Mobile Stroke Units (MSU)
Now and Into the Future

Matthew E. Fink, MD
Louis and Gertrude Feil Professor & Chairman
Department of Neurology
Associate Dean for Clinical Affairs
New York-Presbyterian Hospital/Weill Cornell Medicine

October 22, 2017
Disclosures

- Editor, Neurology ALERT
- Consultant, Pfizer
- Consultant, Procter & Gamble
Stroke Epidemiology in U.S.

- 795,000 Strokes in the US annually
  - 1 of 6 Americans will be affected

- Fifth leading cause of death and #1 leading cause of serious, long-term disability
  - 1 in 19 deaths is due to stroke
  - Of those who survive, 90% have deficit

Treatment for Stroke Has Advanced, But Time Is Critical

The typical patient loses 1.9 million brain cells each minute in which stroke is untreated

- tPA: thrombolytic drug that is the standard treatment for ischemic strokes
  - Must be administered within 4.5 hours of stroke symptom onset
- Endovascular treatment: minimally invasive procedures using a special device to remove the clot
  - Should be initiated within 6 hours of stroke symptom onset
- Better neurologic outcomes are associated with decreases in time to treatment
- AHA/ASA national stroke quality improvement campaign goal: treatment of ischemic stroke patients within 60 minutes of ED arrival

1. Time Is Brain—Quantified, Jeffrey L. Saver
2005 American Heart Association. All rights reserved.
Print ISSN: 0039-2499. Online
Every Minute Counts

- Every 15 minute delay to IV thrombolysis:¹
  - Worsens in-hospital mortality
  - Increases the risk of symptomatic ICH
  - Reduces recovery to independent ambulation
  - Decreases likelihood of discharge home

- For every 1 minute delay, we lose:²
  - 1.9 million neurons
  - 14 billion synapses
  - 7.5 miles of myelinated fibers

2) Saver, J. *Stroke* 2006; 37: 263-266
**Table 1. Time-to-treat impact on stroke outcomes**

<table>
<thead>
<tr>
<th></th>
<th>Neurons lost&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Synapses lost</th>
<th>Accelerated aging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per stroke</td>
<td>1.2 billion</td>
<td>8.3 trillion</td>
<td>36 yr</td>
</tr>
<tr>
<td>Per hour</td>
<td>120 million</td>
<td>830 billion</td>
<td>3.6 yr</td>
</tr>
<tr>
<td>Per minute</td>
<td>1.9 million</td>
<td>14 billion</td>
<td>3.1 wk</td>
</tr>
<tr>
<td>Per second</td>
<td>32,000</td>
<td>230 million</td>
<td>8.7 hr</td>
</tr>
</tbody>
</table>

Saver, Stroke, 2006
Milestones in Stroke Care

**1995:** NINDS rt-PA Stroke Study, NEJM
- 624 patients treated with 0.9 mg/kg/hour
- Treated in less than 3 hours; ½ less than 90 minutes
- tPA group: 31-50% complete recovery
- Control: 20-38% complete recovery
- ICH: 6.4% v. 0.6%
- Mortality: 17% v. 20%

**2008:** ECASS-III, NEJM
- Time window for tPA extended to 4.5 hours

---

1. ASA/AHA Stroke 2009; 40; 2945-2948
Quality Indicators– Cross-Campus
Percent of patients receiving tPA in 60 minutes or less

<table>
<thead>
<tr>
<th>Year</th>
<th>NYP/CU</th>
<th>NYP/WC</th>
<th>NYP/AH</th>
<th>NYP/LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>100</td>
<td>100</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>2015</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2016</td>
<td>93.6</td>
<td>96.7</td>
<td>92.3</td>
<td>96.7</td>
</tr>
</tbody>
</table>

Data Source and Average: Get With The Guidelines Database (GWTG)
Benchmark: 2016 Academic Medical Center Average (81.4%)
Odds Ratio for Good Outcomes After Intravenous rTPA

Lees, Lancet, 2010
Milestones in Stroke Care

Mechanical Thrombectomy

- 2015: International Stroke Conference

- Five separate randomized trials confirmed the added benefit of endovascular clot extraction in addition to IV rt-PA
MR CLEAN Intra-arterial Clot Extraction – Time v. Outcome

Fransen, et. al. JAMA Neurol 2016
A Solution: Telemedicine
Increasing Use of Telemedicine in Stroke Research

Ebinger M et al. JAMA Neurology 2016; 73 (2): 153-4
Why Telemedicine? Why MSU?

