Establishing the First Mobile Stroke Unit in the United States

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Background and Purpose—Recently, the Mobile Stroke Unit (MSU) concept was introduced in Germany demonstrating prehospital treatment of more patients within the first hour of symptom onset. However, the details and complexities of establishing such a program in the United States are unknown. We describe the steps involved in setting up the first MSU in the United States.

Methods—Implementation included establishing leadership, fund-raising, purchase and build-out, knitting a collaborative consortium of community stakeholders, writing protocols to ensure accountability, radiation safety, purchasing supplies, licensing, insurance, establishing a base station, developing a communication plan with city Emergency Medical Services, Emergency Medical Service training, staffing, and designing a research protocol.

Results—The MSU was introduced after ≈1 year of preparation. Major obstacles to establishing the MSU were primarily obtaining funding, licensure, documenting radiation safety protocols, and establishing a smooth communication system with Emergency Medical Services. During an 8 week run-in phase, ≈2 patients were treated with recombinant tissue-type plasminogen activator per week, one-third within 60 minutes of symptom onset, with no complications. A randomized study to determine clinical outcomes, telemedicine reliability and accuracy, and cost effectiveness was formulated and has begun.

Conclusion—The first MSU in the United States has been introduced in Houston, TX. The steps needed to accomplish this are described.

Key Words: acute stroke ■ ambulance ■ EMS ■ prehospital ■ thrombolysis

The importance of shortening time to treatment for improving outcome in acute stroke patients treated with recombinant tissue-type plasminogen activator (r-tPA) is a consistent finding in all preclinical and clinical studies[1–8] and has been identified recently in clinical trials of endovascular approaches as well.[9] Although this relationship to time is particularly true for reperfusion of acute ischemic stroke, it probably also applies for other acute stroke therapies, such as cytoprotection or preventing hemorrhage enlargement after spontaneous or coagulopathic intracerebral hemorrhage.

Recently, 2 groups in Germany have put a computed tomography (CT) scanner on an ambulance, along with either on-board or remote (via Telemedicine) stroke expertise, and point of care laboratory testing to take the stroke unit to the patient to allow earlier treatment.[10,11] This Mobile Stroke Unit (MSU) concept moves stroke treatment to the prehospital environment from the Emergency Department (ED), where there are inherent delays caused by ED triage, registration, evaluation, testing, and treatment. In fact, despite 2 decades of efforts to streamline ED systems of care, including formation of designated stroke centers, proliferation of telemedicine support, placement of CT scanners in the ED, dedicated 24/7 in-house stroke teams, and ED pathways to speed treatment, the median door-to-needle time in stroke center EDs in the United States approximates 60 minutes,[12] and most patients are treated beyond 2 hours when r-tPA is less effective.[8] Fewer than 1% are treated within the first hour after symptom onset. Such delay not only likely results in less patients completely recovering, but reduces the total number of patients who can be treated within the 4.5 hour maximum time window of r-tPA effectiveness, contributing to the overall low national treatment rate estimated to be ≈5% of all acute ischemic stroke.[1]

Received November 4, 2014; final revision received February 3, 2015; accepted February 6, 2015.

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Guest Editor for this article was Natan M. Bornstein, MD.

The online-only Data Supplement is available with this article at http://stroke.ahajournals.org/lookup/suppl/doi:10.1161/STROKEAHA.114.007993/-/DC1.

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(*Stroke*. 2015;46:1384-1391. DOI: 10.1161/STROKEAHA.114.007993.)

Using their MSUs in Homberg and Berlin Germany, Walter et al achieved a median onset to treatment time with r-tPA of 70 to 80 minutes[10] and Ebinger et al increased r-tPA treatment rates from 21% to 33%, shortened time to treatment by 25 minutes, and increased the proportion of patients treated within 90 minutes of symptom onset from 37% to 58%.[11] Despite the logic and preliminary success of the MSU concept, however, many questions remain before it can be advocated for widespread adoption in the United States. Some of these questions can only be answered by a trial comparing MSU to standard management, such as how much better outcome will occur with such ultra-early treatment, and what are the costs versus benefits. Others will be specific to the particular practice environment where the MSU is implemented and include the financial, regulatory, legal, and logistic steps needed. There is no existing pathway for identifying, approaching, and solving these issues in the United States

To address these gaps, in March 2013, we embarked on establishing the first MSU in the United States in Houston, Texas. Herein, we describe the steps needed to fund, design, build, license, credential, insure, supply, and put into daily operation this project, and our initial experience, to help inform those who would like to establish their own MSU programs. Our MSU was intended to operate as a research project under a prospective randomized protocol comparing MSU to Standard Management. The study design and research-specific aspects of our program will be described in a separate report. Our purpose here is to describe the nuts and bolts of establishing this program.

Methods

The following steps were taken more or less chronologically but in parallel between March 2013 and February 2014.

