Reliability of Real-Time Video Smartphone for Assessing National Institutes of Health Stroke Scale Scores in Acute Stroke Patients

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**Background and Purpose**—Telestroke reduces acute stroke care disparities between urban stroke centers and rural hospitals. Current technologies used to conduct remote patient assessments have high start-up costs, yet they cannot consistently establish quality timely connections. Smartphones can be used for high-quality video teleconferencing. They are inexpensive and ubiquitous among health care providers. We aimed to study the reliability of high-quality video teleconferencing using smartphones for conducting the National Institutes of Health Stroke Scale (NIHSS).

**Methods**—Two vascular neurologists assessed 100 stroke patients with the NIHSS. The remote vascular neurologist assessed subjects using smartphone videoconferencing with the assistance of a bedside medical aide. The bedside vascular neurologist scored patients contemporaneously. Each vascular neurologist was blinded to the other’s NIHSS scores. We tested the inter-method agreement and physician satisfaction with the device.

**Results**—We demonstrated high total NIHSS score correlation between the methods (r=0.949; P<0.001). The mean total NIHSS scores for bedsides and remote assessments were 7.93±8.10 and 7.28±7.85, with ranges, of 0 to 35 and 0 to 37, respectively. Eight categories had high agreement: level of consciousness (questions), level of consciousness (commands), visual fields, motor left and right (arm and leg), and best language. Six categories had moderate agreement: level of consciousness (consciousness), best gaze, facial palsy, sensory, dysarthria, and extinction/inattention. Ataxia had poor agreement. There was high physician satisfaction with the smartphone.

**Conclusions**—Smartphone high-quality video teleconferencing is reliable, easy to use, affordable for telestroke NIHSS administration, and has high physician satisfaction. *(Stroke. 2012;43:3271–3277.)*

**Key Words**: cellular phone ■ emergency medicine ■ stroke ■ telemedicine

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cute ischemic stroke treatment decision-making requires timely and accurate neurological assessment, preferably by a stroke specialist. Patients who experience stroke in remote or underserved urban or rural health care community hospital facilities can gain access to timely expert care by stroke specialists via telemedicine. American Heart Association/ American Stroke Association guidelines classify the use of high-quality video teleconferencing for National Institutes of Health Stroke Scale (NIHSS) telestroke consultation by a remote stroke specialist when in-person stroke specialist care is not available as a class I, level of evidence A recommendation.1 The NIHSS is a validated 13-category examination tool for measuring stroke deficit with established inter-rater reliability.2–9 Studies have demonstrated reliability of NIHSS assessments at the bedside compared with a remote user on an audiovisual telemedicine system.1,10–20 We hypothesize that the accuracy, efficiency, and reliability of contemporary telemedicine technology for assessing suspected stroke patients can be realistically extended to telestroke consults with videophones (VPs). The purpose of this study was to determine the reliability of smartphones, specifically the iPhone 4, with video-conferencing on iOS using FaceTime (Apple) for telestroke consultations.

Although effective, the current technology used in telestroke consultations has 2 major barriers: (1) time-consuming equipment set-up and establishment of connection and (2) high start-up costs for remote medical facilities with limited financial resources to acquire, install, and maintain telemedicine communication systems. Studies have demonstrated that telemedicine consultations take longer to initiate and have more technical complications than telephone-only consultations, leading to delays in delivery of care.11,14,19,20 Such time delays in assessment and treatment resulting from physician travel and computer set-up need to be minimized. The overall cost of remote stroke assessments also should be made more affordable. The average cost of a spoke
The use of smartphones, particularly VPs, could cut technology costs by an order of magnitude and expedite the set-up, connection, and consultation process.16,18

Methods
The study protocol was approved by the Mayo Clinic Institutional Review Board (ID: 11-003621). The procedures followed were in accordance with institutional guidelines. The proposal was to include 100 consecutive adult patients aged ≥18 years who presented to Mayo Clinic Hospital with a suspected acute stroke syndrome. A sample of 100 subjects was selected to ensure that the margin of error for correlation would be no wider than ±0.05 if the correlation in the target population is at least 0.90. This sample size also ensured margin of error no wider than ±4% if the incidence of disagreement in the target population is no more than 5%. Subjects were not required to have a confirmed stroke before enrollment. Eligible subjects were identified using the hospital’s stroke alert database and electronic stroke census. The subjects were assessed at the first in-patient location to which they were admitted (intensive care unit, stroke unit, or neurology ward) after their emergency evaluation, emergency diagnostic studies, and emergency treatment.