- Leverage specialists who are scarce
- Speed up access for patients
- Shorten time to thrombolysis
- Patient convenience
- Rapid and accurate triage
- Home care – reduce ED visits – reduce hospitalization
- SAVE MONEY
Need for TeleStroke

- Only about 3-5% of patients with stroke receive IV tPA
- Lack of stroke expertise in small and rural hospitals
- Stroke specialists needed for:
  - Rapid assessment to make clinical diagnosis of stroke
    - Imaging to exclude hemorrhage but infarct not apparent on CT
    - No brain troponin or marker of infarction
    - Examination for diagnosis
    - Identification of large vessel syndrome
  - Determine eligibility for TPA, endovascular therapy
  - Imaging review
  - TPA protocol
  - Time sensitive
Telestroke – Hub and Spoke Model
Ambulance-based Telemedicine for Hospital Triage of Stroke Patients

- Telemedicine can bring specialized expertise and help provide diagnosis, treatment, therapy, and direction for hospital triaging stroke patients on standard ambulances or MSTUs.

Stroke Center Triaging for Prehospital Large Vessel Occlusion Patients

- LVO+ Patients should be sent to nearest Comprehensive Stroke Center and LVO-patients can be sent to any nearest stroke center.

- Several dedicated LVO prediction scores (RACE, CPSSS, FAST-ED)
  - Difficult to predict LVO in prehospital setting (may miss >20% of LVO)
  - Cutoffs to reduce the false-negative rate to 10% would result in sending almost every patient with acute neurological symptoms to a Comprehensive Stroke Center.

- No nonimaging biological marker, alone or in combination with clinical parameters, is highly specific for LVO prediction.

Mobile Stroke Unit is Pre-hospital Telestroke

- Overview of MSTUs and their effect on time to treatment; review disability outcomes and cost data
- Inter-rater reliability of MSTU telemedicine
- Non-MSTU ambulance-based telesroke
- Prehospital Large Vessel Occlusion screening tools
**NIH Stroke Scale Values, Between Bedside and Remote Locations**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Bedside</th>
<th>Approximate Time</th>
<th>Remote</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>9</td>
<td>6:00</td>
<td>10</td>
<td>5:00</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>23</td>
<td>5:00</td>
<td>24</td>
<td>9:00</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>10</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>8</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>15</td>
<td>3:00</td>
<td>16</td>
<td>5:00</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>9</td>
<td>6:00</td>
<td>9</td>
<td>9:00</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>4</td>
<td>5:00</td>
<td>2</td>
<td>10:44</td>
</tr>
<tr>
<td>13</td>
<td>F</td>
<td>10</td>
<td>7:00</td>
<td>13</td>
<td>8:52</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>1</td>
<td>8:00</td>
<td>3</td>
<td>8:43</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>4</td>
<td>6:00</td>
<td>6</td>
<td>9:34</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>4</td>
<td>7:00</td>
<td>3</td>
<td>8:52</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>6</td>
<td>8:00</td>
<td>4</td>
<td>11:36</td>
</tr>
<tr>
<td>18</td>
<td>F</td>
<td>13</td>
<td>7:00</td>
<td>10</td>
<td>8:18</td>
</tr>
<tr>
<td>19</td>
<td>M</td>
<td>13</td>
<td>8:00</td>
<td>14</td>
<td>10:22</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>2</td>
<td>6:00</td>
<td>3</td>
<td>10:06</td>
</tr>
</tbody>
</table>

**Remote evaluation of acute ischemic stroke: reliability of National Institutes of Health Stroke Scale via telestroke.**

Wang S; Lee SB; Pardue C; Ramsingh D; Waller J; Gross H; Nichols FT 3rd; Hess DC; Adams RJ

DOI: 10.1161/01.STR.0000091847.82140.9D
### TABLE 1. Interrater Agreement in NIHSS Items for All Patients (n=41)