1. Establishing project leadership. The Principle Investigator (PI; J.C. Grotta) identified a project manager (PM; S.A. Parker) to assist with the steps listed below. Essential job requirements of the project manager (PM) were experience with bedside medical management of critically ill acute stroke patients, conducting clinical research and regulatory requirements, excellent organizational skills, and commitment to work in the prehospital environment. Within a few months, it became clear that the work involved would require 100% effort by the PM and at least 50% effort by the PI. The PI recruited a 50% faculty collaborator (E.A. Noser) and 80% administrator to help with fund-raising and project administration, and in Feb 2014, he resigned his academic position and reduced his other clinical responsibilities to devote 80% effort to the MSU project, including Emergency Medical Services (EMS) training and staffing the MSU once it was online.
2. Funding. A budget was established for 3 years operation. See Table 1 for costs excluding personnel and r-tPA (see Discussion). The Houston MSU is funded largely from philanthropic funds donated to 501C3 or 509A1 accounts at the University of Texas Medical School (UT) and Memorial Hermann Foundation. No funds were contributed by the city of Houston, hospital, or medical school. Between March and December 2013, ≈$1 500 000 was raised and another $200,000 contributed via grants from Genentech (Genentech Corp, South San Francisco, CA) and Covidien (Covidien, Mansfield, MA).
3. Purchase and build-out. A manufacturer of emergency medical vehicles located in Houston, Texas, offered to donate the ambulance box and was contracted to build the MSU on the footprint of a standard 12 foot ambulance currently in use by the City of Houston Fire Department EMS. After the first $750,000 was raised into the account at UT, the Ceretom CT scanner (Neurologica, Danvers MA) was purchased by UT on October 11, 2013. Important modifications of the standard ambulance included reinforcing the front wall and floor to accommodate the CT scanner mounts, installing brackets to lock the CT scanner in the stowed position during transit, wiring in an extra shore power circuit to power the CT scanner's charging circuit, upgrading the standard on-board generator to provide additional power for the CT scanner, modifying the floor to allow the gurney to be raised aligning the patient's head with the scanner when performing a scan, and miscellaneous modifications to the patient compartment to facilitate the scanner operator's work flow. It was necessary to bring the base height of the scanner down 3.5 inches by removing the fenders and caster wheels from the retail design. A Chevrolet chassis was purchased, and the completed MSU was delivered to UT on February 3, 2014 (see Figure 1A and 1B).
4. Collaboration with stakeholders. At the outset of the project, the PI approached the Medical Director of Houston EMS (D. Persse) who enthusiastically agreed to collaborate provided that no city funds were to be allocated and that a plan be designed to ensure that patients be delivered equally to the 3 Comprehensive Stroke Centers (CSCs) in the city and any subsequent CSCs that became certified. The Directors of those stroke programs and emergency departments (UT Medical School/Memorial Hermann Hospital (MHH), The Methodist Hospital, and Baylor College of Medicine/St Luke's Hospital) were approached and agreed to participate. The PI drew up a plan for MSU project collaboration among these stakeholders (Houston Mobile Stroke Unit Consortium). A Clinical Trial Agreement was then signed with each of the institutions.
5. Develop accountability system. To be certified as an ambulance, it was necessary to write and implement physician standing orders/protocols for the various conditions we were likely to encounter consistent with existing Houston EMS standards. These included adult Advanced Life Support protocols for seizure, myocardial infarction, and airway and Advanced Cardiac Life Support protocols for managing serious arrhythmias and cardiac arrest (see online-only Data Supplement). In addition, guidelines were developed for staff expectations, including quality assurance and quality improvement for all equipment, maintenance, and certifications.
6. Radiation safety. Once the CT scanner was purchased, an operation and safety procedures manual for the scanner and its operation was written to establish compliance for the operation, maintenance, quality assurance, and safety of operators and patients. The manual included the following:
   a. Product information—manufacturer, model, product information sheet, radiation dose mapping showing radiation levels at different distances.
   b. The general purpose of the scanner (to perform CT Brain without contrast to evaluate patients with acute signs and symptoms of stroke).
   c. Estimation of the frequency of use for the scanner.
   d. A layout showing the normal configuration of the CT scanner and basic components within the vehicle, such as the doors, and personnel location. The layout included all dimensions, the operator's position, and any ancillary personnel's location during exposures. The protective shielding was also described.

Approval for the policies and procedures were submitted to the Radiation and Safety Council/Board consisting of physicists, a neuroradiologist, and radiation safety specialists within the MHH/UT system. Once approved within the institution, the state health application for radiation safety was submitted with all exhibits, including policies and procedures. Once this was complete, a shielding evaluation by a licensed medical physicist was completed.

7. Supplies. The MSU was stocked for adult Advanced Life Support, including oxygen, Zoll X series monitor (Zoll

Medical Corp, Chelmsford MA), IV pumps, suction, various needles, syringes, IV tubing and catheters, bandaging, intubation equipment, Advanced Life Support required medications, r-tPA, Labetalol, Nicardipine, Midazolam, Point-of –Care Laboratory equipment, including an i-STAT (Abbot Point of Care, Princeton, NJ) with printer, Chemistry, PT/INR cartridges and controls for quality assurance, and InTouch RPx express with a 4G wifi connectivity (INTOUCH Health, Santa Barbara, CA). A Stryker power pro X gurney (Stryker Corp, Kalamazoo, MI) in standard use by Houston EMS was also purchased.

