Utilization of Workflow Process Maps to Analyze Gaps in Critical Event Notification at a Large, Urban Hospital

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Abstract Stroke care is a time-sensitive workflow involving multiple specialties acting in unison, often relying on one-way paging systems to alert care providers. The goal of this study was to map and quantitatively evaluate such a system and address communication gaps with system improvements. A workflow process map of the stroke notification system at a large, urban hospital was created via observation and interviews with hospital staff. We recorded pager communication regarding 45 patients in the emergency department (ED), neuroradiology reading room (NRR), and a clinician residence (CR), categorizing transmissions as successful or unsuccessful (dropped or unintelligible). Data analysis and consultation with information technology staff and the vendor informed a quality intervention—replacing one paging antenna and adding another. Data from a 1-month post-intervention period was collected. Error rates before and after were compared using a chi-squared test. Seventy-five pages regarding 45 patients were recorded pre-intervention; 88 pages regarding 86 patients were recorded post-intervention. Initial transmission error rates in the ED, NRR, and CR were 40.0, 22.7, and 12.0 %. Post-intervention, error rates were 5.1, 18.8, and 1.1 %, a statistically significant improvement in the ED ($p < 0.0001$) and CR ($p = 0.004$) but not NRR ($p = 0.208$). This intervention resulted in measureable improvement in pager

communication to the ED and CR. While results in the NRR were not significant, this intervention bolsters the utility of workflow process maps. The workflow process map effectively defined communication failure parameters, allowing for systematic testing and intervention to improve communication in essential clinical locations.

Keywords Workflow · Communication · Reading room · Reporting

Introduction

Acute stroke care requires coordination of complex, time-sensitive, and multi-disciplinary processes to mitigate critical neuronal loss, morbidity, and potential mortality [1, 2]. With each minute of ischemia engendering the loss of 7 miles of axonal fibers, and each hour, 3.6 years of aging, timely and accurate communication among the interdisciplinary acute ischemic stroke (AIS) team is essential to patient care [3]. Rapid alert of an interdisciplinary team ensures fast initiation of key diagnostic steps, including CT, a prerequisite to appropriate, timely treatment. Reducing delays in communication of these CT results is critical to diagnosis, prognostication, and therapy selection.

Current guidelines for AIS management advise that patients who are candidates for therapeutic intravenous thrombolysis receive treatment within 4.5 h of symptom onset, with door-to-needle (DTN) time goals of less than 60 min and door-to-CT initiation and door-to-CT interpretation times of less than 25 and 45 min, respectively [4]. Studies have shown that adherence to this timeline improves patient outcomes, with the odds of good functional outcomes increasing as the time since the patient's last known normal (LKN) neurological status decreases [1, 5]. Previous studies have shown that patients who receive imaging within the recommended door-to-

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CT time window of 25 min are three times more likely to receive critical treatment (in the form of recombinant tissue plasminogen activator (tPA)) within 60 min than those with door-to-CT times greater than 25 min ($p<0.001$) [6].

Coordinating timely imaging is thus crucial to reduction in DTN times. A single, all-points stroke alert has contributed to reduced DTN times and increased tPA administration in single-center studies [7–9]. Notwithstanding such improvements, continued and multifactorial delays preclude successful therapy within the treatment window. Among myriad factors contributing to such delays, a generally under-recognized vulnerability to acute stroke workflow is transmission failure of the wireless pager distribution alerting the multi-disciplinary care team.

We have observed and documented the potential for communication errors to specifically impede the stroke imaging workflow, due to non-transmission of pager alerts to regions of the hospital, particularly within the radiology department. This study aims to investigate the frequency and downstream consequences of pager transmission failure in acute stroke care, within a dedicated and comprehensive, certified academic stroke center. Workflow process maps of the AIS notification system are developed, hypothesizing enhancements to clinical stroke workflow, enabling identification of specific points of weakness in the alert process, and permitting for targeted interventions to reduce communication gaps between radiology and the acute stroke care team.