<table>
<thead>
<tr>
<th>Item</th>
<th>Unweighted (95% CI)</th>
<th>Weighted (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consciousness</td>
<td>0.79 (0.39–1.0)</td>
<td>0.99 (0.97–1.0)</td>
</tr>
<tr>
<td>Questions</td>
<td>0.73 (0.52–0.94)</td>
<td>0.90 (0.82–0.96)</td>
</tr>
<tr>
<td>Commands</td>
<td>0.83 (0.61–1.0)</td>
<td>0.93 (0.86–1.0)</td>
</tr>
<tr>
<td>Best gaze</td>
<td>0.69 (0.37–1.0)</td>
<td>0.95 (0.90–0.99)</td>
</tr>
<tr>
<td>Facial paresis</td>
<td>*</td>
<td>0.85 (0.79–0.90)</td>
</tr>
<tr>
<td>Visual field</td>
<td>0.44 (0.06–0.81)</td>
<td>0.89 (0.84–0.96)</td>
</tr>
<tr>
<td>Motor arm</td>
<td>0.58 (0.37–0.80)</td>
<td>0.90 (0.85–0.95)</td>
</tr>
<tr>
<td>Motor leg</td>
<td>*</td>
<td>0.92 (0.89–0.96)</td>
</tr>
<tr>
<td>Ataxia</td>
<td>0.82 (0.64–1.0)</td>
<td>0.95 (0.90–0.99)</td>
</tr>
<tr>
<td>Sensory</td>
<td>0.78 (0.60–0.96)</td>
<td>0.91 (0.86–0.96)</td>
</tr>
<tr>
<td>Language</td>
<td>0.89 (0.73–1.0)</td>
<td>0.98 (0.96–1.0)</td>
</tr>
<tr>
<td>Dysarthria</td>
<td>0.70 (0.47–0.92)</td>
<td>0.92 (0.90–0.97)</td>
</tr>
<tr>
<td>Neglect</td>
<td>0.88 (0.72–1.0)</td>
<td>0.96 (0.93–1.0)</td>
</tr>
</tbody>
</table>

Ci indicates confidence interval. n = 41.

*Calculation of unweighted $\kappa$ coefficient was impossible because values were not equally distributed in bedside and face-to-face examination.

---

**Telemedicine in emergency evaluation of acute stroke: interrater agreement in remote video examination with a novel multimedia system.**

Handschu R; Littmann R; Reulbach U; Gaul C; Heckmann JG; Neundorfer B; Scibor M

DOI: 10.1161/01.STR.0000102043.70312.E9
### Cost-effectiveness of hub-and-spoke telestroke networks for the management of acute ischemic stroke from the hospitals' perspectives.

Switzer JA; Demaerschalk BM; Xie J; Fan L; Villa KF; Wu EQ

DOI: 10.1161/CIRCOUTCOMES.112.967125

<table>
<thead>
<tr>
<th>Incremental Outcomes</th>
<th>Network (1 Hub + 7 Spokes)</th>
<th>Hub</th>
<th>Spoke (per Hospital)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS patients admitted to inpatient, n/y</td>
<td>0.00</td>
<td>-113.74</td>
<td>16.25</td>
</tr>
<tr>
<td>AIS patients treated with IV thrombolysis, n/y</td>
<td>44.60</td>
<td>0.00</td>
<td>6.37</td>
</tr>
<tr>
<td>AIS patients treated with endovascular stroke therapy, n/y</td>
<td>20.39</td>
<td>20.39</td>
<td>0.00</td>
</tr>
<tr>
<td>Costs per year, 2011 US $</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base case</td>
<td>-358,435</td>
<td>405,121</td>
<td>-109,080</td>
</tr>
<tr>
<td>With same cost savings for all hospitals</td>
<td>-358,435</td>
<td>-44,804</td>
<td>-44,804</td>
</tr>
<tr>
<td>Effectiveness, n/y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home discharges</td>
<td>6.11</td>
<td>4.60</td>
<td>0.87</td>
</tr>
<tr>
<td>Rehab/nursing home discharges</td>
<td>-6.11</td>
<td>-4.60</td>
<td>-0.87</td>
</tr>
</tbody>
</table>

AIS indicates acute ischemic stroke.
“Mobile Stroke Unit” for Hyperacute Stroke Treatment

To the Editor:

Ilicshemic stroke is a major cause of death and of permanent severe functional deficits in the developed countries. In most cases this disease is caused by obstruction of the cerebral blood vessels, i.e., emboli originating from the heart or large or small-supplying blood vessels. Experimental studies show that within minutes after vascular obstruction, cell death occurs. If the region around this core (penumbra), cells exhibit a compromised metabolism but might be rescued by adequate therapies.