8. Licensing. Because the state of Texas had a moratorium on new ambulance provider licenses, the MSU was licensed as an ambulance by the Texas Department of State Health Services (TxDSHS) under the existing ambulance license of the MHH air ambulance service (Life Flight). This required that the MSU be leased by MHH from UT who had purchased and owned the MSU. An Ambulance Provider License and Ambulance Driving Permit were obtained from the City of Houston Health Department, and Radiation Safety Permit was obtained from TxDSHS. All permits required inspection by the individual departments at state and city level.
9. Insurance. The MSU required full commercial emergency vehicle insurance coverage carried by UT. The equipment and scanner required increased property insurance coverage. The physicians, nurses, CT technician, and paramedics on board the MSU were covered for liability and malpractice under their existing employment contracts with UT or MHH.
10. Establishing a base station. An office for the MSU staff, including the PI, PM, CT technician, and paramedic, with computer, phone, and radio connectivity with EMS was rented in the Texas Medical Center, within one-quarter mile of all 3 CSCs. A secure parking place for the MSU with video surveillance was rented adjacent to the office (down one elevator) and power supply routed to the parking space.
11. EMS communications. Initially, it was decided that the MSU would respond to all acute stroke 911 calls to Houston EMS, as well as to the cities of Bellaire and West University Place, from within a 5 mile radius of the MSU base station and CSCs. The 5 mile radius was determined because the average on-scene time for Houston EMS is ≈ 15 minutes, and pilot runs indicated that 5 miles was about the distance the MSU could travel during peak traffic hours in 15 minutes. The goal was for the MSU to arrive on scene before the EMS unit leaves the scene to not delay EMS standard of care processes. A pathway was developed for notifying the MSU by the dispatch centers of these 3 cities following a 911 call suggestive of an acute stroke. This was accomplished by giving the MSU an apparatus name and dedicated beeper number which was called by the dispatch centers for any suspected stroke within the 5 mile catchment area.

In addition, the MSU team was equipped with 2 Houston EMS radios enabling the MSU team to directly contact the EMS squad in the field and also monitor all dispatches from the Houston dispatch center. The paramedics and first responders were encouraged to call for the MSU (either via the dispatch center or direct dedicated cell phone number) if they identified a patient with a stroke once on-site, even if not dispatched as such, or if they planned to deliver a stroke patient to one of the CSCs if they were coming from beyond the 5 mile catchment area. In addition, if the MSU team heard over the radio of a stroke dispatch outside our 5 mile catchment for which we were not alerted, we were able to add ourselves on to the dispatch by directly contacting the EMS squad involved. Finally, if the EMS squad on site was ready to transport the patient before MSU arrival, we could arrange to rendezvous with EMS en route to the Texas Medical Center and evaluate the patient at the rendezvous site.

Other aspects of MSU communications include the following:

a. Mobile Data Terminal: to enable dispatch location communications with Houston Fire Department and create a timeline of events for each dispatch.
b. Intercom system within the MSU: Because the CT scanner covers the entire back wall of the MSU, an intercom system was placed within the MSU to allow communication between the front and rear compartments.
c. Data cradle for Telemedicine and CT scanner connections: 4G and static wifi connectivity was established to allow for scanned images to be pushed to destination CSCs, as well as Telemedicine physicians.
d. Health Insurance Portability and Accountability Act (HIPPA) compliant DICOM Sharing grid for sharing CT images: because we are taking patients to 3 different independent CSCs, we had to develop a HIPPA compliant DICOM sharing grid that enabled us to push images to the different CSCs.

12. Training. All physicians and nurses staffing the MSU were Advanced Cardiac Life Support certified. The MSU operates under a research protocol (see No. 14) and training occurred in context of that protocol. The research, nursing, and physician members of the Stroke Teams and Emergency Department staffs at all 3 CSCs were in-serviced on the protocol and MSU operations and offered the opportunity to share in the MSU on-call schedule. The Telemedicine staff at UT Medical School was instructed on MSU-Telemedicine operations, communications, and the Telemedicine case report form. All EMS providers in the region, including Houston, Bellaire, and West University, operate under the umbrella of the Southeast Texas Regional Advisory Council, which was also in-serviced. Two thousand two hundred of the 4000 Houston EMS first responders, paramedics, dispatchers, and call receivers, as well as all incoming cadets on a monthly basis, were in-serviced on the MSU program, their responsibilities, and given a tour of the MSU. All West University and Bellaire dispatch and Fire Department/EMS personnel were also in-serviced. Importantly, the on-scene coordination of MSU and EMS activities were reviewed and rehearsed with all paramedics and first responders at fire stations likely to respond to calls within 5 miles of the MSU base station. It was anticipated that the MSU would arrive on scene before the EMS squad departed from the scene with the patient, and if it was determined jointly by the EMS squad and the MSU team that the patient had stroke symptoms which may be treated on the MSU, they would be moved into the MSU and evaluated. Once the patient was moved onto the MSU, they would be transported by the MSU team even if not treated with r-tPA. This also allows the EMS teams to go back into service. It was emphasized that if the patient was managed in the MSU, they would be delivered to whichever of the CSCs would have been the destination of the patient if transported by EMS. For those patients without any prior medical record at any of the CSCs or their affiliates, they were taken to the 3 CSCs on a rotating basis. Finally, if the EMS squad was ready to depart the scene before arrival of the MSU, rendezvous with the MSU en route could be arranged.
13. Staffing and scheduling. The MSU is staffed at all times by a Vascular Neurologist (VN) and Registered Nurse with Advanced Cardiac Life Support training and on staff at all 3 CSCs, a licensed CT radiology technician with BLS certification, and a licensed paramedic with Advanced Cardiac Life Support certification. Another VN was also available remotely via Telemedicine. The protocol calls for the MSU to be on call from 8 am to 6 pm daily from Tuesday morning to Monday evening on 50% of weeks (see No. 14). The CT technician, paramedic, and Telemedicine VN work only on these MSU-on weeks. On the other 50% of weeks (MSU-off weeks), the nurse responds to calls from dispatch, but the MSU itself is not deployed.
14. Research protocol. The MSU operates under a research protocol entitled Benefits of Stroke Treatment Delivered Using a Mobile Stroke Unit Compared to Standard Management by Emergency Medical Services—BEST-MSU Study, approved by the UT-Houston IRB on November 1, 2013, clinicaltrials.gov NCT02190500. The protocol will be described

