Integrating RapidAI in an Evolving Hub and Spoke System

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Abstract

Rapid assessment and diagnosis of suspected stroke patients is imperative to reduce death and disability, making timely expert access to neuroimaging studies essential for directing reperfusion treatment decisions. The integration of artificial intelligence (AI) supported imaging platforms within stoke systems has been shown to improve treatment time metrics, thereby increasing practitioners' ability to ensure optimal clinical outcomes. The adoption of AI supported imaging technology has not been previously detailed for hub and spoke systems. In this article we describe adoption of one AI imaging platform, RapidAI, within a hub and spoke healthcare system in the midsouth United States.

Keywords: Artificial intelligence, acute stroke, neuroimaging imaging, RE-AIM implementation framework.

Introduction

Management and treatment of acute ischemic stroke patients has undergone drastic change over the last two decades with wider adoption of thrombolytics and thrombectomy becoming standard of care. Now with the rapid evolution and implementation of artificial intelligence (AI)/machine learning (ML) in stroke imaging, further evolution is underway with the potential to improve both efficiency and effectiveness of reperfusion treatments.

Healthcare setting implementation of AI/ML technologies has grown at a rate of 40% per year. By 2022, the US Food and Drug Administration had approved 22 AI/ML technologies specific to stroke and stroke rehabilitation. Twenty of these are specific to stroke diagnosis and involve imaging capability.[1] These technologies are founded on convolutional neural networks (CNN) which are based on filters designed to learn normal and abnormal features to understand and interpret diagnostic imaging. This process involves complex tasks such as image classification, segmentation, localization, and detection in a method similar to image detection in animals.[2] Wider adoption of AI/ML strategies is estimated to save the US healthcare industry between $200-350 billion while preserving safety and quality.[3] Importantly, these strategies are not designed to replace the clinician, but are designed to increase the efficiency of medical diagnosis and treatment through improved workflows and notifications.[4] Additionally, AI mobile apps have expanded access to stroke imaging to multiple providers involved in the hyperacute phase of stroke management. Since transferring centers often have barriers in moving patients to a higher level of care, AI platforms can facilitate early diagnosis, create urgency, and enhance rapid transfer planning. For example, Hassan and colleagues achieved significant improvement in mean door-in door-out (DIDO) times from a primary stroke center (PSC) to their comprehensive stroke center (CSC) reducing DIDO from 226.7 minutes to 124.4 minutes (p=0.0374) after the introduction of an AI imaging platform.[5]

There are at least three main benefits of AI supported neuroimaging for stroke.[6] One benefit is the rapid detection of abnormalities difficult to see with the naked eye that is tied to corresponding practitioner notification delivered within just a few minutes. Elijovich and colleagues detected significantly faster notification times with AI supported neuroimaging over usual care in 104 patients diagnosed with large vessel occlusion (LVO) stroke, namely 7 minutes compared to 26 minutes to notification ($p<0.001$), with AI clearly superior to radiologist notification.[7] Combining AI imaging platforms with mobile technology also facilities entire stroke teams' awareness across multiple hub and spoke campuses to optimize evaluation and treatment decisions.

The second benefit provided by AI is support for clinical decision making to determine eligibility for thrombolytics and/or thrombectomy, as well as treatment and transfer decision making in hemorrhagic stroke. AI imaging platforms which incorporate multiple modalities including computed tomography angiography (CTA), computed tomography perfusion (CTP), magnetic resonance imaging (MRI), measurement of the Alberta Stroke Program Early CT Score (ASPECTS), hyperdensity detection, intracerebral hemorrhage (ICH) and LVO detection have expedited treatment decisions. Several well-known successful thrombectomy trials, namely, DAWN,[8] EXTEND-IA,[9] DEFUSE 3,[10] and SWIFT PRIME,[11] have utilized AI imaging in determining eligibility for thrombectomy. In addition, the sensitivity and negative predictive value of AI imaging is critical in the triage of LVO patients. In one case series of 477 patients using RapidCTA, the sensitivity for detecting an LVO was 0.94 and the negative predictive value was 0.98.[12] In the case of ICH, ultra early interventions such as blood pressure reduction, agent specific reversal of anticoagulants, and transfer to a CSC can be supported by AI detection of hemorrhage on the initial head noncontrast CT.

