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Telemedicine in Emergency Evaluation of Acute Stroke

Interrater Agreement in Remote Video Examination With a Novel Multimedia System

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Background and Purpose—In acute stroke care, rapid but careful evaluation of patients is mandatory but requires an experienced stroke neurologist. Telemedicine offers the possibility of bringing such expertise quickly to more patients. This study tested for the first time whether remote video examination is feasible and reliable when applied in emergency stroke care using the National Institutes of Health Stroke Scale (NIHSS).

Methods—We used a novel multimedia telesupport system for transfer of real-time video sequences and audio data. The remote examiner could direct the set-top camera and zoom from distant overviews to close-ups from the personal computer in his office. Acute stroke patients admitted to our stroke unit were examined on admission in the emergency room. Standardized examination was performed by use of the NIHSS (German version) via telemedicine and compared with bedside application.

Results—In this pilot study, 41 patients were examined. Total examination time was 11.4 minutes on average (range, 8 to 18 minutes). None of the examinations had to be stopped or interrupted for technical reasons, although minor problems (brightness, audio quality) with influence on the examination process occurred in 2 sessions. Unweighted κ coefficients ranged from 0.44 to 0.89; weighted κ coefficients, from 0.85 to 0.99.

Conclusions—Remote examination of acute stroke patients with a computer-based telesupport system is feasible and reliable when applied in the emergency room; interrater agreement was good to excellent in all items. For more widespread use, some problems that emerge from details like brightness, optimal camera position, and audio quality should be solved. **(*Stroke*. 2003;34:2842-2846.)**

Key Words: diagnosis ■ stroke management ■ stroke, acute ■ telemedicine

In the last decade, various therapeutic strategies were proved to be effective in acute stroke, leading to shortened time windows for intervention. Systemic administration of recombinant tissue plasminogen activator (tPA) has been shown to cause a significant reduction in mortality compared with placebo when given within 180 minutes after symptom onset.[1] On the other hand, tPA may cause severe intracerebral hemorrhage,[2] and crucial factors will influence the risk-to-benefit ratio and may increase mortality[3] in daily practice. One of these factors is the severity of stroke measured by the National Institutes of Health Stroke Scale (NIHSS) score. A recent study investigating routine use of systemic thrombolysis reports an increase in in-hospital mortality after administration of tPA in hospitals with <5 thrombolytic therapies within 1 year.[4] These findings underline the need to have an experienced expert involved in the management of an acute stroke patient. Careful evaluation in a minimum of time is required. Urgent therapeutic decisions in emergency stroke care have to be made by an experienced stroke neurologist on the basis of brain imaging and a structured clinical examination. Such expertise is available mainly in stroke centers of teaching hospitals. However, many stroke patients are seen primarily in local general hospitals where diagnostic possibilities are limited[5] and stroke experts are not available. To offer specific options of modern stroke care to patients in local hospitals, they are usually transferred to an academic stroke center. To accelerate admission, hospital networks[6] were created and helicopter transport systems were initiated.[7] In general, transferring patients is expensive, laborious, time consuming, and risky for the patient. Transfer times for interhospital ground transport were ≈30 minutes in our region,[8] but even with helicopter transport, it takes ≈135 minutes from symptom onset to hospital arrival.[7] Thus, in many cases, it simply takes too long to provide access to specific therapy for the patient.

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A promising opportunity for saving time is bringing expertise to patients treated in smaller hospitals by linking hospitals together with the use of telemedicine. This technology may reduce transfer of patients and adverse events if transfer is neccessary.[9] The needs for telemedicine in stroke medicine were described clearly by Levine and Gorman.[10] They named the mandatory elements of a telestroke system: transfer of imaging data and a review of clinical findings viewable at a remote computer workstation. For imaging data, fairly good systems using Digital Image and Communications in Medicine (DICOM) standards are now available and in use.[11] To perform clinical examination while linked to academic centers, real-time transmission of video and audio sequences with high speed data connections is necessary. First results testing conventional videoconferencing systems are promising.[12–14] In 1 study,[12] administration of the NIHSS was already tested in a telemedicine setting examining patients several days after stroke. We tried to adopt this paradigm into an acute care scenario investigating stoke patients in the emergency room where its validity has not been proved.

