Performance of CT Angiography on a Mobile Stroke Treatment Unit: Implications for Triage

Seby John, Sarah Stock, Thomas Masaryk, Andrew Bauer, Russell Cerejo, Ken Uchino, Stacey Winners, Peter Rasmussen, Muhammad S. Hussain

From the Cerebrovascular Center (SJ, TM, AB, RC, KU, SW, PR, MSH); and Department of Neuroradiology (SS, TM), Cleveland Clinic, Cleveland, OH.

ABSTRACT

BACKGROUND: There is a strong inverse relationship between outcome in patients with acute ischemic stroke from emergent large vessel occlusion (ELVO), and time to reperfusion from intra-arterial therapy. Delay in transferring patients to thrombectomycapable centers is currently a major limitation. The mobile stroke unit (MSU) concept with onboard portable computed tomography (CT) scanner enables rapid performance of CT angiography (CTA) of the intracranial vessels to detect ELVO in the field, and allows for rapid triage of patients to interventional-capable centers.

METHODS: Our institution implemented a mobile stroke treatment unit (MSTU) program that started on July 2014, and CTA capability was added on April 2015. The eligibility criteria, equipment, and method of CTA imaging are described. We report the first case of CTA being performed in the field in the United States to aid in triage of ELVO patients.

RESULTS: MSTU was dispatched for reported new onset of right hemiparesis in a patient. Teleneurological assessment detected findings consistent with a severe left middle cerebral artery (MCA) syndrome. Noncontrast CT head revealed left lenticulostriate hypoattenuation. A CTA was performed subsequently on the MSTU that showed an MCA cutoff. Based on these findings, patient was immediately transferred to the main hospital with neurointerventional capability, where he underwent successful recanalization with improvement in symptoms.

CONCLUSION: CTA is possible on an MSTU, enabling rapid detection and triage of ELVO cases directly to thrombectomy-capable centers, which significantly reduces time to endovascular treatment.

Keywords: Acute stroke, Mobile Stroke Unit, emergent large vessel occlusion, computed tomographic angiography.

Acceptance: Received January 3, 2016, and in revised form February 14, 2016. Accepted for publication February 24, 2016.

Correspondence: Address correspondence to Muhammad Shazam Hussain, MD, 9500 Euclid Ave, S80, Cleveland, OH 44195. E-mail: hussais4@ccf.org

Disclosures: All authors report no conflict of interest or financial disclosures. Funding sources: None. Acknowledgments: This work is supported by Cleveland Pre-Hospital Acute Stroke Treatment (PHAST) Group.

J Neuroimaging 2016;00:1-4. DOI: 10.1111/jon.12346

Introduction

The Challenge

Recently, multiple randomized clinical trials have unequivocally shown the benefit of intra-arterial therapy (IAT) for selected patients with acute ischemic stroke (AIS) from emergent large vessel occlusion (ELVO).^{1–5} There is a strong inverse relationship between outcome and time to reperfusion.⁶ Majority of delays to reperfusion occur before the start of IAT,⁷ and the delay in transferring patients to thrombectomy-capable centers is a major limitation.⁸

The Innovation

The mobile stroke unit (MSU) concept developed in Germany consists of an ambulance equipped with portable computed tomography (CT) scanner and laboratory capabilities, which brings the CT to the patient experiencing stroke. Initial MSU experiences from Saarland and Berlin have demonstrated remarkable improvements in time to intravenous thrombolysis administration.^{9,10} The on board CT scanner can perform CT angiography (CTA) of the intracranial vessels, to detect ELVO and allow for rapid triage of patients to interventional-capable

centers. We describe the first report of CTA being performed in the field in the United States to aid in triage of ELVO patients.