At present, the only acute treatment for acute stroke that has been shown to be effective and that has been approved in most Western countries is thrombolysis by recombinant tissue plasminogen activator (rTPA). However, even in centers specialized for stroke ~25% of the stroke patients are treated by thrombolysis. One explanation for this may be that most patients arrive at the hospital after the temporal window of 3 hours, for the use of rTPA. Even this arbitrarily set temporal window might still be too large as indicated by pathophysiological knowledge and clinical observations. Much better outcomes can be expected if treatment would start within 1 hour. Thus, the major problem of acute stroke treatment is the unacceptable delay between onset of cerebral ischemia and therapeutic reanimation of the cerebral blood flow.

Since thrombolysis for ischemic stroke can only be performed after exclusion of possible hemorrhage, computed tomography (CT) is the major time-determining factor in stroke management. Usually only larger centers can provide this service (24 hours a day), and important time is lost by carrying patients to the CT at such centers.

In order to reduce time to therapeutic intervention, we propose a mobile stroke unit for hyperacute stroke treatment complementary to a stationary stroke unit already in use in many countries. Such a mobile stroke unit (the figure) would be a vehicle (e.g., a Mercedes Vario) carrying both conventional emergency equipment and all relevant diagnostic tools necessary for a decision for or against thrombolysis directly at the place where the patient is found. Such a device implies several technical innovations, such as an integrated small CT scanner (Figure 1a) with an operation console (Figure 1b) and an energy supply. The vehicle has to be shielded by a 5-mm lead layer against radiation produced by the CT (Figure 1c). On the other side this vehicle has to be within normal limits of dimension, in order not to compromise mobility. Although relatively small, lightweight (~350 kg), cooling system in dependent and accumulator-driven, CTIs are already available to be used in this mobile stroke unit (e.g., Tomoscan M, Figure 1a). It can be expected that a CT specialized for brain imaging can be developed in future. As shown in Figure 1b, we suggest that the console for operation is placed at the front part of the car, well isolated from the radiation. In the case of the focal ischemic brain tissue, a metal-free stretcher should be used as a CT table (Figure 1d). Optionally, a small laboratory unit for blood-based analyzation (e.g., coagulation parameters) and a system to transmit CT data to radiologists at the hospital could be included, according to currently discussed concepts of point-of-care laboratory medicine or telemedicine, respectively.

Bringing treatment to the patient rather than the patient to the treatment site, enabled by the mobile stroke unit, could save precious time lost by transport to and within the hospital. Thrombolysis is ~1 hour could become a reality for many patients. The effectiveness of such a mobile stroke unit, however, depends on the presence of well-trained professionals and on the location of its use. It is likely to be more effective in rural areas than in large cities with a high density of hospitals with a 24-hour CT service.

According to the “time is brain” concept, the mobile stroke unit proposed here might offer a novel solution. By reducing the delay between the onset of cerebral ischemia and therapeutic decision, use of the mobile stroke unit can rescue brain tissue from ischemic damage, thereby reducing individual suffering and life-long cost. The additional costs incurred by the use of a mobile stroke during the few first hours of disease will be outweighed by cost savings in cases of these patients for years or decades.

Please direct correspondence to Prof. Klaus Fassbender.

Klaus Fassbender, MD
Silke Walter, MD
Frank Meinl, MD
Department of Neurology
University of Göttingen
Goettingen, Germany
Andreas Rager, MD
Sandra Knehl, MD
Oettl Mielke, MD
Department of Neurology
University of Heidelberg
Mannheim, Germany

Improving Onset-to-Treatment Times

Of all studied tPA protocols, none are faster than prehospital treatment

Walter S et al. *Lancet Neurol* 2012; 11: 397-404
New York City 1869
New York City
2016
Potential of the Mobile Stroke Treatment Unit (MSTU)

- Bring the physician expertise & diagnostic tools to the patient
- Initiate treatment at the scene
- Cut time to treatment
- Increase tPA delivery & access to endovascular therapy
- Increase chances for better neurologic outcomes
MSTU: the European experience

- Largest study of effects of stroke ambulances conducted:
  - Berlin, Germany
  - May 2011 – January 2013
  - 6,182 adult patients (split into “stroke ambulance” and control groups)

- Results: among patients for whom the stroke ambulance was deployed, mean alarm-to-treatment (tpa) time was 25 minutes shorter vs control weeks¹
  - And no increase in adverse events

---

1. JAMA, 2014; 311 (16); Effect of the Use of Ambulance-Based Thrombolysis on Time to Thrombolysis in Acute Ischemic Stroke. Ebinger, MD et al
### Table 1: Baseline Characteristics of Patients Receiving Conventional Care vs. STEMO Care