As a third benefit, an expedited workflow reduces treatment times in eligible patients. Al-Kawaz and colleagues studied time metrics associated with LVO door to puncture times, door to first pass times, and door to recanalization times before and after incorporation of the RapidAI mobile app. They found a significant 33 minute reduction (p=0.02) on average for door to puncture times, a significant 35 minute reduction (p=0.02) on average for door to first pass times, and a significant 37 minute reduction (p=0.02) on average for door to recanalization times after RapidAI was incorporated within their workflow. These reductions in time to treatment were also associated with significant improvement in National Institutes of Health Stroke Scale (NIHSS) scores at 24 hours post-procedure and discharge (p=0.03).[13]

Hub & Spoke Implementation of AI Supported Neuroimaging

Our hospital system chose to implement RapidAI to support our hub CSC and spoke PSC hospitals. RapidAI is a clinically validated AI imaging platform with multiple options that our hub and spoke sites found valuable in evaluation, treatment decision making, and transfer planning for suspected acute stroke patients, including Rapid noncontrast head CT (NCCT), Rapid ASPECTS, Rapid LVO, Rapid CTA, Rapid CTP, Rapid MRI, and Rapid Hyperdensity. Use of these options provide specific notifications for hypodensity, intracerebral hemorrhage with volume measurement, CT perfusion mapping, MRI diffusion and perfusion mapping, detection of subdural hematoma, and perfusion imaging in the interventional suite to reduce redundant imaging. We chose to implement the RapidAI mobile app that includes tools for communication, workflow enhancement, and analytics.

Our stroke program consists of 1 CSC, 1 PSC, 1 advanced PSC with thrombectomy capabilities, and 10 acute stroke ready hospitals with telemedicine capabilities to support acute stroke diagnosis and treatment decision making. Prior to the adoption of the RapidAI platform, CT scans for suspected stroke patients were evaluated by the stroke team either on site in the CT scanner, emergency department, radiology, or off-site via the Picture Archiving and Communication System (PACS). This resulted in delayed treatment times due to the time needed to log in, view, interpret, and communicate diagnoses and treatment plans to all members of the team in each site. Although our system has a policy of tagging CT scans with a stroke diagnosis to facilitate priority radiology reading, the ability to view the images instantly within the RapidAI mobile app offered an opportunity to further expedite time to interpretation and treatment.

Process Improvement Application

Process improvement frameworks vary among organizations. Our organization utilizes the Plan-Do-Study-Act (PDSA) framework, however, PDSA cycles may be inadequate to accurately anticipate the degree of evaluation, planning, implementation, and monitoring required across an entire hub and spoke system. Therefore, we describe our journey using an implementation science framework, namely the *RE-AIM Framework*,[14] which guided our stroke program leaders in the evaluation process providing a more holistic approach that considered the evolution, maturity and context of a stroke program's interaction with AI infrastructure.[15]

The first dimension of the RE-AIM framework is Reach.[14] Our team worked toward identifying the potential reach of RapidAI implementation across our stroke system. Given that all of our sites vary in their access to imaging interpretation and stroke treatment decision making, we quickly recognized the significant advantages that the RapidAI platform would provide in expediting decision making. Across all our sites, we also have multiple providers, including vascular and general neurologists, neurointerventionalists, neuroradiologists, neurosurgeons, emergency physicians and advanced practice providers. We were quick to recognize the importance for all of these stakeholders to receive the same imaging studies and preliminary AI imaging interpretation alerts for LVO and ICH to ensure immediate specialist mobilization and expedite both treatment and transfer.

The second dimension of the RE-AIM framework is Effectiveness.[14] We involved our core stroke expert end users to evaluate the capabilities of RapidAI technology in relation to our system's imaging capabilities and practices. Once all were in agreement to adopt RapidAI, our stroke program leaders moved forward with information technology, security, and radiology leadership evaluation to ensure a clear understanding of AI technology workflow integration, along with the required infrastructure for successful implementation.

The third dimension of the RE-AIM framework is Adoption.[14] Adoption entails the need to ensure stakeholder buy-in while clearly articulating for each provider "what is in it for them." We carefully inventoried each participant along the stroke pathway, from stroke diagnosis to treatment decision making, and ongoing management in each of our centers. Along with these stakeholders, we were sure to continue to promote involvement of our information technology and security experts. Our hospital administrators were also involved to ensure corporate and systemwide administrative support for RapidAI integration. We found that involvement of all of these stakeholders created a strong sustainable partnership which became important throughout the implementation and maintenance dimensions, particularly when changes in stakeholder positions occurred over time.