After informed consent was obtained, the investigative team—2 vascular neurologists (VNs) and a medical aide—sembled. All 3 investigative team members had valid American Heart Association/American Heart Association NIHSS Certification.

To reduce bias, the positions of the VNs were randomly assigned for every assessment using a random number generator (www.random.org), and the sequence was concealed. One VN was positioned at bedside, whereas the other VN was positioned in a remote office location in Mayo Clinic Hospital. (Figure 1A and 1B, respectively) The medical aide was also at bedside. Both the medical aide and the remote VN possessed an iPhone 4 with FaceTime application. The aide initiated FaceTime with the remote VN and conducted the NIHSS assessment while video capturing the subject’s verbal responses, actions, and expressions. The NIHSS assessment was administered once per subject in the standard sequence. The bedside and remote VNs individually observed and noted the scores for each NIHSS category on NIHSS worksheets. Each VN was blinded to the scores of the other. At the end of the assessment, both VNs had the opportunity to request that the medical aide repeat a category. If the aide required temporary supplemental assistance conducting a category of the exam, such as visual fields, while video capturing, then the bedside VN briefly helped with only that category. The NIHSS assessment duration was recorded. The scores were statistically analyzed for agreement and correlation.

After each assessment, the remote VN completed a satisfaction survey rating the VP experience on a scale of 1 to 5, with 1 being the lowest and 5 being the highest rating (1 = very poor, 2 = poor, 3 = neutral/no opinion, 4 = good, and 5 = very good), for the following categories: reception in hospital, image quality, sound quality, ease of use, and ability to assess subject using NIHSS. These scores also were statistically analyzed.

Cellular Videophone
Telestroke consultations require high-speed, clear, and reliable audio-video data transmission to ensure adequate neurological evaluation.22 The smartphone used in this trial was the Apple iPhone 4 with third generation service provided by the AT&T network and Wi-Fi wireless internet network capabilities. The iPhone 4 has a 3.5-inch (diagonal) widescreen multitouch display, 640×960-pixel resolution, high-definition (720p) video recording up to 30 frames/second with audio, a frequency response range of 20 to 20 000 Hz, 5-megapixel still camera, tap to focus video or still images, Advanced Audio Coding–Low Complexity Profile (AAH-LC) audio up to 160 kilobits per second, 48-kHz stereo audio, and front- and back-facing cameras. Users have the option of toggling between the 2 cameras during videoconferencing.23 The videoconferencing software application used was FaceTime. This application allows for fast and simple connection between users via real-time 2-way audio and 2-way video using Wi-Fi.24 To ensure adherence to Health Insurance Portability and Accountability Act (HIPAA) regulations for patient confidentiality, FaceTime was used on the firewall-protected Mayo Clinic Hospital business Wi-Fi network (maximum bandwidth 54 Mbps), which is only accessible to Mayo Clinic employees within the hospital campus. The transmitted audio and video feeds were not saved as a record. Before examinations, iPhone 4 Wi-Fi connectivity and FaceTime functionality were tested throughout Mayo Clinic Hospital. Training (≈15 minutes) was provided to the VNs and medical aide in the use of the technology.

Statistical Methods
Statistical analysis was performed with SAS 9.2 (SAS Institute). The primary measures were the bedside and remote NIHSS scores. Agreement was assessed by using the Pearson correlation coefficient.
coefficient. Normality and homoscedasticity assumptions of the Pearson correlation coefficient were assessed by the scatterplots. Individual item scores were treated as ordered categorical variables, and the associations between bedside score and remote scores were assessed by using weighted Kappa (wK) analysis. wK scores were interpreted following published standards (wK >0.75 is excellent agreement beyond chance, wK >0.4 but ≤0.75 is moderate agreement beyond chance, and wK <0.4 is poor agreement beyond chance).23 We also calculated the Bland-Altman limits of agreement for the total score.26 Remote assessments were considered equivalent to bedside assessment if the 95% limits of agreement were within 3 points (−3, 3). Our reasoning for these stringent guidelines was that a difference of 3 points in the total score may constitute a minimal clinically important difference based on prestudy surveys of vascular neurologists engaged in telestroke.