in detail in a subsequent publication. In summary, the BEST-MSU study aims to answer 3 questions. (1) How much can an MSU speed and increase treatment of ischemic stroke patients with r-tPA compared with standard management (SM), especially within the first 60 minutes from onset? (2) Can the VN aboard the MSU be replaced by a remote VN via Telemedicine? (3) What are the costs of implementing and maintaining an MSU and the healthcare costs of patients transported compared with SM. On 50% of weeks, by blocked randomization, the MSU travels to the site of the call or rendezvous with EMS and evaluates the patient. If the patient meets inclusion criteria (symptom onset within 4.5 hours and meeting guidelines for r-tPA), they are enrolled into the study and moved into the MSU. If after CT scan and point-of-care laboratory testing on the MSU, the patient still fulfills criteria for r-tPA according to the on-site VN (the patient is simultaneously evaluated via Telemedicine with the remote VN making an independent decision), they are immediately given r-tPA and transported to one of 3 CSCs. If the patient does not meet r-tPA criteria, they are managed as per best practice for their diagnosis en route to the CSC. On the other 50% of weeks (SM weeks), the nurse meets the patient without the MSU, determines eligibility by the same criteria, but the patient is transported and managed per current EMS routine. Enrollment, r-tPA treatment, and follow-up assessments are adjudicated by an investigator who is blinded to MSU versus SM assignment. Informed consent is obtained from the patient or next of kin at the CSC after all acute stroke care is complete to obtain follow-up data at 1, 3, 6, and 12 months in 248 patients to answer the 3 aims. The Data Management Center and Health Economics Center is at the UT School of Public Health.

Results

The MSU was delivered on February 3, 2014, and after completion of inspections, licensing, staffing, and supplying, went into service on May 14, 2014. According to a prespecified plan, the MSU was activated for an 8 week run-in phase to test the communication system, rehearse interactions between EMS, the MSU team, and the remote Telemedicine VN, test out the case report forms, and confirm projected MSU activity and treatment rates. Randomization into the BEST-MSU study commenced on August 19, 2014, and the investigators remain blinded to data collected after that date. Here we will present the results for the 8-week run-in period.

The MSU was staffed from 8 am to 6 pm during run-in by a single CT tech, the PI, the PM, one of 5 off-duty Houston EMS credentialed paramedics, and for about half the time by a remote VN via Telemedicine.

Initially, the MSU was dispatched only from the Houston dispatch center, with Bellaire and West University coming on board during that interval. In addition, during the run-in phase, we implemented the rendezvous system for stroke patients identified beyond the 5 mile catchment area where we were unable to arrive before EMS departure from the scene.

The MSU was dispatched by the dispatch center on 130 occasions, or roughly 2.7/d. The MSU was disregarded en-route to the scene for 41 of these dispatches when it was determined by either the first responders or paramedics to not fit study criteria. For another 65 of these dispatches, the MSU team arrived on scene, assessed the patient, and determined the patient did not qualify (see Table 2 for on-scene diagnoses of these patients). These 106 patients were considered screen failures. They were transported as per EMS routine, and no further data were obtained.

Twenty-four patients met criteria for enrollment (symptom onset within 4.5 hours, and meeting published criteria for r-tPA treatment pending CT scan and baseline laboratories; see Table 3). Eleven of these patients were not treated. Four had primary intracerebral hemorrhage and had their blood pressure acutely lowered according to current standard of care protocol at our ED. Three had seizures on board the MSU, which were thought to be the cause of their presentation and which were treated on board the MSU. Two patients improved to the point where the MSU staff determined that r-tPA was not indicated. The time of onset could not be confidently determined in 1 patient, and 1 had a subdural hematoma. Thirteen patients were treated with r-tPA on the MSU; 4 (31%) between 0 and 60 minutes of onset, 4 (31%) between 61 and 80 minutes from onset, and 5 (38%) between 81 and 270 minutes of onset (Figure 2A–2D). Average baseline NIHSS score was 11.2 and average on-scene time from MSU arrival to r-tPA bolus was 24 minutes (range 12–53) in the 13 treated patients. There were no hemorrhagic or other complications and no malfunctions of the CT scanner or MSU. The intravenous infusion pump malfunctioned on one patient, and the i-STAT device malfunctioned because of heat on one occasion. Telemedicine assessment of the patient was performed successfully in all 11cases in which remote assessment was attempted, and agreement between the remote and on-site VN was 91%. Three of our 13 patients had endovascular treatment with onset to groin times of 224, 140, and 150 minutes. Ninety day mRS was 0 or 1 in 33% of tPA-treated patients and was within 1 point of baseline mRS in 58% (3 patients had baseline mRS >1).