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Conventional care (n=353)</th>
<th>STEMO care (n=305)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td>70.2 (72, 65-79)</td>
<td>70.7 (72, 63-79)</td>
<td>0.99</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>130 (37%)</td>
<td>146 (48%)</td>
<td>0.004</td>
</tr>
<tr>
<td>Male</td>
<td>223 (63%)</td>
<td>159 (52%)</td>
<td>--</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes*</td>
<td>77 (22%)</td>
<td>64 (21%)</td>
<td>0.76</td>
</tr>
<tr>
<td>Atrial fibrillation†</td>
<td>106 (31%)</td>
<td>100 (33%)</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Blood pressure before thrombolysis (mm Hg)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure‡</td>
<td>155.9 (153, 140-171)</td>
<td>163.1 (160, 140-180)</td>
<td>0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure§</td>
<td>83.8 (82, 74-91)</td>
<td>93.3 (90, 80-100)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Blood glucose before thrombolysis (mg/dL)¶</td>
<td>135.5 (126, 110-151)</td>
<td>129.9 (119, 107-143)</td>
<td>0.017</td>
</tr>
<tr>
<td>NIHSS at inclusion</td>
<td>8.9 (7.4-13)</td>
<td>8.9 (7.4-13)</td>
<td>0.60</td>
</tr>
<tr>
<td>Intra-arterial co-treatment</td>
<td>52 (14.7)</td>
<td>30 (9.8)</td>
<td>0.058</td>
</tr>
<tr>
<td>Time from onset to deployment (dispatch) (min)</td>
<td></td>
<td></td>
<td>47 (28, 9-71)</td>
</tr>
<tr>
<td>Time from alarm to thrombolysis (min)**</td>
<td>82 (76, 64-93)</td>
<td>48 (46, 39-53)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Time from admission to thrombolysis (min)</td>
<td>43.1 (37, 29-51)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Time from onset to thrombolysis (min)† †</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>129.3 (55.5)</td>
<td>96.3 (60.4)</td>
<td>--</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>112 (85-175)</td>
<td>73 (53-120)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Time from onset to thrombolysis ≤60 min</td>
<td>14 (4%)</td>
<td>112 (37%)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Time from onset to thrombolysis ≤90 min</td>
<td>123 (35%)</td>
<td>187 (62%)</td>
<td>&lt;0.0005</td>
</tr>
<tr>
<td>Primary outcome</td>
<td>Conventional care (n=353)</td>
<td>STEMO care (n=305)</td>
<td>p value</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------------------</td>
<td>--------------------</td>
<td>----------</td>
</tr>
<tr>
<td>3-month mRS score 0–1</td>
<td>166 (47%)</td>
<td>161 (53%)</td>
<td>0.14</td>
</tr>
<tr>
<td>Secondary outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-month mRS score 0–3</td>
<td>260 (74%)</td>
<td>253 (83%)</td>
<td>0.004</td>
</tr>
<tr>
<td>3-month mortality</td>
<td>37 (10%)</td>
<td>17 (6%)</td>
<td>0.022</td>
</tr>
<tr>
<td>3-month mRS score</td>
<td></td>
<td></td>
<td>0.10*</td>
</tr>
<tr>
<td>0</td>
<td>106 (30%)</td>
<td>85 (28%)</td>
<td>...</td>
</tr>
<tr>
<td>1</td>
<td>60 (17%)</td>
<td>76 (25%)</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>55 (16%)</td>
<td>32 (10%)</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>39 (11%)</td>
<td>60 (20%)</td>
<td>...</td>
</tr>
<tr>
<td>4</td>
<td>37 (10%)</td>
<td>22 (7%)</td>
<td>...</td>
</tr>
<tr>
<td>5</td>
<td>19 (5%)</td>
<td>13 (4%)</td>
<td>...</td>
</tr>
<tr>
<td>6</td>
<td>37 (10%)</td>
<td>17 (6%)</td>
<td>...</td>
</tr>
<tr>
<td>Safety outcomes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Symptomatic intracranial haemorrhage†</td>
<td>17 (5%)</td>
<td>9 (3%)</td>
<td>0.27</td>
</tr>
<tr>
<td>7-day mortality‡</td>
<td>14 (4%)</td>
<td>7 (2%)</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Post-hoc Analysis of PHANTOM-S: Distance to Scene’s Influence on tPA Times

Mean Alarm-to-Treatment Times (min):

