Emerging Artificial Intelligence Imaging Applications for Stroke Interventions

Stroke is the most frequent cause of acquired disability and the fifth most frequent cause of death in the United States. Treatment options for acute ischemic stroke (AIS) caused by large-vessel occlusion (LVO) are rapid recanalization of the occluded large vessels using IV thrombolysis with alteplase (recombinant tissue plasminogen activator) within 4.5 hours and mechanical thrombectomy (MT) within 6 hours.[1] In either treatment, identifying a substantial and salvageable ischemic penumbra is essential for a patient to be eligible for therapy. Recent randomized controlled trials—Clinical Mismatch in the Triage of Wake Up and Late Presenting Strokes Undergoing Neurointervention with Trevo (DAWN),[2] Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3 (DEFUSE-3),[3] and Efficacy and Safety of MRI-based Thrombolysis in Wake-up Stroke (WAKE-UP)[4]—that revolutionized the management of patients with LVO stroke laid the foundation for a further revolution in the selection of patients eligible for late MT, up to 24 hours, regardless of whether they receive IV alteplase for the same ischemic stroke event. An ongoing phase III trial (Tenecteplase in Stroke Patients Between 4.5 and 24 Hours; TIMELESS) is investigating the efficacy of tenecteplase in an extended time window from 4.5 to 24 hours.[5] Because of rapid changes in the evidence, the American Heart Association/American Stroke Association updated their acute stroke guidelines from 2018, which replaced the 2013 guidelines.[6,7] In this context, a transition takes place from the concept of a "temporal therapeutic window" to that of a "cerebral tissue window" accounting for the degree of collateral perfusion, incorporating advanced neuroimaging methods, such as CT perfusion and MR imaging with FLAIR, diffusion, and perfusion-weighted imaging, for the assessment ischemic core (irreversibly damaged tissue) and of ischemic penumbra (potentially reversible ischemic tissue).[8] The best method for the correct selection of such patients is still a matter of debate. Nevertheless, because the benefit of reperfusion therapy decreases over time, it is critical to treat patients as quickly as possible before cell death ensues.

However, several challenges may limit the widespread clinical use of LVO stroke interventions, specifically MT. Indeed, only 13,000 MTs were performed in the United States as of 2016 (<2% of total AIS cases).[9] First, only an estimated 10% of patients with AIS have a proximal LVO in the anterior circulation and present early enough to qualify for MT within 6 hours,[10,11] but approximately 9% of patients presenting in the 6- to 24-hour time window may qualify for MT.[12] Second, after the patient arrives at a medical center, urgent imaging, either CT or MR imaging, is performed and must be promptly analyzed by qualified radiologists to determine if MT is required. However, image interpretation is subject to inconsistent local expertise and time delays and varies between institutions. Third, because of increasing centralization of acute stroke care at specialist facilities, only a few stroke centers have sufficient advanced neuroimaging and neurointerventional resources and expertise to deliver this therapy,[13] which make it necessary to transfer eligible patients from a primary stroke center to a comprehensive stroke center, many times after initiation of thrombolysis, a strategy called "drip and ship."[14] Even at experienced facilities, activation of interhospital communication for LVO triage and transport to a thrombectomy center can be operationally challenging.

To address this need, artificial intelligence (AI) tools using machine learning algorithms are being developed as a rapid clinical decision support system for complete assessment and identification of LVO. These tools can automatically generate quantitative measures, such as a patient's Alberta Stroke Program Early CT Score calculated on noncontrast CT, process perfusion maps and determine salvageable brain tissue on CT or MR perfusion imaging, and detect LVO on CT angiography. Thereafter, the resultant data are automatically delivered with email or text notifications on a cellphone application to the relevant emergency department and stroke team members, aiming to achieve faster onset-to-treatment time in fibrinolytic-eligible patients and MT-eligible patients. Additional outputs can be sent as DICOM images or to a web browser user interface.

Over the past several years, a few software platforms have been commercialized, of which some of the most popular are RapidAI (iSchemaView), e-Stroke-Suite (Brainomix Ltd) in collaboration with Olea Sphere (Olea Medical Solutions), and VIZ.ai (Viz.ai). Other similar solutions from different companies are being developed with different stages of pending European CE mark or FDA approval. The applications share the same concept but have variations regarding the algorithm and available features.

Initial clinical data focus mainly on accuracy and compare AI performance and precision with the interpretation of experienced radiologists. Albers et al[15] evaluated the performance of automatically generated RapidAI ASPECTS relative to scores determined by experienced radiologists and showed similar or even better relative accuracy of the automatic ASPECTS after comparison with matched DWI. Similar results were achieved using the e-ASPECTS software (Brainomix).[16,17] With regard to LVO detection in CTA, a recent study found sensitivity, specificity, and negative predictive value of 0.94, 0.76, and 0.98, respectively, using RapidAI software.[18] Recently, e-CTA software (Brainomix) was assessed for automated measurement of collateral score in 98 patients with LVO eligible for MT with sensitivity and specificity for identifying favorable collateral flow of 0.99 and 0.94, respectively.[19]

In the current *AJNR* issue, automatic AI-driven detection of LVO with Viz.LVO software was assessed on all head CTAs in a single comprehensive stroke center for 14 months. Sixty-one of 75 LVO cases were identified by the software (sensitivity = 0.81), with additional positive predictive value, negative predictive value, and accuracy of 0.65, 0.99, and 0.94, respectively. In stroke CTAs, subgroup results for sensitivity, positive predictive value, negative predictive value, and accuracy were 0.82, 0.64, 0.96, and 0.89, respectively.[20] As a screening tool, future versions of the software's algorithm should be oriented for higher sensitivity with an acceptable price of lower specificity and higher false-positive rates. The suboptimal sensitivity of Viz.LVO currently prevents it from being used as a diagnostic tool; however, early evidence supports its utility in reduction in time to treatment and improved clinical outcomes. Recently, the Centers for Medicare & Medicaid Services has granted Viz.ai the first New Technology Add-on Payment for AI software, up to $1040 per use in Medicare patients with suspected strokes.

To conclude, recent years have seen a substantial increase in the fraction of patients whose AIS can be treated with reperfusion therapy. Future development of AI applications that integrate software platforms intended for automatic rapid imaging review and provide a communication platform and optimized workflow to multidisciplinary teams will undoubtedly play a key role in more rapid and efficient identification of eligible candidates for reperfusion therapy, resulting in better neurologic outcomes.

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