Is Mobile Teleconsulting Equivalent to Hospital-Based Telestroke Services?

Heinrich J. Audebert, MD; Sandra Boy, MD; Ralf Jankovits, MD; Philipp Pilz, MD; Jochen Klucken, MD; Nando P. Fehm, MD; Johannes Schenkel, MD, MPH

**Background and Purpose**—Telemedicine is increasingly used to provide acute stroke expertise for hospitals without full-time neurological services. Teleconsulting through mobile laptop computers may offer more flexibility compared with hospital-based services, but concerns about quality and technical reliability remain.

**Methods**—We conducted a controlled trial, allocating hospital-based or mobile teleconsulting in a shift-by-shift sequence and evaluating technical parameters, acceptability, and impact on immediate clinical decisions. Both types of telemedicine workstations were equipped with DICOM (Digital-Imaging-and-Communications-in-Medicine) viewer and videoconference software. The laptop connected by asymmetrical broadband UMTS (Universal-Mobile-Telecommunication-Systems) technology with a one-way spoke-to-hub video transmission, whereas the hospital-based device used landline symmetrical telecommunication, including a 2-way videoconference.

**Results**—One hundred twenty-seven hospital-based and 96 mobile teleconsultations were conducted within 2 months without any technical breakdown. The rates per allocated time were similar with 3.8 and 4.0 per day. No significant differences were found for durations of videoconference (mean: 11±3 versus 10±3 minutes, \(P=0.07\)), DICOM download (3±3 versus 4±3 minutes, \(P=0.19\)), and total duration of teleconsultations (44±19 versus 45±21 minutes, \(P=0.98\)). Technical quality of mobile teleconsultations was rated worse on both sides, but this did not affect the ability to make remote clinical decisions like initiating thrombolysis (17% versus 13% of all, \(P=0.32\)).

**Conclusions**—Teleconsultation using a laptop workstation and broadband mobile telecommunication was technically stable and allowed remote clinical decision-making. There remain disadvantages regarding videoconference quality on the hub side and lack of video transmission to the spoke side. *(Stroke. 2008;39:3427-3430.)*

**Key Words:** mobile telecommunication ■ stroke ■ telemedicine

Despite evidence of clinical effectiveness\(^1,2\) and international recommendations,\(^3\) only a minority of European patients with stroke receive stroke unit care and systemic thrombolysis.\(^4\) The lack of acute stroke expertise is a major barrier for optimal stroke management. Telestroke using video examination and teleradiology has been implemented in several regions and yielded good results regarding thrombolysis\(^5,6\) and overall quality of care.\(^7\)

Most existing telestroke networks are using landline connections like ISDN (Integrated-Service-Digital-Network) or broadband DSL (Digital-Subscriber-Line) with fixed telemedicine workstations in hub hospitals. Staff organization of such a teleconsultations service remains difficult because consultants either need to provide a continuous presence in the hospital or have to come into the hub hospital after emergency calls.

Teleconsulting using mobile Internet technology may lead to a more flexible 24/7 service, but faces a number of disadvantages like incomplete coverage of UMTS (Universal-Mobile-Telecommunication-Systems) or third-generation (G3), not symmetrical bandwidths and unstable transmission rates. Because these criteria are crucial for teleconsultation quality, we compared mobile with hospital-based teleconsultations.

**Methods**

We conducted a controlled study evaluating 2 months of the TEMPiS teleconsultations service. The network comprises 2 stroke centers and 14 local hospitals. The TEMPiS concept, including effects on quality of care and prognosis, has been described previously.\(^7\) The regular telemedicine setting is based on a 2-way videoconference using secured landline DSL connections with symmetrical bandwidths of 2 MB/s and hospital-based workstations.
Technology
The mobile telemedicine workstation was developed by the MEYTEC GmbH telemedicine company and consists of a 15-inch laptop computer equipped with access protection and headset. Data transmission is based on a “fast UMTS” broadband network. Downstream bandwidth is up to 1.8 MB/s and upstream up to 385 KB/s. Because UMTS is not sufficiently available in all remote areas, the mobile workstations connect to a central server. This server is then linked to the local hospitals through virtual private network (VPN)-tunneled DSL lines. For limited bandwidth of the upstream UMTS connection, the mobile telemedicine setup uses only one-way video transmission from the local hospital to the stroke center but bilateral audio transmission. Both the laptop and the hospital-based workstation use VIMED COMM videoconference software and are linked to a server-based DICOM viewer (VIMED WEB).