Zone 1 - 41.8 (MSU) vs 76.5
Zone 2 - 50.2 (MSU) vs 79.1
Zone 3 - 54.5 (MSU) vs 76.6
Zone 4 - 59.3 (MSU) vs 78.0

($p < 0.001$ for all zones)
MSTU Cost-Effectiveness Estimate: Berlin Registry

- **Actual Expenses:**
  - Initial cost of unit: 955,666 euros
  - Annual cost of operations: 963,954 euros

- **From the observed patient volume and tPA-treatment times:**
  - Estimated that MSUs saved 16 patients from disability over 10.5 months of service
  - The cost per quality adjusted life year (QALY) gained by MSU treatment is 32,456 euros
    - Consistent with what US has historically paid for health gains ($50,000-$100,000)

- Results are preliminary. BEST-MSU trial will perform a more formal cost-effectiveness analysis of MSU care in US

Reduction in time to treatment in prehospital telemedicine evaluation and thrombolysis

Ather Taqui, MD
Russell Cerejo, MD
Ahmed Itrat, MD
Farren B.S. Briggs, PhD
Andrew P. Reimer, PhD, RN
Stacey Winners, RT, MSc
Natalie Organek, DO
Andrew B. Buletko, MD
Lila Sheikh, MD
Sung-Min Cho, DO
Maureen Buttrick, RN
Megan M. Donohue, MD
Zeshan Khawaja, MD
Dolora Wisco, MD
Jennifer A. Frontera, MD
Andrew N. Russman, DO
Fredric M. Hustey, MD
Damon M. Kralovic, DO
Peter Rasmussen, MD
Ken Uchino, MD
Muhammad S. Hussain, MD

ABSTRACT

Objective: To compare the times to evaluation and thrombolytic treatment of patients treated with a telemedicine-enabled mobile stroke treatment unit (MSTU) vs those among patients brought to the emergency department (ED) via a traditional ambulance.

Methods: We implemented a MSTU with telemedicine at our institution starting July 18, 2014. A vascular neurologist evaluated each patient via telemedicine and a neuroradiologist and vascular neurologist remotely assessed images obtained by the MSTU CT. Data were entered in a prospective registry. The evaluation and treatment of the first 100 MSTU patients (July 18, 2014-November 1, 2014) was compared to a control group of 53 patients brought to the ED via a traditional ambulance in 2014. Times were expressed as medians with their interquartile ranges.

Results: Patient and stroke severity characteristics were similar between 100 MSTU and 53 ED control patients (initial NIH Stroke Scale score 6 vs 7, p = 0.679). There was a significant reduction of median alarm-to-CT scan completion times (33 minutes MSTU vs 56 minutes controls, p < 0.0001), median alarm-to-thrombolysis times (55.5 minutes MSTU vs 94 minutes controls, p < 0.0001), median door-to-thrombolysis times (31.5 minutes MSTU vs 58 minutes controls, p = 0.0012), and symptom-onset-to-thrombolysis times (97 minutes MSTU vs 122.5 minutes controls, p = 0.0485). Sixteen patients evaluated on MSTU received thrombolysis, 25% of whom received it within 60 minutes of symptom onset.

Conclusion: Compared with the traditional ambulance model, telemedicine-enabled ambulance-based thrombolysis resulted in significantly decreased time to imaging and treatment. Neurology® 2017;88:1305-1312
## MSTU: the Cleveland Clinic experience since 2014

<table>
<thead>
<tr>
<th></th>
<th>MSTU</th>
<th>Conventional care model</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary end point</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alarm to treatment: mean</td>
<td>51.8 min</td>
<td>76.3 min</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Secondary end points</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alarm to imaging: mean</td>
<td>37.7 min</td>
<td>52.4 min</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Imaging to treatment: mean</td>
<td>14.1 min</td>
<td>23.8 min</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Thrombolysis rates in ischemic stroke</td>
<td>33%</td>
<td>21%</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

MSTU = mobile stroke treatment unit.
### IV tPA Agreement Between Telemedicine Vascular Neurologist and Onboard Vascular Neurologist

<table>
<thead>
<tr>
<th>κ (95% CI)</th>
<th>Positive agreement, %</th>
<th>Negative agreement, %</th>
<th>Overall raw agreement, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.73 (0.62–0.84)</td>
<td>90.6</td>
<td>82.5</td>
<td>87.7</td>
</tr>
</tbody>
</table>