Discussion

The first MSU in the United States has been introduced in Houston, Texas, after ≈1 year of preparation. Before our study, there had been no previous experience implementing an MSU in the United States, so we did not know the steps needed ahead of time to get our MSU up and running. We found that major obstacles to establishing the MSU were primarily obtaining funding, licensure, documenting radiation safety protocols, and establishing a smooth communication system with EMS. The latter remains a work in progress. Although most of our enrollments have resulted from alerts from EMS dispatchers handling 911 calls, we have found additional stroke patients by having EMS first responders notify us directly for stroke patients that they recognize on arrival on-scene that have not been dispatched as such and that we can enlarge our geographic range of accessing stroke patients by monitoring dispatch calls from outside our catchment area and arranging to rendezvous with the EMS team en route to the CSCs. Finally, we found that we need to make extra efforts to encourage notification of the MSU team on SM weeks when the MSU is not deployed.

Cooperation by all stakeholders has been excellent, and ensuring that all were involved in the planning and roll-out of the program was important in gaining their acceptance. Most importantly, substantial percentage effort by dedicated program leadership (80% for PI, 100% for PM, 50% for second backup VN, and 80% administrator) is essential.

All in all, we feel that being able to fund and build the MSU from first concept to completion within 11 months, and getting it up and smoothly running on a daily basis within another 3 months, attests to the feasibility of implementing additional MSU programs in the United States

One question is how generalizable are the processes and solutions described in this report. Certain of the steps we have described would probably apply universally. These include dedicated leadership and involvement of all community stakeholders. Staffing requirements are also likely to be the same in all locations if our model of having a VN, RN, CT tech, and paramedic on board is followed. One of the aims of our ongoing research study is to determine the accuracy and reliability of using remote presence of a VN through Telemedicine to replace the VN on board the MSU. Even with using remote VN expertise via Telemedicine, however, either a RN or additional paramedic would need to be on board to interact with the remote VN. It is also possible that a paramedic could be cross-trained as a CT tech. Therefore, we envision that the future MSU team will include 3 individuals on board; a combination of paramedics, EMTs, and nurse who could carry out patient care, do the CT scan, and interact with the remote VN via Telemedicine. Note that staffing costs are not included in the MSU sample budget presented in Table 1. Therefore, when configuring costs of maintaining and operating an MSU, salaries for one full-time nurse practitioner or equivalent, Telemedicine on-call support (one full-time VN), and administrative support (50%) should be added.

Other issues, besides staffing, that will determine net costs include the design of the MSU and reimbursement for drugs, transport, and physician services. With regards to the design and build-out costs of the MSU, our MSU was designed on a relatively simple platform for several reasons. We felt that using the existing ambulance design in use by Houston EMS would make the project more feasible, acceptable, understandable, and most importantly, affordable to the EMS supervisors, city administrators, and paramedics who might someday have to both purchase and use such a system. Furthermore, judicious attention to cost control will improve the cost–benefit ratio when making the case for MSU coverage by healthcare payers. Other options including a larger vehicle, such as the Berlin STEMO, would involve more expense. Among other things, the STEMO has a separate shielded area for the CT tech on board and more headroom, though we are not familiar with all the details of that vehicle. Although we would make some minor modifications to our MSU if we were building it again, we have been able to carry out all the work required with the current design and plan on maintaining this basic footprint in the future. One observation is that the CT scanner does not move smoothly on its tracks if the MSU is on a steep incline or angle. Although this has not been a problem in Houston which is flat, it might be a problem in a more hilly location

Table 1. Mobile Stroke Unit Project Budget (Excluding Personnel)

Equipment/Supplies	First Year	Subsequent Years
Ambulance box (donated)	$82 000	$0
Ambulance chassis	$23 000	$0
Ambulance customization for MSU	$53 000	$0
Ambulance maintenance	$0	$1200
Telemedicine equipment (lease)	$24 000	$24 000
CereTom CT scanner for ambulance	$375 000	$0
Warranty/maintenance contract for CereTom	$0	$30 000
Laboratory supplies i-STAT	$12 000	$4800
Power Pro X Stryker stretcher	$14 000	$0
Zoll X series monitor/AED	$25 000	$0
ALS: Ambulance supplies (suction, backboard, ALS bags, etc)	$7000	$0
Supply maintenance (oxygen and IV supplies)	$0	$5000
IV pumps	$4500	$200
Gas	$6000	$6000
Insurance	$3000	$3000
Medications (ALS meds, Nicardipine). Excludes tPA	$4800	$4800
Total equipment/supplies	$633 300	$79 000

AED indicates automated external defibrillator; ALS, Advanced Life Support; CT, computed tomography; MSU, Mobile Stroke Unit; and tPA, tissue-type plasminogen activator.

Table 2. Screen Failures Seen by MSU Team

Preliminary Diagnoses	No. of Patients
Last seen normal unknown	5
Last seen normal >4.5 h	7
Headache	5
Hypo/hypertension	6
Hypo/hyperglycemic	6
Symptoms resolved	6
Fall	2
Syncope	6
Psych	5
Seizure	5
Previous ICH/IVH	3
Other (COPD exacerbation, bells, overdose, UTI)	9
Total	65

COPD indicates chronic obstructive pulmonary disease; ICH, intracerebral hemorrhage; IVH, intraventricular hemorrhage; MSU, Mobile Stroke Unit; and UTI, urinary tract infections.