Methods

Process Map

Over a period of 2 months, a workflow process map of the stroke notification system at a Grady Memorial Hospital was created (Fig. 1). Direct communication with the paging dispatcher, university call center and emergency medical services (EMS) manager outlined the architecture of the communication pipeline, beginning from pre-hospital notification (Fig. 2). Direct observation of the AIS response process from alert to CT interpretation identified the major locations, processes, and decision points within the treatment workflow. Using the map as a guide, subsequent interviews with hospital staff, including attending physicians and house staff across departments, CT technologists, and nurses, were conducted to identify points of process delay and workflow bottlenecks. These anecdotally implicated the paging system as a weak point in the AIS structure. We targeted this issue for measurement, analysis, and intervention.

Initial Data Collection

Following obtaining an exemption from the institutional review board (IRB), we recorded all pager-based

communications for 45 consecutive patients from April 20 to May 6 2014 in three locations: the emergency department (ED), the neuroradiology reading room (NRR), and a nearby clinician residence (CR) within the paging system coverage range. Each transmission was categorized as successful or unsuccessful as compared to source logs from the University Technology Services office. A transmission was characterized as unsuccessful if it was not received or if the received message was unintelligible (including truncated transmissions lacking the necessary patient identifiers and garbled, unreadable messages). The data was analyzed for the proportion of unsuccessful transmissions.

Intervention

The antenna used to transmit pages, located on the hospital roof, was originally an omnidirectional DB-589 with 3° of downtilt, located 18 floors above the ED. The vendor, American Messaging (Lewisville, TX), measured the signal reception in the ED and NRR, which confirmed a significant signal drop-off in these locations. The original antenna was replaced with an omnidirectional DB-589 with 6° of downtilt, supplemented with the original antenna reinstalled on a neighboring building, and directed toward the emergency department.

Post-Intervention Data Collection

Post-intervention data was collected from September 17 to October 19 2014 for 86 consecutive patients using the same methods as the pre-intervention phase. Post-intervention testing utilized two pagers each in the ED and NRR rather than one pager.

Analysis

Differences in transmission error rates in all locations before and after the intervention were compared using a chi-squared test and an $\alpha=0.05$.

Results

The stroke alert workflow process map demonstrated that initiating a page to the stroke team came after three parties—EMT personnel, a dispatcher located in the ED, and an ED attending—interacted with the hospital call operator. It further showed that the page initiated by the call operator was the key signal engaging stroke team action, including notification of the on-call radiologist. Confirmation of low signal in the ED reinforced the possibility of pager communication failure, as suggested in the process map interviews.

Fig. 1 The AIS workflow at Grady Memorial Hospital as constructed by direct observation of the AIS response process from alert to CT interpretation and interviews with hospital staff

A total of 75 pages regarding 45 patients was recorded in the pre-intervention test in both ED and the neuroradiology reading rooms and a clinician residence (CR) located within the paging system's transmission radius. Eighty-eight pages regarding 86 patients were recorded post-intervention in the same locations. The messages received on the pagers were compared to the outgoing messages as recorded in University Technology Services source logs.

Acute Stroke Page Workflow

Fig. 2 The acute stroke page workflow used to alert the interdisciplinary stroke team, assembled by direct communication with the paging dispatcher, university call center, and EMS manager

Post-intervention testing utilized two pagers each in the ED and the NRR rather than one; however, the difference in error rates between pagers in the same room was non-significant (ED $p=0.782$, NRR $p=0.847$), indicating that the transmission errors occur before end-target reception.

The initial transmission failure rate in the ED was 40.0 % (45 successful, 24 missed, 6 unintelligible). The initial failure rate in the NRR was 22.7 % (58 successful, 14 missed, 3 unintelligible), while it was 12.0 % (66 successful, 6 missed, 3 unintelligible) at the CR. Following antenna modifications, the failure rate dropped to 5.1 % in the ED, to 18.8 % in the NRR, and to 1.1 % in the CR. These results reached statistical significance for the ED ($p<0.0001$) and the clinician residence ($p=0.004$) but not for the NRR ($p=0.208$) (Fig. 3). This represents an 87.2 % reduction in errors in the ED and 78.2 % in the CR. Additionally, errors were reduced in the NR by 1.7 %

Discussion

Our workflow process map revealed the pivotal role of the page transmission system and identified the point of greatest vulnerability for communication delay from within the AIS workflow. Throughout the AIS response process, communication was the cornerstone of obtaining timely imaging, a crucial component of DTN times. Nationally, communication failure was the most commonly cited cause of all delay-of-care sentinel events reported to the Joint Commission from 2004 to 2014 [10].