### Agreement of hemorrhage on CTH between telemedicine vascular neurologist and onboard vascular neurologist

<table>
<thead>
<tr>
<th>κ (95% CI)</th>
<th>For raw NIHSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.97 (0.92–1.00)</td>
<td></td>
</tr>
</tbody>
</table>

### NIHSS agreement between telemedicine vascular neurologist and onboard vascular neurologist

<table>
<thead>
<tr>
<th>Intraclass correlation (95% CI)</th>
<th>For raw NIHSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.88 (0.84–0.91)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weighted κ (95% CI)</th>
<th>For NIHSS groups (0–5, 6–12, and &gt;13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.71 (0.62–0.79)</td>
<td></td>
</tr>
</tbody>
</table>

### IV tPA decision time metrics between telemedicine vascular neurologist and onboard vascular neurologist (MSU arrival to decision)

<table>
<thead>
<tr>
<th></th>
<th>Mean (min)</th>
<th>Median (min)</th>
<th>25th to 75th %tile (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telemedicine vascular neurologist</td>
<td>35.8</td>
<td>32</td>
<td>25–41</td>
</tr>
<tr>
<td>Onboard vascular neurologist</td>
<td>18.8</td>
<td>18</td>
<td>14–23</td>
</tr>
</tbody>
</table>

Tzu-Ching Wu et al. Stroke 2017; 48: 493-496
Active MSTU Sites with Research Programs

The NewYork-Presbyterian Mobile Stroke Unit: Overview

- Joint project of NYP (Weill Cornell Medicine and Columbia University Medical Center) and the FDNY
- Allows for timely prehospital treatment of acute stroke patients
  - On-board CT scanner
  - Immediate neurologist consultation
  - tPA administration in field
- Operational as of October 3, 2016
  - 6th program in the United States
  - 1st program on the East Coast
- **Integrated** into the NYC 911 System
  - **Hours of deployment:** M-F, 9am-5pm
  - **Catchment areas:** WC & CU, 2-week rotations

- **Dual-dispatched** with BLS unit for CVA-C calls
  - Other units can request MSU backup, and paramedics screen dispatch frequencies to “add-on” the MSU as needed

- **Transports patients to ED** at closest appropriate stroke center per FDNY protocol
  - Fully integrated into NYP EMR

- **Transition to Telemedicine** in Spring 2017
  - Install AV capabilities on MSU to communicate with remote neurologist; MSU NP to replace on-board physician

- **Plan for Clinical Research:** BEST-MSU
Potential Diagnostic/Treatment Algorithm for Acute Stroke

**Pre-hospital**

1. **Noncontrast Head CT**
2. **Administer IV-tPA if eligible (within 4.5 hours of onset)**

**In-hospital**

3. **CT angiography**
4. **Perform IAT if eligible (within 6 hours of onset)**
MSU Workflow and Clinical Information Systems Integration

On Scene
- Places phone call to Registrar
- Orders IV, CT, labs, t-PA, other medications in Allscripts SCM (electronic health record)
- Receives laboratory orders in Cerner Millennium (lab system)

On MSU
- Performs CT scan
- Interpret s CT image (radiologist + neurologist)
- Makes t-PA treatment decision
- Documents encounter and medications administered
- Sends samples to lab on arrival
- Processes orders; generates laboratory results
- Cerner Millennium
- Allscripts SCM

In Hospital
- Creates visit in EAGLE 2000 (registration system)
- EAGLE 2000
- PACS
- Lab Tech Remote
  - Abbreviations: t-PA, tissue plasminogen activator; CT, computed tomography; PACS, picture archiving communication system; SCM, Sunrise Clinical Manager

Figure Used with permission of Benjamin R. Kummer, MD

Weill Cornell Medicine
Columbia University College of Physicians and Surgeons
NewYork-Presbyterian
Operation time change from 7-3 to 9-5 should increase annual MSU volume
Example of MSU Workflow - October 4, 2016

- CVA-C Call at 12:20 PM
  - MSU Dispatched to scene

- 90 year old woman with DM, recently off ASA at the instruction of her PMD
  - Developed acute left sided weakness and dizziness at 12:15 PM while at a routine doctor’s appointment

- MSU arrived on the scene (office waiting room) at 12:24 PM
  - Paramedics and physician begin patient evaluation
Initial Survey

- Last known normal was confirmed to be 12:15 PM
- Awake, alert, speaking and following commands, in no acute distress
- Initial VS: BP 149/60, HR 89, SPO2 97%
- 3-lead EKG: Sinus rhythm
Initial History

- Patient reports she was seated in waiting room when symptoms began
  - She suddenly became dizzy, and noted her left face/arm/leg became weak
    - Denies headache, nausea/vomiting
  - Her symptoms are improving, but she is still dizzy and reports left arm and leg weakness
Neurologist’s examination

- CPSS= arm drift only; NIHSS=4 (minor stroke)
- Awake, alert, oriented with fluent speech
- No facial weakness or other cranial nerve deficit
- Left arm drift and left leg cannot be lifted antigravity
- No other focal deficits
Head CT on the MSU

- The patient was brought onto the unit and a head CT was obtained.
- Her symptoms continue to improve, but she still has left leg weakness.