Furthermore, we conducted a detailed examination of agreement between each category. For NIHSS items 1B, 1C, 2, 7, 8, 10, and 11, we reported the percentage of subjects whose remote score differed from the bedside score by ≥1 point. For items 1A, 3, 4, 5, 6, and 9, we reported the percentage of subjects whose remote score differed from the bedside score by ≥2 points. We reported the percentage of subjects who had a difference as defined for ≥2 categories, and the percentage of subjects whose total scores differed by ≥3 points. Confidence intervals were calculated by using the exact binomial method. Remote assessments were considered equivalent to bedside assessments if ≥95% of subjects had differences on ≤1 category, and if ≥95% of subjects had total scores that differed by ≤2 points.

The satisfaction survey data were summarized as means ± standard deviations. These survey data also were treated as categorical and summarized as percentage for category of good or very good.

### Results

One hundred subjects (55 males and 45 females) with mean age of 72 years (range, 30–96 years) were assessed. The final diagnoses at discharge were as follows: ischemic stroke = 46.8%; transient ischemic attack = 8.7%; hemorrhagic stroke = 7.5%; other diagnoses mimicking stroke = 36.1%; uncertain = 0.9%; and unknown = 0%. From among all ischemic stroke alert patients, 14.1% received intravenous thrombolysis, an additional 3.5% received intravenous thrombolysis plus intra-arterial treatments (thrombolysis and mechanical thrombectomy), and an additional 4.0% received intra-arterial treatment only. Table 1 compares the wK for each NIHSS category with results from previous telemedicine device studies. For 8 categories there was high agreement: level of

### Table 1. Interrater Agreement on Individual National Institutes of Health Stroke Scale Categories Using iPhone 4 Compared With Previous Studies