Confidentiality
The mobile laptop is only used in confidential environments complying with access and data-protection algorithms. Technical settings and procedures were approved by the Bavarian authority for data protection.

Course of Teleconsultations
Right after the telephone request for a teleconsultation, DICOM downloads and videoconferences are started. The teleconsultant examines the patient by real-time video and audio transmission from the remote side.

Data Collection
A template was completed by the assisting local doctor and the teleconsultant after each teleconsultation. Predefined standards for data collection were applied, including a manual for rating definitions. Both parties rated video respective audio quality, time need, and clinical relevance of the consultation. The grades consisted of excellent (1), good (2), satisfying (3), acceptable (4), poor (5), and insufficient (6). Free text statements were invited. Download transmission rates were measured by an online speed test. To avoid missing values due to communication disorders, local physicians rated the overall teleconsultation quality in their perception of the patient’s perspective. Categories of indications and clinical decisions were derived from the ongoing network documentation.

Study Procedures
Whether the mobile or hospital-based setting was used was predetermined for every teleconsultant shift and alternating aiming for a shift-by-shift order. Because UMTS coverage was not found to be sufficient at all teleconsultants’ homes in a preceding evaluation of available bandwidths, these consultants used only hospital-based technology. To avoid any critical time delays due to technical failures, the conventional telemedicine workstation had to be continuously accessible within 15 minutes.

The study design was approved by the ethics committee of the Bavarian Board of Physicians.

Statistical Analysis
The needed sample size was calculated with the hypothesis of a 15% lower satisfaction rate with laptop telecommunication and based on previous satisfaction analyses. All ratings were dichotomized into excellent or good (1 or 2) and worse. Using SPSSv14, we analyzed differences in proportions with the \( \chi^2 \) test or Fisher exact and continuous variables with the Mann-Whitney \( U \) test. An \( \alpha \) level of 5% was considered to be statistically significant.

Results
A total of 223 teleconsultations with video examination was conducted between June 28 and August 26, 2007. Mobile telemedicine was used on an equivalent of 24 days and hospital-based teleconsultations on 33 days because some shifts were covered by 2 teleconsultants without sufficient UMTS coverage at home. Three days were excluded because all teleconsultations were done without videoconference. The average rate per day was 4.0 for mobile and 3.8 for hospital-based teleconsultations. Seventy-nine (82%) of 96 mobile teleconsultations were done at home and 17 were conducted at other places. There were no technical failures that led to a complete breakdown of teleconsultation.

The recorded laptop-download rates were higher then 700 KB/s in all measurements. In contrast to the almost identical time measurements (Table), the time expenditure was graded worse by the teleconsultants when using the laptops. Significant differences apply for teleconsultants’ ratings of video and audio quality with better results for the hospital-based system.

Ratings from doctors in the local hospitals for the mobile teleconsultations were worse regarding audio quality but similar regarding time expenditure. The inability to see the teleconsultant live was expressed in 7 teleconsultations as a major disadvantage. However, the overall quality of the teleconsultations taking the patient perspective was not different and the clinical relevance of teleconsultations was rated high for both forms of teleconsultations.

Discussion
The findings suggest that a mobile teleconsultation using the available European mobile network technology provides good feasibility and stability. Although the technical quality is sufficient to make relevant clinical decisions in acute stroke care, the perceived subjective quality of the video examination was worse and there were critical comments regarding the lack of a video stream on the spoke side. In addition, a pretest UMTS connection with a lower bandwidth (upstream up to 128 KB/s) led to several breakdowns when used in the area of one of the centers. New UMTS standards promise bidirectional video transmission as used in the United States.

There are few reports about the usefulness of mobile telemedicine for stroke. Meyer et al found good interrater reliability of an Internet-based mobile telestroke system compared with onsite examination of the National Institutes of Health Stroke Scale.