Page Transmission Error Rates

Comparing transmission failures in acute stroke alert pages in two reading rooms before and after antenna modification.

Fig. 3 Comparing transmission failures in acute stroke alert pages in two reading rooms before and after antenna modification

The creation of a workflow process map allowed for targeted measurement of paging failure; sharing these initial findings with hospital information technology staff and the paging vendor initiated an intervention that resulted in a measureable, statistically significant improvement in pager communication.

Workflow process maps are a critical part of major business improvement methodologies invented by manufacturers Toyota (the Lean Concepts method) and Motorola (Six Sigma) to identify inefficiencies and reduce waste and error. In the last decade, the Lean Concepts method, designed to increase efficiency in manufacturing, has been increasingly applied in various sectors ranging from technology to healthcare. Value stream mapping (VSM) is one such *Lean* tool used for analyzing the current workflow in order to design an improved one; in the method, a problem is identified and direct observation is used to map the current process from end-to-end.

These business intelligence and improvement tools have been widely and successfully utilized in radiology [11, 12]. In radiology departments, *Lean* has been shown to maximize the number of examinations performed and decrease wait lists [13–15]. Similarly, Six Sigma techniques have been used in healthcare quality improvement projects, through the reduction of “defects,” the Six Sigma term for error. These techniques utilize measurement and analysis through mapping, which is then used to identify areas of unnecessary variation for improvement. Like the Lean Concepts, Six Sigma processes have been used to reduce wait times and improve imaging consistency [16].

While accounts of healthcare implementation of these techniques have been published with increasing frequency, few include statistical analysis of projects and outcomes,

diminishing the evidence base for their effectiveness [17]. We believe our workflow process map adds to the fund of evidence.

Process maps have been used in various specialties to improve efficiency, clinician, and patient experience, including the following: (1) development of electronic health record interfaces in the primary care setting, (2) development of QI measures for pediatric intubations, (3) reducing gastrointestinal biopsy processing time, and (4) development of carotid stenosis mortality risk calculations [18–21]. The potential uses for process maps within BI-conductive imaging informatics are far-reaching and include identifying variability in acquisition methods or protocol use, identifying efficient visual search patterns in combination with event log analysis, and efficiency optimization in urgent teleradiology processes such as telestroke.

While unidirectional paging remains the core of AIS alert in many institutions such as our own, these findings compel further research into the effectiveness and fidelity of non-pager based communication methods, including page-to-text transmission and HIPAA-compliant texting applications, which are used in addition to pager communication in AIS alerts. Prior studies have substantiated the cost-saving and time-saving benefits of switching to more modern communication systems from pagers; however, a recent meta-analysis has shown that technologically advanced systems do not independently improve clinician-clinician communication [22–24]. We therefore propose that the use of process maps would be generalizable to institutions with other modalities of alert notification. Many such workflow steps relevant to AIS care can generalize to imaging intensive diagnoses and have recently been outlined through the Society for Imaging Informatics in Medicine Workflow Initiative in Medicine (SWIM) [25].

Non-contrast-enhanced CT remains the standard of care for confirmation of AIS vs. hemorrhagic or non-vascular etiologies, but recent research has shown the potential of Doppler, CTA, CTP, and PWI MRI penumbral identification in sub-selecting patients for therapeutic interventions for both patients ineligible for rtPA and possibilities for further interventions such as mechanical thrombectomy, as well as predicting responses to and outcomes from rtPA [26–30]. As use of these enhanced modalities increases, requiring additional scanning and interpretation time, continual process analysis to reduce workflow delays and improve communication will become ever more important.

Conclusions

Optimizing the paging system use in acute stroke alerts can improve care coordination, potentially reducing time to treatment in time-sensitive events, improving the likelihood of

saving at-risk brain tissue, and providing more of a window for additional image acquisition and evaluation. Our workflow process map effectively defined likely communication failure parameters, and systematic testing revealed the frequency of transmission failures in clinical locations essential to stroke care workflow. Identifying such weak points and involving IT and the vendor led to an intervention which measurably reduced communication failures during AIS treatment.

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