<table>
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<tbody>
<tr>
<td>1a. LOC, consciousness</td>
<td>0.67 (0.48-0.86)</td>
<td>N/R</td>
<td>0.99</td>
<td>1.0</td>
<td>0.99</td>
<td>N/R</td>
<td>0.50</td>
<td>0.49</td>
</tr>
<tr>
<td>1b. LOC, questions</td>
<td>0.94 (0.87-1)</td>
<td>1.0</td>
<td>1</td>
<td>0.93</td>
<td>0.90</td>
<td>0.75</td>
<td>0.64</td>
<td>0.80</td>
</tr>
<tr>
<td>1c. LOC, commands</td>
<td>0.89 (0.74-1)</td>
<td>N/R</td>
<td>0.63</td>
<td>1.0</td>
<td>0.93</td>
<td>0.29</td>
<td>0.41</td>
<td>0.58</td>
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<tr>
<td>2. Best gaze</td>
<td>0.72 (0.54-0.90)</td>
<td>N/R</td>
<td>1</td>
<td>1.0</td>
<td>0.95</td>
<td>0.41</td>
<td>0.33</td>
<td>0.82</td>
</tr>
<tr>
<td>3. Visual fields</td>
<td>0.91 (0.82-1)</td>
<td>0.92</td>
<td>N/R</td>
<td>0.93</td>
<td>0.89</td>
<td>0.6</td>
<td>0.57</td>
<td>0.81</td>
</tr>
<tr>
<td>4. Facial palsy</td>
<td>0.59 (0.46-0.72)</td>
<td>0.72</td>
<td>0.59</td>
<td>0.22</td>
<td>0.85</td>
<td>0.4</td>
<td>0.22</td>
<td>0.57</td>
</tr>
<tr>
<td>5a. Motor left arm</td>
<td>0.83 (0.75-0.91)</td>
<td>1.0*</td>
<td>0.74*</td>
<td>0.88</td>
<td>0.90*</td>
<td>0.82*</td>
<td>0.77*</td>
<td>0.85*</td>
</tr>
<tr>
<td>5b. Motor right arm</td>
<td>0.79 (0.65-0.93)</td>
<td>—</td>
<td>—</td>
<td>0.82</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>6a. Motor left leg</td>
<td>0.79 (0.71-0.87)</td>
<td>0.97*</td>
<td>0.62*</td>
<td>0.74</td>
<td>0.92*</td>
<td>0.83*</td>
<td>0.78*</td>
<td>0.83*</td>
</tr>
<tr>
<td>6b. Motor right leg</td>
<td>0.79 (0.68-0.91)</td>
<td>—</td>
<td>—</td>
<td>0.80</td>
<td>—</td>
<td>—</td>
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<tr>
<td>7. Limb ataxia</td>
<td>0.03 (~0.12 to 0.17)</td>
<td>0.35</td>
<td>0.98</td>
<td>0.34</td>
<td>0.95</td>
<td>~0.07</td>
<td>~0.16</td>
<td>0.57</td>
</tr>
<tr>
<td>8. Sensory</td>
<td>0.64 (0.46-0.83)</td>
<td>1.0</td>
<td>N/R</td>
<td>0.80</td>
<td>0.91</td>
<td>0.48</td>
<td>0.50</td>
<td>0.60</td>
</tr>
<tr>
<td>9. Best language</td>
<td>0.75 (0.63-0.88)</td>
<td>0.85</td>
<td>0.99</td>
<td>0.73</td>
<td>0.98</td>
<td>0.65</td>
<td>0.79</td>
<td>0.64</td>
</tr>
<tr>
<td>10. Dysarthria</td>
<td>0.68 (0.55-0.82)</td>
<td>0.75</td>
<td>0.66</td>
<td>0.61</td>
<td>0.92</td>
<td>0.55</td>
<td>0.32</td>
<td>0.55</td>
</tr>
<tr>
<td>11. Extinction and inattention</td>
<td>0.61 (0.44-0.79)</td>
<td>N/R</td>
<td>N/R</td>
<td>0.80</td>
<td>0.96</td>
<td>0.77</td>
<td>0.61</td>
<td>0.58</td>
</tr>
<tr>
<td>Total NIHSS score correlation coefficient (κ) for P&lt;0.001</td>
<td>0.94</td>
<td>0.98</td>
<td>0.97</td>
<td>0.94</td>
<td>N/R</td>
<td>0.97</td>
<td>N/R</td>
<td>N/R</td>
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<tr>
<td>Length of remote assessment, min</td>
<td>8.77±3.45</td>
<td>8.45±2.82</td>
<td>3.38±0.77</td>
<td>11.4</td>
<td>9.70</td>
<td>N/R</td>
<td>N/R</td>
<td>N/R</td>
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</table>

LOC, level of consciousness; N/R, not reported or performed; NIHSS, National Institutes of Health Stroke Scale; VP indicates prehospital real-time cellular videophones; wk, weighted κ (inter-rater agreement).

Anderson et al,16 NIHSS using VP in 20 patients with stroke (nonacute); Gonzalez et al,18 simplified NIHSS using VP performed by 40 physicians on 1 patient actor with stroke symptoms; Meyer et al,17 NIHSS using StROKE DOC telemedicine unit performed in 25 patients with stroke (nonacute); Handschu et al,18 German version of NIHSS using ESVTA telemedicine unit within 36 hours of symptom onset in 41 patients with stroke; Shaqat et al,19 NIHSS using telemedicine SmartStation in 20 patients with acute stroke with the assistance of a nurse at the bedside; Goldstein et al,20 NIHSS performed on 20 patients with stroke by 4 stroke fellows; Brott et al,21 NIHSS scores performed on admission in 24 patients with acute stroke.

*Either side affected.
consciousness (questions); LOC (commands); visual fields; motor left arm; motor right arm; motor left leg; motor right leg; and best language. Six categories had moderate agreement: LOC (consciousness); best gaze; facial palsy; sensory; dysarthria; and extinction/inattention. One category had poor agreement: ataxia.

The mean total NIHSS scores for bedside and remote assessments were 7.93±8.10 and 7.28±7.85, with ranges of 0 to 35 and 0 to 37, respectively. Figure 2 displays strong positive correlation between bedside and remote total scores ($r=0.949; P<0.001$). In 67% of assessments, there was a difference in ≤1 category. In 76% of assessments, the total of both scores differed by ≤2 points. Figure 3 is a Bland-Altman plot that shows that the differences in total scores had more variation as the mean of the bedside and remote total score for an individual assessment increased. The Bland-Altman 95% limits of agreement had a difference in total scores of (−4.44, 5.61).