Methods

Cleveland Clinic implemented a mobile stroke treatment unit (MSTU) program that started on July 18, 2014 (Fig 1). The equipment and staffing of this vehicle have been published previously.^{11,12} CTA capability was added to the MSTU on 4/13/15. Once the nonenhanced CT of the brain and neurological assessment via telemedicine are completed, the technologist on board may be instructed to proceed with a CTA if findings are suggestive of a potential LVO by the vascular neurologist performing the telemedicine evaluation. The CTA eligibility protocol is based on patient criteria of an NIHSS \geq 6, fluctuation of symptoms, a single focal deficit that may indicate an LVO, and/or a hyperdense vessel on unenhanced CT. Additionally, the patient needs to be able to remain still for the examination and point of care creatinine and eGFR should be within normal range for administration of intravenous (IV) contrast. IV access with an 18 gauge or larger peripheral IV is recommended, preferably antecubital. The patient is repositioned



Fig 1. Exterior of Cleveland Clinic MSTU vehicle.

in the scanner, and immobilized. A single slice scan at the level of C1-C2 is performed. This scan serves as a reference to be used with a contrast tracking feature on the scanner. Contrastenhanced helical images are obtained, extending from the skull base through the Circle of Willis at 1.25 mm slice thickness. Eighty cubic centimeters of Optiray 350 is injected at a rate of 4 cc/second using a single lumen Liebel-Flarsheim Optistat injector. Technical parameters include tube current of 7 mA, peak kilovoltage of 120 kVp, at a pitch of 1. Images are transmitted to the vascular neurologist and radiologist for review. Once the CTA is obtained, images are transmitted to the vascular neurologist and neuroradiologist. The vascular neurologist interprets the images and is able to make treatment decision based on it. The neuroradiologist also provides an official read of the imaging.

Results

MSTU was dispatched for reported right hemiparesis in a 47-year-old male with history sarcoma and cardiomyopathy secondary to successful chemotherapy. He was last known well at 2100 hours the night before. MSTU arrived on the scene at 1421 and he was transported into the truck at 1423 (time 00:00). Telemedicine evaluation revealed a National Institute of Health Stroke Scale score of 14 for left gaze preference, dense right hemiparesis, right facial droop, aphasia, and dysarthria. Noncontrast CT head (+15 minutes) showed left lenticulostriate hypoattenuation (Alberta Stroke Program Early CT Score [ASPECTS] 7). CTA (+28) revealed a mid-M1 middle cerebral artery (MCA) cutoff (Fig 2). Patient arrived at the main hospital (+47 minutes) and was taken for a hyperacute magnetic resonance imaging (MRI) scan that showed restricted diffusion limited to the left basal ganglia and left temporal pole. He was taken for emergent IAT (groin puncture +107 minutes), in which successful recanalization of a completely occluded M1 segment was achieved (+137 minutes) (Fig 3). His examination improved postprocedure with resolution of all cortical signs, but persistent right-sided hemiparesis (NIHSS 8). He was discharged to an acute rehabilitation facility within 48 hours.

Discussion

Key features that led to the success of the recent clinical trials compared to the previous failed studies were improved patient selection by requiring CTA documentation of vessel occlusion, and utilization of modern stent-retriever therapy that achieved faster and more complete recanalization. Similar to previous trials, they have also demonstrated striking proportionality between patients achieving good outcome and successful recanalization, and good outcome to the time from last seen normal to groin puncture. Therefore, it is imperative that advanced imaging for IAT selection is efficiently integrated into stroke system workflows to ensure rapid assessment and treatment.

The translation from positive trials to a widely used and similarly effective therapy poses additional challenge in terms of rapid and effective triage to appropriate treatment. Currently, patients with suspected stroke are transported to the nearest stroke center, diagnosed and treated with intravenous alteplase if eligible, and then receive evaluation for IAT onsite or at a thrombectomy-capable hospital ("drip and ship"). Many primary stroke centers (PCSs), acute stroke ready hospitals, or equivalents do not have the resources for performing thrombectomy or round the clock CTAs. As such, the "hub-and-spoke" model of interfacility transfers is becoming commonplace and a large proportion of patients eligible for and treated with IAT will eventually be transferred from PSCs to thrombectomy-capable hospitals. A recent single-center retrospective study suggested that for every minute of delay in transfer, there is a 2.5% lower probability that a patient receives IAT.8 With the known strong correlation of time and stroke outcome, such delays are expected to produce lower than anticipated outcomes with IAT. A recent publication from the Madrid Stroke Network demonstrated for the first time the rate of futile interhospital transfers for stroke IAT.¹³ In this study, 41% of patients who were transferred from the first hospital to an IAT-capable center did not eventually undergo endovascular treatment. Clinical improvement or arterial recanalization was the most common cause for not performing the procedure. However, repetition of neuroimaging tests and its findings in the receiving hospital was the second most common cause for ineligibility of IAT performance.