Table 3. Patients Meeting MSU Criteria

Ischemic stroke, treated with tPA	13
Ischemic stroke >4.5 h	1
TIA with resolving symptoms	2
Intracerebral hemorrhage	4
Seizure	3
Subdural hematoma	1

MSU indicates Mobile Stroke Unit; TIA, transient ischemic attack; and tPA, tissue-type plasminogen activator.

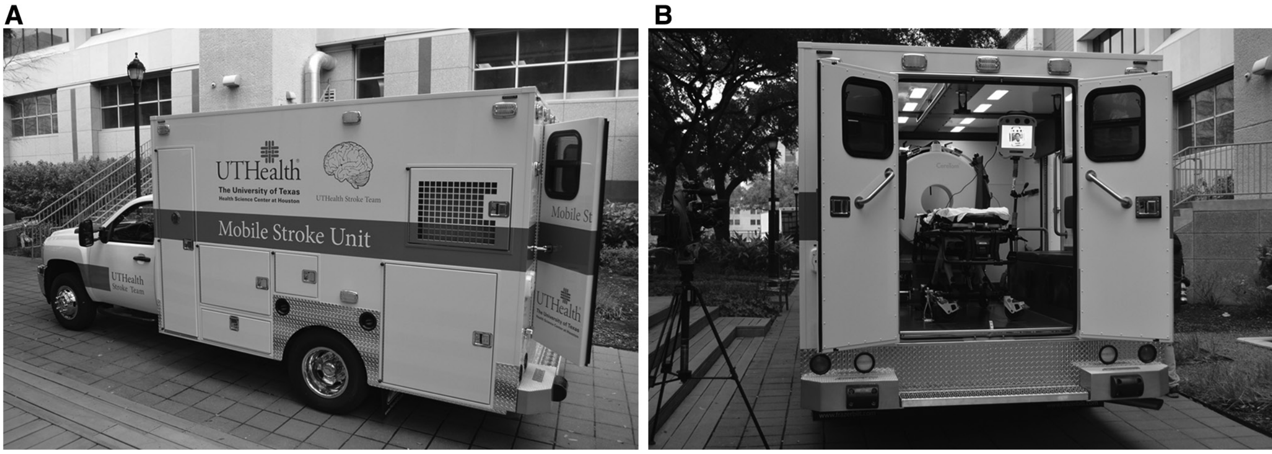

Figure 1. A, Exterior of the Mobile Stroke Unit. **B**, Interior showing CT scanner against the front wall of rear compartment and Telemedicine camera mounted on gurney. CT indicates computed tomography.

and might require some sort of levelling mechanism on the MSU chassis.

Another important cost issue is paying for the r-tPA. The current retail price of a 100 mg vial of r-tPA (Alteplase, Genentech, South San Francisco) is $7816. There is no existing Centers for Medicare and Medicaid Services billing code to reimburse us for the cost of r-tPA given in the prehospital environment, as in our MSU, which is licensed as an ambulance. Note that the cost of r-tPA is not included in Table 1, and so when configuring costs of implementing