The mean evaluation duration was 8.9 minutes (range, 4–19 minutes). This time excluded ≈1 minute of system set-up time (eg, adjusting patient position, lighting, and establishing connection). The evaluation duration was not captured for 7 assessments. The bedside medical aide required temporary assistance from the bedside VN in <5 instances. The results of the VN satisfaction survey are presented in Figure 4. The VNs rated image quality, sound quality, ease of use, and ability to assess subject using NIHSS as good or very good in ≥94% of the assessments. They rated reception in hospital as good or very good in 83% of the assessments.

**Discussion**

Our study results demonstrate that the iPhone 4 is a very reliable tool for stroke telemedicine, given the high inter-method agreement and high correlation coefficient for total scores ($r=0.949, P<0.001$). The iPhone 4 also has excellent physician acceptance and satisfaction. Fourteen of 15 subcategories of the NIHSS had high to moderate levels of agreement beyond chance. Our wK values were within the range of wK scores reported in previous telemedicine and VP studies (Table 1). Only ataxia had poor inter-method agreement beyond chance; this is consistent with nearly all previous studies except that of Gonzalez et al, which used a patient actor. This established low agreement or no agreement for ataxia may be partially attributable to inherent inter-rater variability and the subjectivity of the NIHSS protocol instructions for ataxia. We retrospectively observed that 1 VN rater consistently scored lower than the other rater for this particular category regardless of position.

Sixty-seven percent of the assessments had differences in total scores of ≤2 points, and 76% had a difference in ≤1 category as defined in our methods. Both of these results were lower than the stringent 95% limits of agreement proposed in our methods. The Bland-Altman 95% limits of agreement range was (−4.44, 5.61), which was greater than the range proposed previously (−3, 3). Although the results did not meet these strict a priori requirements, the study results were comparable with previous VP studies (Table 2).

Although telemedicine has been proposed for assessment and treatment of acute stroke patients since 1999, few studies have been performed on the reliability of VPs. The 2 existing studies, by Gonzalez et al and Anderson et al, that evaluated...
the reliability of VPs for telestroke were conducted on smaller patient populations and had low statistical power. This study is the first to assess a large number of real patients with a relatively high mean and a wider range of NIHSS scores (Table 2). We also used a bedside medical aid to recreate the circumstances of a real remote acute stroke evaluation and to reduce the bias and advantage the bedside VN would have in assessing the patient if conducting the examination directly. Our results are consistent with those of previous studies despite the inclusion of a greater number and variety of patients.

Both our study and the study by Gonzalez et al.18 evaluated physician satisfaction with the technology. Both studies had similarly high rater scores for reception in hospital, ease of use, and ability to score subject using NIHSS.18 These results reflect excellent physician acceptance and satisfaction with VPs for telestroke. The model of the phone and the technical specifications may not have a significant effect on the reliability of the VP.

### Implications for Clinical Practice

The main requirements of a telestroke consultation include fast and accurate neurological assessment (preferably by a stroke specialist), review of brain imaging, formulation of diagnosis and treatment plan, including assessment of eligibility for standard thrombolytic therapy, endovascular devices, or neuroprotective clinical trials.1 VPs may be used to accomplish all of these as a standalone tool or as an adjunct to existing telemedicine technology. More than 80% of physicians use smartphones today.28 The widespread use of smartphones, coupled with the prevalence of health care apps, could allow for the affordable expansion of telestroke networks. The smartphone apps marketplace has a plethora of videoconferencing and teleradiology apps available to facilitate the telestroke consultation. The Food and Drug Administration—approved ResolutionMD Enterprise (Calgary Scientific) is a smartphone app on a client-server system that allows VNs to view patient imaging securely, reliably, and quickly.29,30 Mitchell et al.31 reported high agreement in interpretation of noncontrast CT and computed tomography angiography radiology brain scans viewed on a traditional workstation compared with the same scans viewed on an iPhone/iPad using ResolutionMD (intraparenchymal hemorrhage \(wK=1\), acute parenchymal ischemic change \(wK=0.8\), dense vessel sign \(wK=0.69\), vessel occlusion on computed tomography angiography \(wK=1\)). This teleradiology app coupled with videoconferencing software may make the smartphone a complete tool for acute stroke evaluation. Additionally, physicians can access electronic medical records directly from their smartphones and conduct live patient monitoring by tracking patient status and receiving alerts32 or tweets33 when conditions worsen.