![CT scans of the head](image-url)
Our First tPA Patient

- October 4, 2016
- Onset-to-tPA time= 55 minutes, “golden hour thrombolysis”
- Patient was discharged home, back to her baseline

- Treatment course:
  - Onset to 911 call: 5 min
  - Dispatch to arrival: 4 min
  - Arrival to CT completion: 28 min
  - Unit arrival to r-tPA: 46 min
- Discharge outcome:
  - mRS=0 (no disability)
  - Discharged home with services
10-Month MSU Patient Volume

Aggregate MSU Activity
OCT 3, 2016 - AUG 15, 2017

- Deployments: 366
- Contacts: 265
- Transports: 70
LKN, last known well
63.7% good discharge disposition, from weekday admissions with AIS in the Nationwide Inpatient Sample 2002-2007
- Hoh et al. *Stroke* 2010; 41: 2323-2328

76% good discharge disposition, from all AIS patients treated with tPA in single center registry in Houston
Median Operational Time Metrics, 10/3/16-4/27/17

<table>
<thead>
<tr>
<th>Event</th>
<th>NYP ED Care</th>
<th>MSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scene Arrival-CT Completion</td>
<td>54</td>
<td>40</td>
</tr>
<tr>
<td>Scene Arrival-Departure</td>
<td>17</td>
<td>57</td>
</tr>
<tr>
<td>Scene Arrival-Hospital Arrival</td>
<td>24</td>
<td>70</td>
</tr>
</tbody>
</table>

N=16 MSU cases; N=24 non-MSU cases
Despite longer median arrival-to-CT times, MSU care results in faster onset-to-tPA and arrival-to-tPA times.

We expect times from arrival-to-CT and arrival-to-tPA to improve with more clinical experience on board the MSU.

A direct-to-CT protocol has been implemented in the Target: Stroke campaign and is known to reduce door-to-needle times.

A CT-direct protocol at a US CSC led to a 10-minute decrease in median DTN times without an increase in sICH rate (1%).

Caputo et al. Neurohospitalist 2017; 7 (2): 70-73
Operational Metrics (median)
MSU vs. NYP (WC+CU)
OCT 3, 2016 - AUG 15, 2017

- Scene Arrival-CT Completion: NYP 54 minutes vs. MSU 31 minutes
- Scene Arrival-Departure: NYP 48 minutes vs. MSU 17 minutes
- Scene Arrival-Hospital Arrival: NYP 61 minutes vs. MSU 24 minutes
Increasing Annual MSU Call Volume

- Aggressively monitor FDNY dispatch frequencies to add MSU to existing calls
- Educate FDNY and 911 operators on criteria to activate MSU
- Change operational hours to maximize captured call volume
- Public awareness campaign to increase knowledge of stroke symptoms and need to dial 911 immediately
Key Points

- The first MSU in NYC was deployed October 3, 2016, in conjunction with NewYork-Presbyterian Hospital and FDNY

- MSU care leads to faster tPA treatment times. It is known that faster stroke treatment results in better patient outcomes

- Maximizing call volume requires systems and public education and optimizing hours of operation

- Expediting tPA delivery on the MSU requires a collaborative approach with streamlined clinical systems integration and workflow prioritizing rapid CT acquisition

- Spread the word: be aware of the MSU and its operations and know that MSU backup can be requested to a 911 call if a potential stroke patient is identified during our hours of operations
Next Steps

- Conversion to telemedicine model
- Expansion to Queens and other areas of New York City
- Collaboration with Houston, Denver, Memphis, and LA in PICORI-funded study of “Cost-Effectiveness of Mobile Stroke Unit Prehospital Care” – BEST-MSU
- Collaboration with international consortium of mobile Stroke Unit Programs in innovative clinical trials- PRESTO - “Early Treatment of ICH”.