The implementation of CTA in the context of the MSTU concept offers a novel solution for expedited triage among varying levels of regional stroke centers. Successful performance of multimodal CT imaging on an MSU was first demonstrated in Saarland, Germany.¹⁴ With capabilities for performing CT and CTA in AIS patients, it not only allows for immediate prehospital treatment with intravenous thrombolysis, but also enables expeditious triage of patients with ELVO to IAT-capable hospitals. The clinical presentation, CT APSECTS score, and presence or absence of target vessel occlusion taken together already provide majority of the information needed to determine eligibility for IAT. Additional advanced imaging paradigms may be performed per institutional protocols to ensure optimal eligibility and is supported by recent trials. While the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands (MR CLEAN)¹ was least selective about excluding patients requiring no additional imaging criteria beyond the need to demonstrate a proximal arterial occlusion, other studies used low ASPECTS on noncontrast CT, poor collaterals on multiphase CTA, or large ischemic core CT perfusion for exclusion.²⁻⁴

In our initial experience of patients triaged by the MSTU (prior to CTA capability) who underwent IAT, we identified substantial reduction in the first "picture-to-puncture" time

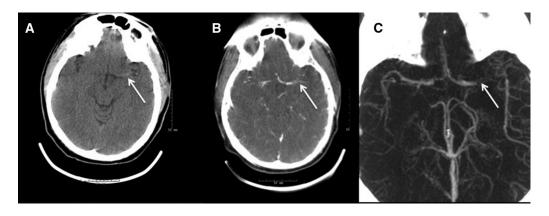


Fig 2. Axial unenhanced mobile CT (A) demonstrates a hyperdense left MCA sign (arrow). Mobile CTA (B and C) shows a cutoff in the left M1 segment (arrow). MCA = middle cerebral artery.

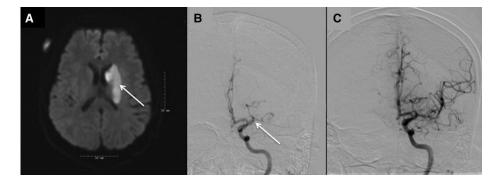


Fig 3. Axial-diffusion-weighted images from the hyperacute MRI (A) show restricted diffusion in the corona radiata and caudate head (arrow). Pre- (B) and postintervention (C) digital subtraction angiography images show occlusion of the left M1 segment (arrow), with subsequent thrombolysis in cerebral infarction 2b grade recanalization.

compared to historical controls.¹¹ This was largely driven due to direct transport of potential IAT-eligible patients to a neurointerventional-capable center. Breakdown of time metrics revealed that although time from Emergency Medical Services (EMS) dispatch to arrival at the PSC (control group) was similar to the MSTU, significantly longer time was spent in the PSC before the patient was eventually transferred to a thrombectomy-capable center. The door to MSTU departure was 37 minutes, compared to departure from the PSC in historical controls, which took 106 minutes. Consequently, the time from first door to groin puncture (93 vs. 200 minutes) and the first picture to groin puncture (82 vs. 165 minutes) was significantly shorter in the MSTU group. Multiple time metrics have been proposed for IAT in AIS, including door-to-puncture⁷ and picture-to-puncture,¹⁵ both of which measure in part delays associated with patient transfer. In the current case, these times were 107 and 92 minutes, respectively, despite the performance of an MRI that was required to establish viable tissue given the long time from last normal. Irrespective of the metric used, the MSTU reconfigures these times by bringing the emergency room to a patient with stroke and directly transporting to the appropriate center, obviating additional hospital stops in between. In addition to interfacility transport times, it is also faster to perform CT followed by CTA in the same scanner, rather than performance of a CT followed by CTA in two separate scanners at different locations.