The introduction of smartphones and tablets in business proposals to spoke sites may overcome a significant cost barrier to the expansion of telestroke networks to remote hospitals. The cost for a spoke site to purchase an InTouch Health RP Lite telepresence robot is $38,000, and the RP-7 costs $5000 to 7000 per month to lease. On the lower end, a VGo Communications robot costs $6000 to purchase. Software for this technology has a 1-time fee between $1200 (LifeSize Communications) and $38,000 (Polycom; D. Channer, unpublished data, 2012). The iPhone 4 provides a significant reduction in the cost of technology. The iPhone 4 with the most expensive voice, third-generation data plan, and free Wi-Fi costs $100 for the phone purchase plus $1440 per year ($50 per month for 5-GB data plus $70 per month for nationwide unlimited talk time).33 The software is included in the price of the phone. A variety of smartphones, tablets, and data plans are readily available.

In our study, poor internet connectivity rarely delayed consultations. Only 6% of the assessments were ranked poor for the category reception in hospital. Clinical decision-making was only prevented in 1% of assessments, in which case we easily acquired a replacement iPhone 4 from a staff member. The reliability of the internet connection was studied only within the Mayo Clinic Hospital campus, which is a limitation of this investigation. As observed in previous teledicine studies, it is possible for the connection to falter with increased distance between hub- and -spoke sites and with the implementation of additional security measures. For example, the Stroke Telemedicine for Arizona Rural Residents (STARR) study reported an 18% technical complications rate, of which 2% prevented clinical decision-making.13 The Stroke Team Remote Evaluation using a Digital Observation Camera Doctor in Arizona—The Initial Mayo Clinic Experience (STRoKE DOC AZ-TIME) trial reported a higher rate of technical complications (74%), largely attributed to incompatibility of hub- and -spoke security profiles and consequential interruptions in the telemedicine software.20 Specific methods of achieving security and HIPAA compliance for videoconferencing on VPs still need to be established because data encryption is not possible over third generation/fourth generation.34

Because of the advantages of portability and reliability, VPs could be used in prehospital settings as well. Gonzalez et al.18 suggest that nonneurologists can be quickly trained in the steps of the NIHSS or the simplified NIHSS and conduct the exam en route to the hospital. Reliable videoconferencing in an ambulance may increase appropriate triage, prepare health

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### Table 2. Study Methods and Results Compared With Previous Videophone Telestroke Studies

<table>
<thead>
<tr>
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<th>Demaerschalk et al, 2012</th>
<th>Anderson et al, 201116</th>
<th>Gonzalez et al, 201118</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects</td>
<td>100</td>
<td>20</td>
<td>1*</td>
</tr>
<tr>
<td>Physician raters</td>
<td>2</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>Mean NIHSS score (bedside, remote)</td>
<td>7.93±8.10, 7.28±7.85</td>
<td>6.05, 6.30</td>
<td>6.63±0.98, 6.82±1.06; P=0.08†</td>
</tr>
<tr>
<td>Range of NIHSS score (bedside, remote)</td>
<td>0–35, 0–37</td>
<td>0–22, 0–22</td>
<td>6–7, 6–7</td>
</tr>
<tr>
<td>Total NIHSS correlation coefficient (P&lt;0.001)</td>
<td>0.95</td>
<td>0.98</td>
<td>0.97</td>
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</table>

*Single patient actor and single scenario.
†Used simplified NIHSS indicates National Institutes of Health Stroke Scale.