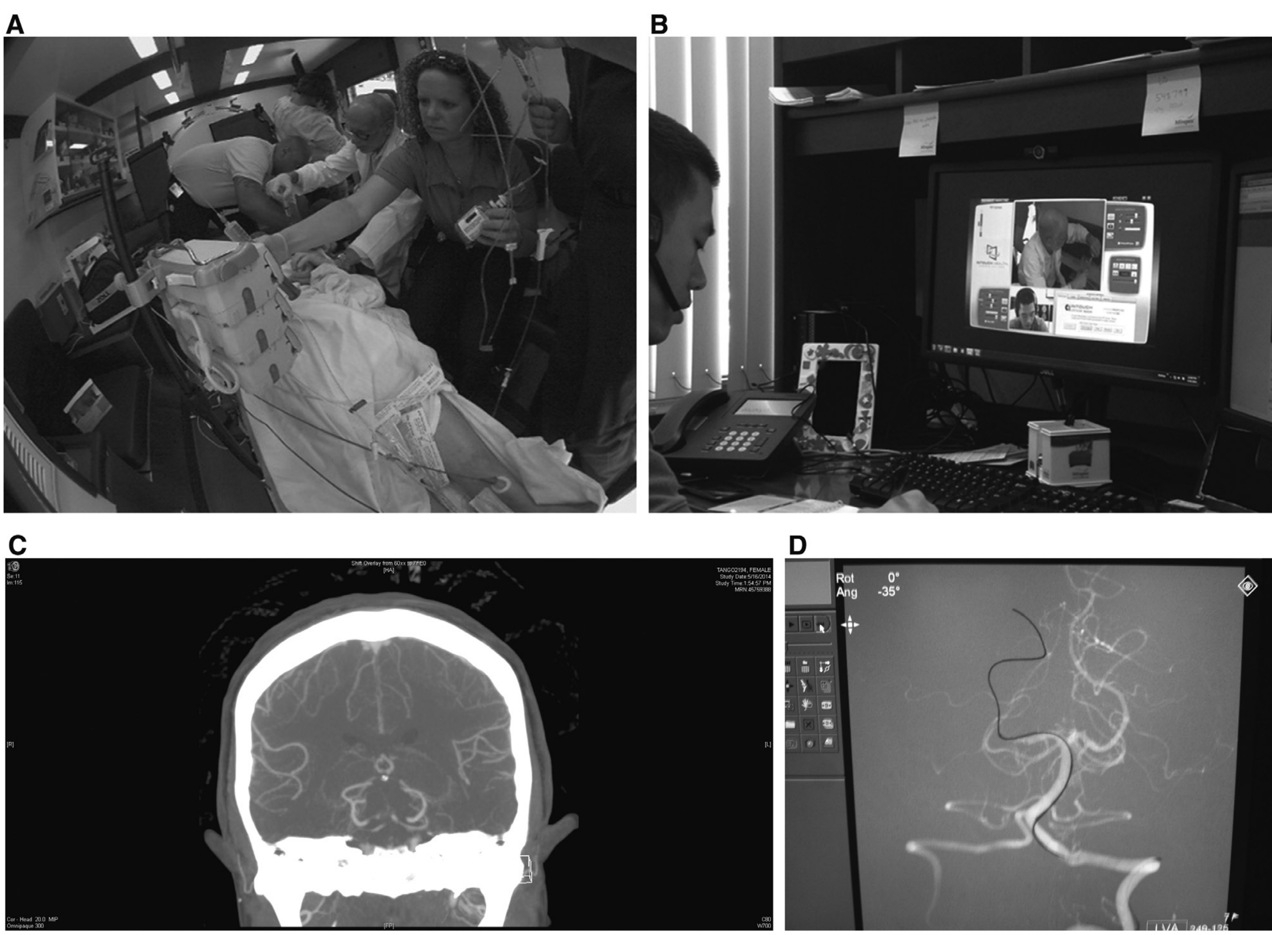

Figure 2. A, Inside the Mobile Stroke Unit treating the first patient with recombinant tissue-type plasminogen activator (r-tPA). **B**, Simultaneous assessment by remote vascular neurologist. **C**, CT angiogram on admission to the Emergency Department with r-tPA infusion still running, showing basilar occlusion. **D**, Catheter arteriogram 151 minutes after r-tPA bolus showing complete recanalization of the basilar artery after r-tPA. The thrombectomy catheter is in the right posterior cerebral artery where there is residual clot. CT indicates computed tomography.

an MSU, the cost of r-tPA must also be added unless those costs are covered by one of the following solutions. One is to have the MSU licensed within the umbrella of the hospital system as a mobile clinic, allowing MSU supplying, billing, and collections (including r-tPA) to take place as per hospital routine. This would allow the MSU to bill and collect for r-tPA using the outpatient J code. Also, Genentech will replace the r-tPA given to underinsured patients under their Access to Care Foundation patient assistance program. The long-term solution to reimbursement for r-tPA cost would come from Centers for Medicare and Medicaid Services, creating the appropriate MSU billing pathway.

The projected costs described earlier and in Table 1 will be offset somewhat by income generated by insurance reimbursement for transport and physician services. Currently, to keep the costs to patients enrolled in our study comparable to standard care, patients transported by our MSU are billed the same transport fee as standard EMS transport, and we do not charge for physician or telemedicine consultation. The health economic analysis we will be carrying out as part of our ongoing randomized trial is designed to provide the data needed by Centers for Medicare and Medicaid Services to determine whether there should be higher compensation to MSU providers for MSU transport and treatment, thereby allowing providers to amortize the costs of establishing and operating their MSU programs.

Other issues may not be so generalizable. Each state, municipality, and collaborating EMS agency might have different requirements for ensuring accountability, licensing, radiation safety, and insurance. However, although the specifics may differ, our results can be useful to remind anyone contemplating an MSU that these requirements and regulations need to be dealt with and carefully considered ahead of time to prevent delays in implementing the program. Other location-specific aspects of an MSU program are likely to be the location of the MSU base station and communication system with EMS. The MSU location must be secure, easily accessible to the on-call team, and have a power source. Our communication system with EMS as described previously would likely require modification for each location based on the training and accuracy of dispatchers, deployment paradigm of EMTs versus paramedics, geographical region covered, and existing communication scheme between EMS units. How much time can be saved by use of MSUs in the United States where traffic patterns, distances, market forces, and local regulations differ from Germany, is also likely to be location-specific and differ between urban and rural areas. If results with the MSU are superior to SM in Houston, which has an already excellent SM environment, it is likely that the same or greater benefits would be found in most other US urban settings. Based on our preliminary data covering a radius of 5 miles around the Texas Medical Center, we calculate it would require ≈4 to 5 MSUs to cover the entire Houston metropolitan area. However, deployment of an MSU in a rural or ex-urban area would require different organization. In such cases, an MSU might best be used to rendezvous with patients travelling from distances to a centrally located stroke center in order not only to shorten onset to treatment times, but also to possibly provide more comprehensive management on board.

