanic	766, 9.2%
	White	6367, 76.6%
	Other	85, 1.0%
	Unknown	198, 2.4%
Disposition (#, %)		
	Discharge	3301, 39.7%
	Inpatient	3484, 41.9%
	ED observation	1448, 17.4%
	Other	79, 1.0%
Length of stay (hours)		
	Median	6.4
	Quartile 1	4.6
	Quartile 3	9

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