While MSTU holds significant promise for improving outcomes in AIS patients eligible for IAT by decreasing time

to IV thrombolysis and time to IAT, the associated operational costs may pose additional considerations to this strategy. The Stroke Emergency Mobile unit (STEMO) consortium from Berlin, Germany, recently reported improved prehospital triage of stroke patients, both ischemic and hemorrhagic to appropriate centers compared to conventional care.¹⁶ Dietrich et al of the Saarland group performed a 1-year cost-benefit analysis of the MSU concept of prehospital stroke treatment across a number of different scenarios.¹⁷ They calculated a 1.96 benefitcost ratio in the baseline experimental setting, with increase in the benefit-cost ratio with higher population density. The ratio could also be markedly increased with the reduction of staff. This can be achieved with the use of telemedicine, as utilized in the Cleveland MSTU. Although further studies are required, these data lend support to the cost effectiveness of this novel treatment strategy. Another potential limitation for performing mobile CTA is that due to the smaller bore and limited craniocaudal axis translation inherent to the portable CT equipment employed (35 and 25 cm, respectively),¹⁸ only CTA of the head as opposed to the more conventional CTA of the neck and head is currently feasible on the mobile unit. Thus, if there is clinical need to characterize more proximal disease, additional vessel imaging may be necessary.

Conclusion

CTA is possible on an MSTU, enabling rapid detection and triage of ELVO cases directly to thrombectomy-capable centers. Further experience is warranted to explore the feasibility of routine use of this imaging strategy.

References

- Berkhemer OA, Fransen PS, Beumer D, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. N Engl J Med 2015;372:11-20.
- Goyal M, Demchuk AM, Menon BK, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 2015;372:1019-30.
- Campbell BC, Mitchell PJ, Kleinig TJ, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med 2015;372:1009-18.
- Saver JL, Goyal M, Bonafe A, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015;372:2285-95.
- Jovin TG, Chamorro A, Cobo E, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. N Engl J Med 2015;372:2296-306.
- Khatri P, Yeatts SD, Mazighi M, et al. Time to angiographic reperfusion and clinical outcome after acute ischaemic stroke: an analysis of data from the Interventional Management of Stroke (IMS III) phase 3 trial. Lancet Neurol 2014;13:567-74.
- Sun CH, Ribo M, Goyal M, et al. Door-to-puncture: a practical metric for capturing and enhancing system processes associated with endovascular stroke care, preliminary results from the rapid reperfusion registry. J Am Heart Assoc 2014;3(2):e000859.
- Prabhakaran S, Ward E, John S, et al. Transfer delay is a major factor limiting the use of intra-arterial treatment in acute ischemic stroke. Stroke 2011;42:1626-30.
- Walter S, Kostopoulos P, Haass A, et al. Diagnosis and treatment of patients with stroke in a mobile stroke unit versus in hospital: a randomised controlled trial. Lancet Neurol 2012;11:397-404.

- Ebinger M, Winter B, Wendt M, et al. Effect of the use of ambulance-based thrombolysis on time to thrombolysis in acute ischemic stroke: a randomized clinical trial. JAMA 2014;311:1622-31.
- Cerejo R, John S, Buletko AB, et al. A mobile stroke treatment unit for field triage of patients for intraarterial revascularization therapy. J Neuroimaging 2015;25:940-5.
- Itrat A, Taqui A, Cerejo R, et al. Telemedicine in prehospital stroke evaluation and thrombolysis: taking stroke treatment to the doorstep. JAMA Neurol 2015;7:1-7.
- Fuentes B, de Leciñana MA, Ximénez-Carrillo A, et al. Futile interhospital transfer for endovascular treatment in acute ischemic stroke the Madrid Stroke Network experience. Stroke 2015;46:2156-61.
- Kostopoulos P, Walter S, Haass A, et al. Mobile stroke unit for diagnosis-based triage of persons with suspected stroke. Neurology 2012;78:1849-52.
- Sun CH, Nogueira RG, Glenn BA, et al. "Picture to puncture": a novel time metric to enhance outcomes in patients transferred for endovascular reperfusion in acute ischemic stroke. Circulation 2013;127:1139-48.
- 16. Wendt M, Ebinger M, Kunz A, et al. Improved prehospital triage of patients with stroke in a specialized stroke ambulance: results of the pre-hospital acute neurological therapy and optimization of medical care in stroke study. Stroke 2015;46:740-5.
- Dietrich M, Walter S, Ragoschke-Schumm A, et al. Is prehospital treatment of acute stroke too expensive? An economic evaluation based on the first trial. Cerebrovasc Dis 2014;38:457-63.
- John S, Stock S, Cerejo R, et al. Brain imaging using mobile CT: current status and future prospects. J Neuroimaging 2016;26: 5-15.