The successful solution of the nuts and bolts of establishing an MSU program as demonstrated in this report will make treatment possible within the first 60 minutes after symptom onset and allow us to determine how much better outcome will occur compared with later treatment. 31% of patients treated with tPA using the Berlin MSU were treated within 60 minutes of onset compared with 4.9% with standard management.[13] Without the MSU, treatment within 60 minutes of onset is rare. Among the 302 patients treated within 90 minutes of onset with tPA versus placebo in the NINDS study, only 2 were randomized within 60 minutes of onset (both were randomized to the placebo group) and 41 were randomized between 61 and 80 minutes after onset.[2] Of 58 353 patients treated with tPA in the Get With The Guidelines Stroke Program, <1% were treated within 60 minutes of symptom onset.[8] The slope and shape of the relationship between outcome and time to treatment within the first 60 minutes after stroke symptom onset is uncertain as reflected in the wide confidence intervals surrounding outcomes in various pooled analyses. Patients treated within the first 60 minutes of onset by the Berlin MSU had an odds ratio of 1.93 (95% CI 1.09–3.41) of discharge to home compared with later treatment.[13] Based on data from our run-in phase, we should be able to treat at least one third of patients (30–40 per year) within the first 60 minutes of onset with a single MSU. The establishment of more MSUs and pooling of prospectively obtained longer term outcome data will allow us to determine the benefit of treatment in the first 60 minutes.

Eventually, more widespread use of MSUs based on the model we have described in this report will depend on adequate manpower to guide treatment. Our preliminary experience suggests that the ratio of MSU alerts from EMS dispatch to r-tPA treatments is ≈10:1, making it inefficient in eventual daily operation to have a VN on board the MSU for all calls. However, the decision whether to give r-tPA based on clinical criteria requires training, experience, and careful judgment. Telemedicine may be able to help provide this expertise,[14] but has not been tested for treating actual stroke patients with r-tPA in the prehospital environment. Our preliminary data suggest that we will be able to determine the accuracy of Telemedicine in the MSU by simultaneous Telemedicine evaluation of the stroke patient on-scene using a monitor mounted on the MSU gurney and facilitated by the MSU paramedic.

We have also found that the MSU may have benefits in acute stroke patients beyond r-tPA treatment. MSU deployment may speed access to intra-arterial treatment. Post hoc analysis from Interventional Management of Stroke-III (IMS-III) showed that patients who achieve recanalization within 4 to 5 hours from symptom onset have potential to benefit most from intra-arterial treatment,[9] so if and when intra-arterial treatment becomes widely used, reducing time to treatment will be important. MSU deployment allows prehospital identification of patients with probable large artery occlusion, facilitating their in-hospital treatment by prehospital notification, earlier assembly of the endovascular team, and eliminating in-house delays incurred by acquiring imaging and laboratory data and treating with r-tPA. In our run-in phase, 3 patients received intra-arterial treatment, with groin puncture on average 171 minutes from symptom onset. Although this interval is shorter than what is usually achieved by standard management, there remains much room for improvement in shortening door to groin time in our CSCs to take full advantage of the early management provided by the MSU. Finally, 4 of the 24 patients transported during our run-in phase had primary ICH. Earlier treatment of these patients with blood pressure lowering or correction of coagulopathy may be more effective than later introduction of these therapies in the ED.

Finally, there are several potential complexities in assessing the effect of earlier treatment on the MSU. One is the increased chance of treating stroke mimics, for example, patients with other pathologies, such as migraine or seizures, or patients with TIAs, for example, patients who would recover within 24 hours even without treatment. Ebinger et al reported the rate of stroke mimic treatment with MSU to be 2%, and no different than with SM,[11] and we have not treated any stroke mimics during our initial run-in phase. The incidence of patients completely recovering within 24 hours in the placebo arm of the NINDS study was 2.4% in patients treated 91 to 180 minutes after symptom onset and 2.1% in patients treated within 0 to 90 minutes.[2] This does not suggest a dramatic increase with earlier treatment between 80 and 180 minutes. However, this incidence could be higher in patients evaluated by the MSU within the first 60 minutes after onset. A final potential problem would be an increase in the number of intracerebral hemorrhages, angioedema, or other complications of r-tPA treatment with MSU management. During the run-in period, we have had no episodes of hemorrhage or angioedema, and for the same reasoning as with stroke mimics, we also do not expect to find an increase in these complications with MSU management. However, we are prepared to deal with these complications on the MSU if they arise.

Conclusions

The first MSU in the United States has been introduced in Houston, Texas, after ≈1 year of preparation. Major obstacles to establishing the MSU were obtaining funding, licensure, documenting radiation safety protocols, and establishing a smooth locally tailored communication system with EMS. Preliminary data during a run-in phase indicate no complications, roughly 2 patients treated with r-tPA per week, one third within the first 60 minutes. Further studies are underway to determine the time savings, clinical outcomes, Telemedicine reliability, and cost effectiveness of the MSU strategy.

Sources of Funding

The project received grant support from Genentech (Genentech Corp, South San Francisco, CA), Covidien (Covidien, Mansfield, MA), and Frazer Ltd who also donated a portion of the ambulance.

Disclosures

Dr Wu is on the speaker's bureau for Genentech. Ms Richardson is Chief Executive Officer of Frazer Ltd, which donated the ambulance to UTHealth and provides research support to Dr Grotta. Dr Persse is employed by the City of Houston, which purchases ambulances from Frazer Ltd via a competitive bid process that predates this project. Dr Grotta receives research support from Genentech, Covidien, and Frazer Ltd and has a consulting agreement with Specialists on Call (modest), and Stryker (modest). The other authors report no conflicts.

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