The fourth dimension of the RE-AIM framework is Implementation.[14] We started this process by first integrating RapidAI into our CSC ensuring that workflows were optimized and all "bugs" were worked out. Following this, we gradually integrated RapidAI across our spoke sites; this step required strong program leadership with a deep understanding of the organizational structure and processes at each site. Because RapidAI reduces the time to evaluation and treatment of acute stroke patients while not replacing the contribution of each team member, we worked carefully to reinforce appropriate use of the technology and provide positive reinforcement as uptake succeeded. We were cautious to avoid the "Turing Trap" which implies that AI/ML will substitute technology for people, specifically stroke clinicians.[16] Rather, we ensured the focus was shifted toward adopting AI to enhance patient care and improve outcomes when used by providers with knowledge, skills and expertise in acute neurovascular care.[17]

The final dimension of the RE-AIM framework is Maintenance.[14] New technology adoption requires ongoing oversight to ensure that it is valued, utilized, and impacting the system in a positive and fruitful manner. This includes overseeing the success of program upgrades, rolling out new capabilities, and careful, meaningful quality monitoring with widespread sharing of results as they occur.

Furthering RapidAI Capabilities with Pulsara

To further interprofessional communication, our organization incorporated the Pulsara platform (Pulsara, Bozeman, MT). Pulsara is a comprehensive, interactive, on demand, HIPAA-compliant communication and logistics platform that allows bidirectional communication among emergency medical services (EMS) ambulance providers, emergency department, neurovascular clinicians, radiology, and other key stroke system stakeholders.[18] Pulsara has interoperability with RapidAI and incorporates the imaging link from RapidAI within the platform so that all providers, including ambulance personnel have the same communication and image capabilities. We have found Pulsara's interoperability to be critical to building and enhancing our relationships with EMS while streamlining our provision of performance feedback.

Our highly positive experience with Pulsara led to the Arkansas Department of Health securing the Pulsara communication platform across all of our state's EMS agencies, hospitals, other healthcare facilities, public health agencies, and emergency management systems.[19] Since Pulsara can be used as a communication tool for patients with various time sensitive diagnoses including stroke, the interoperability feature exclusive to RapidAI further justified our selection of this essential technology.

Next Steps for AI Supported Neuroimaging

While our manuscript summarizes the clinical implementation of AI, the evolution of AI should be valued by stroke clinicians as a method to support ongoing improvement in diagnosis and treatment decision making. Medium vessel occlusions (MeVO) account for 25% to 40% of ischemic stroke patients. At least 4 trials (DISTAL, DISCOUNT, ESCAPE-MeVO, AND DISTALS) are underway to assess whether endovascular treatment improves outcomes in these patients given that only 1 out of 4 MeVO patients attains functional independence with usual care and only 50% have an excellent outcome.[20] Detecting MeVO with AI software has historically been challenging due to the distal location, smaller vessel diameter, possible branches and tortuous course. Sowlat and colleagues determined that combining Rapid LVO with vessel density maps increased identification of MeVO in the ACA, MCA, and PCA territories by 27.6% in the P2/P3 territories to 71.4% in the A2/3 territories.[21] Others are exploring whether CTP Tmax improves detection of MeVO.[22] Since the results of the MeVO trials are not expected soon, stroke program leaders must monitor findings as they become available to determine acceptability for practice uptake.

Conclusion

We have found that implementation of AI supported neuroimaging in a hub and spoke model, especially use of technology with interoperability that promotes systemwide communication, can dramatically improve the daily workflow for emergency management of acute stroke patients. As recommended in the American Heart Association/American Stroke Association's scientific statement on stroke center foundations,[23] implementation of AI supported neuroimaging across the stroke system of care will play an important role in improving stroke patient outcomes, particularly in under-resourced smaller stroke center hospitals that have affiliated with a regional CSC. For hub and spoke systems of care, integration of AI technology is no longer just a strategic decision but is a necessity to improve workflows for time-sensitive diseases such as stroke.

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