Because we chose a quasirandomized way to allocate the 2 teleconsultations modes, systematic biases in patient selection and user ratings are unlikely. However, the numbers of assessed teleconsultations are too small to exclude minor effects on acceptability or on the ability to make complex decisions in teleconsultations.

The consequences of our results for the practical implementation of telestroke services will depend on the individual structures of networks. With low frequency of teleconsultations and a long time needed for the teleconsultants to arrive at the hospital, mobile or Internet-based solutions may be the preferred solution. With the high teleconsultation frequency of a network like TEMPiS, the service will better run with a hospital-based device to ensure optimal quality. Because the
numbers of teleconsultations are much lower during late
night, the mobile systems may be used even for those
networks to reduce hospital nights of teleconsultants and
costs of staffing.

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Klinikum Freising, Kreiskrankenhaus Kelheim, Klinikum Land-
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### Table. Technical Parameters, Grading, and Clinical Impact

<table>
<thead>
<tr>
<th></th>
<th>Hospital-Based Teleconsultation (N=127)</th>
<th>Mobile Teleconsultation (N=96)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time intervals, minutes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Videoconference duration</td>
<td>Median (IQR) 11 (9–14)</td>
<td>10 (9–13)</td>
<td>0.07</td>
</tr>
<tr>
<td>Duration of DICOM download</td>
<td>Median (IQR) 3 (2–5)</td>
<td>3 (2–5)</td>
<td>0.19</td>
</tr>
<tr>
<td>Total time of teleconsultations</td>
<td>Median (IQR) 40 (30–57)</td>
<td>41 (30–57)</td>
<td>0.98</td>
</tr>
<tr>
<td>Delay caused by technical problems (%)</td>
<td>4 (3)</td>
<td>8 (8)</td>
<td>0.09</td>
</tr>
<tr>
<td>UMTS download transmission rate*</td>
<td>in MB, mean (SD; range)</td>
<td>1.63 (0.46; 0.8–2.6)</td>
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</table>

Grading by teleconsultants

<table>
<thead>
<tr>
<th></th>
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<th>Mobile Teleconsultation (N=96)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video quality</td>
<td>Not excellent or good, N (%)</td>
<td>8 (6)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Audio quality</td>
<td>Not excellent or good, N (%)</td>
<td>14 (11)</td>
<td>0.01</td>
</tr>
<tr>
<td>Expenditure of time</td>
<td>Not excellent or good, N (%)</td>
<td>9 (7)</td>
<td>0.26</td>
</tr>
<tr>
<td>Relevant input to clinical decisions</td>
<td>Not excellent or good, N (%)</td>
<td>25 (20)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Grading by local doctors

<table>
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<th>Hospital-Based Teleconsultation (N=127)</th>
<th>Mobile Teleconsultation (N=96)</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Video quality</td>
<td>Not excellent or good, N (%)</td>
<td>8 (7)</td>
<td></td>
</tr>
<tr>
<td>Audio quality</td>
<td>Not excellent or good, N (%)</td>
<td>11 (9)</td>
<td>0.03</td>
</tr>
<tr>
<td>Expenditure of time</td>
<td>Not excellent or good, N (%)</td>
<td>5 (4)</td>
<td>0.17</td>
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<tr>
<td>Relevant input to clinical decisions</td>
<td>Not excellent or good, N (%)</td>
<td>17 (14)</td>
<td>0.85</td>
</tr>
<tr>
<td>Overall quality in patient’s perspective</td>
<td>Not excellent or good, N (%)</td>
<td>35 (33)</td>
<td>0.55</td>
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<tr>
<td>Clinical decision with immediate impact (%)</td>
<td>Nonstroke diagnosis</td>
<td>19 (15)</td>
<td>0.25</td>
</tr>
<tr>
<td>Interhospital transfer</td>
<td>1 (1)</td>
<td>4 (4)</td>
<td>0.17</td>
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<tr>
<td>Systemic tissue plasminogen activator</td>
<td>22 (17)</td>
<td>12 (13)</td>
<td>0.25</td>
</tr>
<tr>
<td>Total</td>
<td>41 (32)</td>
<td>32 (33)</td>
<td>0.87</td>
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Disclosures
H.J.A. has received speaker honoraria from Meytec GmbH (Telemedicine Company).

References
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