The Benefit of a Triage System to Expedite Acute Stroke Head Computed Tomography Interpretations

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Background and Purpose: We developed and tested a triage system to accelerate the interpretation of stroke head computed tomographies (CTs), with the goal of optimizing the time available for acute stroke therapy. *Materials and Methods:* In our practice, acute stroke protocol head CTs have been given the highest reading priority. We implemented a technologically enabled prioritization infrastructure to consistently present these critical cases to our radiologists so they are evaluated before other examinations. In our 1-year retrospective multicenter study of 350,495 head CT examinations, we compared the reading time of stroke protocol head CTs to our next highest priority head CT. *Results:* Our average acute stroke head CT reading turnaround time was 6.5 minutes. This represented a 17.3-minute improvement over the next highest priority head CT in our practice (confidence interval: 17.2-17.4 minutes, $P < .001$). *Conclusions:* A technologically enabled acute stroke protocol CT triage system consistently improves the reading times of critically time-dependent head CT examinations. As a result, this system has the potential to improve treatment times, treatment eligibility, and clinical outcomes. **Key Words:** stroke—TPA—neurology—triage—technology—telemedicine—process improvement.

Introduction

An estimated 1.9 million neurons are lost for each minute an acute ischemic stroke is left untreated.[1] Earlier thrombolytic treatment with intravenous (IV) tissue plasminogen activator (tPA) has demonstrated improved patient survival, recovery, and prognosis. For eligible patients, there is a disproportional benefit of IV tPA treatment within the first hour from the onset of symptoms.[2-5] Because the advantages of tPA are strongly time dependent, the American Heart Association and American Stroke Association have established guidelines for a hospital door-to-needle treatment time of 60 minutes or less, with an updated "Target: Stroke Phase II" goal of 45 minutes or less in at least 50% of patients.[6,7] Unfortunately, broad multicenter studies have reported that fewer than 30% of U.S. patients are treated with tPA within the recommended 60-minute door-to-needle benchmark.[8,9] However, there are initiatives that have demonstrated a door-to-needle time of less than 60 minutes as a result of stroke workflow improvements at specific centers.[7,10-15]

An indispensable requirement for determining tPA eligibility is the interpretation of a nonenhanced head computed tomography (NECT) examination.[6] A recent study has evaluated the overall stroke workup time in relationship to obtaining a NECT by splitting the door-to-needle time into the "door-to-imaging" time and the subsequent "imaging-to-treatment" time. The imaging-to-treatment time has contributed to a greater treatment delay and greater variability in treatment times, and has also been disproportionally responsible for failures to achieve a door-to-needle time within 60 minutes.[16] Because the radiologist reading time is an important component of the imaging-to-treatment time, efficiencies introduced

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to expedite the interpretation of a NECT have the potential to improve outcomes.

In recognition of the critically time-dependent nature of acute ischemic stroke, we developed a quality improvement project to accelerate the speed of acute stroke NECT interpretations. The technological infrastructure we created is designed to provide a sustainable, reliable, and automated system to appropriately triage the reading of acute stroke NECTs.

Materials and Methods

Practice Examination Workflow

Our practice provides teleradiology interpretation services to hospitals, clinics, and imaging centers for all 50 U.S. states. Diagnostic images obtained at partner facilities are electronically transmitted to our headquarters and then automatically distributed to our U.S. board-certified radiologists based on credentialing profiles. A diagnostic examination is initially made available on multiple different radiologists' reading lists until it is picked to be read by a single radiologist. At a foundational level, the oldest examinations are presented at the top of a radiologist reading list to be read first. However, we have created additional technical layers to allow the automatic reordering of a reading list based on clinically determined urgency factors. We have implemented several different examination priority designations, some of which are general labels available for any examination, and some of which are specific for a particular clinical indication. For patients with suspected acute stroke, their critical examinations have been given the highest priority, and we have programmed our PACS/RIS software to ensure that these cases are automatically prioritized at the top of a radiologist reading list.

A NECT can be designated with "stroke protocol" urgency in 3 different ways. We have created a software system to interface with onsite HL7 systems, so that the acute stroke protocol urgency can be determined at the time of the initial written examination order. For facilities without an HL7 infrastructure, we have added a stroke protocol urgency option to the onsite computed tomography (CT) technologist order management system. In the event that a partner facility requests a change in urgency after the images have been transmitted, we have also created additional functionality that allows our operations center team members to make necessary adjustments.

Study Procedure

Examination metrics from our data warehouse were evaluated on anonymized dashboards. From January 1, 2016, to January 1, 2017, a total of 5,502,513 diagnostic imaging examinations, from 1972 partner facilities, were interpreted by 463 radiologists in our practice. These included a variety of examination types including radiographs, ultrasounds, CTs, magnetic resonance imaging, and nuclear medicine studies.

NECT examinations designated as stroke protocol urgency were evaluated as the investigational group. The examinations protocoled as "stat emergent" urgency represent the next highest priority NECT in our practice and were evaluated as the control group.

NECT examinations with alternative urgency designations such as "nonemergent," and "trauma protocol" were not included in the evaluation. NECT cases, which were combined with other examination types such as CT angiogram and CT cervical spine, were not included in the evaluation. NECT examinations, which were performed with IV contrast, were also excluded from the evaluation. All duplicate examinations in the dataset were excluded, which included 2 examinations in the stroke protocol category and 6 duplicate examinations in the stat emergent category. There was a total of 351,065 remaining unique examinations designated as either stroke protocol or stat emergent protocol. Of those, there were 540 (.15%) records where the turnaround time was less than 0, and there were 30 (.01%) records with a greater than 3-hour turnaround time (more than 4 standard deviations from the mean). We excluded these records as extreme outliers and data entry errors. Our final study cohort included a total of 350,495 examinations; 296,635 (85%) NECT examinations were in the stat emergent group, and 53,860 (15%) NECT examinations were in the stroke protocol group. The stroke protocol NECT group represented 1% of the total examinations interpreted in our practice during the 1-year study time frame.

Our evaluation focused on 3 different NECT examination time intervals. Our examination "available to picked time" is the time from when an examination is available on a radiologist worklist to when it is picked by a radiologist to be read. The picked time to reported time is the "radiologist reading time" for an examination. The examination "turnaround time" is the overall time from when an examination is available on a radiologist worklist to when the completed written radiology report is signed by a radiologist (Fig 1).

Institutional Review Board

We submitted our study proposal to the Western IRB who considered the study to be exempt because our retrospective research was performed on selected clinical datasets, which were deidentified.

Statistical Analysis

We used unpaired *t* test to evaluate the differences in the mean values in the times for the reading of stat emergent and stroke protocol NECTs. The *t* test was corrected for unequal variance in the 2 groups. We calculated the