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[4] The introduction of smartphones and tablets in business proposals to spoke sites may overcome a significant cost barrier to the expansion of telestroke networks to remote hospitals. The cost for a spoke site to purchase an InTouch Health RP Lite telepresence robot is $38,000, and the RP-7 costs $5000 to 7000 per month to lease. On the lower end, a VGo Communications robot costs $6000 to purchase. Software for this technology has a 1-time fee between $1200 (LifeSize Communications) and $38,000 (Polycom; D. Channer, unpublished data, 2012). The iPhone 4 provides a significant reduction in the cost of technology. The iPhone 4 with the most expensive voice, third-generation data plan, and free Wi-Fi costs $100 for the phone purchase plus $1440 per year ($50 per month for 5-GB data plus $70 per month for nationwide unlimited talk time). The software is included in the price of the phone. A variety of smartphones, tablets, and data plans are readily available. In our study, poor internet connectivity rarely delayed consultations. Only 6% of the assessments were ranked poor for the category reception in hospital. Clinical decision-making was only prevented in 1% of assessments, in which case we easily acquired a replacement iPhone 4 from a staff member. The reliability of the internet connection was studied only within the Mayo Clinic Hospital campus, which is a limitation of this investigation. As observed in previous teledicine studies, it is possible for the connection to falter with increased distance between hub- and -spoke sites and with the implementation of additional security measures. For example, the Stroke Telemedicine for Arizona Rural Residents (STARR) study reported an 18% technical complications rate, of which 2% prevented clinical decision-making. The Stroke Team Remote Evaluation using a Digital Observation Camera Doctor in Arizona—The Initial Mayo Clinic Experience (STRoKE DOC AZ-TIME) trial reported a higher rate of technical complications (74%), largely attributed to incompatibility of hub- and -spoke security profiles and consequential interruptions in the telemedicine software. Specific methods of achieving security and HIPAA compliance for videoconferencing on VPs still need to be established because data encryption is not possible over third generation/fourth generation. Because of the advantages of portability and reliability, VPs could be used in prehospital settings as well. Gonzalez et al. suggest that nonneurologists can be quickly trained in the steps of the NIHSS or the simplified NIHSS and conduct the exam en route to the hospital. Reliable videoconferencing in an ambulance may increase appropriate triage, prepare health...
care providers, and allow for administration of neuroprotective drugs such as intravenous magnesium sulfate.\textsuperscript{35}

Limitations and Improvements to Study

A drawback of the VP is that it limits the autonomy of the remote VN compared with pan-tilt-zoom operations of standard telemedicine platforms, because a medical aide must capture the video and facilitate the exam, especially for the categories of visual fields, sensory, best language, dysarthria, and extinction/inattention. We observed that for some assessments it was challenging for the medical aide to simultaneously conduct and video record a complete NIHSS exam. In most robotic telepresence consults, a medical aide (eg, Registered Nurse, Licensed Practical Nurse, mid-level provider) still serves as a facilitator but is less involved than someone facilitating a VP consult. The iPhone 4 has autofocus, yet the medical aide must be acutely aware of the quality of the video, the angles of the shot, lighting, acoustics, and background.\textsuperscript{11,16} Another disadvantage is that the VP allows only the medical aide and not the patient to see the VN, which may hinder the development of a necessary physician–patient relationship and rapport.

This study adds to the existing body of VP telestroke research evidence of reliability and should fuel further research. We elected to assess an acute stroke population immediately after the emergency encounter was completed. Prospective studies will test VP technologies in acute, hyperacute, subacute, and chronic stroke settings in different environments (ranging from prehospital, emergency department, hospital, rehabilitation, assisted living, and home) to better understand potential uses and limitations of the technology in more relevant time frames for clinical decision-making. VPs should be compared with telemedicine technology and evaluated on many parameters, such as accuracy, sensitivity, specificity, determination of thrombolysis eligibility, cost of installation, cost-effectiveness, ability to distinguish between strokes and stroke mimics, accurate medical decision-making, patient outcomes, time efficiency, rate of technical complications that prevent clinical decision-making, patient privacy and security features, and physician and patient acceptance.

Conclusions

VPs are reliable, easy to use, and affordable devices for telestroke NIHSS administration. This technology can be readily implemented into telestroke networks to potentially expedite telestroke consultations and increase appropriate use of thrombolysis. VPs have high physician acceptance. With the variety of smartphones and professional medical applications available today, the telestroke practitioner has all the tools necessary for fast clinical decision-making by accessing electronic medical records, viewing images, and tracking patient vitals on this singular technology.

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Disclosures

None.

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