In a pilot study, we tried to evaluate whether a remote video examination is possible for hyperacute stroke patients within the first hours after onset of symptoms and if such an examination will produce the same results as a bedside testing using the German version of the NIHSS.[15]

Materials and Methods

Over a 6-week period, patients admitted to our stroke unit with symptoms suggestive of stroke within 36 hours of symptom onset were included in this study and examined in the emergency room as soon as possible after admission. Patients with decreased consciousness (Glasgow Coma Scale <9) or instability in vital signs were excluded, as were those patients in whom video examination would delay any diagnostic or therapeutic intervention. The emergency room of the Neurology and Neurosurgery departments, where all examinations took place, is a small (3×4 m) room on the ground floor of the hospital. It has no windows, and light is provided by 2 standard neon lighting systems. All patients were lying on a stretcher or in a hospital bed and connected to standardized monitoring of vital signs (ECG, noninvasive blood pressure, oxygen saturation) during the whole examination. All patients (or their next of kin, if appropriate) gave informed consent before participation. The study protocol was approved by the local ethics subcommittee of the university.

Remote examination of patients was performed using the prototype of a novel audiovisual telesupport system (EVITA, ORI - Optics Research and Information Ltd), providing real-time transmission of video and audio sequences from the emergency room to the stroke unit in a distant part of the building. The EVITA system is implemented as a component-based architecture to use electronic communications infrastructure for high-speed transfer of data of different sources like voice, video, or imaging data. Within its modular component, a special Internet protocol–based communication protocol with a strong data security concept is used, but the system is also able to integrate other communication methods like DICOM, file transfer protocol (FTP), or hypertext transfer protocol (HTTP).

The system was originally designed to integrate the requirements of healthcare professionals into 1 telemedicine device. We adapted it to the special needs of acute stroke care; for example, we optimized the compression factor in the video stream especially for diagnostics of the face (eye movements, etc) and the viewing size finally to 384×288 pixels. The located factor composed a tradeoff between image size, image dynamic, details fidelity in the local and color resolution and the data transfer rate. To guide the optimization process, we made some pretests with volunteers mimicking examination conditions.

Finally, within our pilot study, the system consisted of the multimedia server unit, a personal computer as part of a client-server system, and a pan, tilt, and zoom camera with video-inside interactive control. The remote-controllable cameras CAM2 used in this study had the following technical characteristics: video signal, PAL color; power zoom f=5.4 to 64.8 mm; autofocus, F1.8 to F2.7; rotation range: vertical angle, 25°; horizontal angle, 100°; illumination range, 7 to 100 000 lux; and gain selector automatic.

The interactive remote control allowed very fast and exact camera movements by simple mouse click within the overview image. Therefore, we did not use preset camera positions. The remote examiner was viewing at a 17-in computer monitor presented in a Netscape (version 4.7) browser frame (the Figure). Image size and compression quality of the resulting video image were modifiable. In this study, we used 25 images per second in a standard view of 384×288 pixels up to 768×576 pixels (detail view mode).

To establish audio connection, a microphone and speakers were used at the patient's side in the emergency room, and a headset was used at the examiner's side at the stroke unit. The video server was connected to a personal computer as part of the client-server network. For data transmission, existing in-house ethernet connections were used, providing a data speed of up to 1500 kilobytes per second. The video examinations were done in the emergency room in its normal size and shape using the standard lighting as described above. Standardized video examination was performed by use of the NIHSS (German version[15]) by the remote examiner at the desktop personal computer in his office. The remote examiner directed the whole process, giving instructions to the patient and assistant via an audio line. Assistance was provided by a trained medical student.

Before or after video examination, administration of the NIHSS was repeated at bedside by a different examiner who was not involved in video assessment and was blinded to its result (and vice versa). Both examiners were stroke neurologists experienced in administration of the NIHSS. Additionally, special training was provided before the study to train examiners again in administration of the NIHSS and use of the multimedia system

For each item of the NIHSS, unweighted and weighted κ statistics were calculated. Factors for weighted scores were used as in the original work of Berger at al.[15] Examination times were compared by use of 2-tailed t test (α=0.05).

Results

Of 57 patients admitted to the stroke service during the study period, 41 were included in this study; their mean age was 63.3 years (range, 25 to 93 years), and 22 were male. Twelve patients were seen within 6 hours of symptom onset; another 27, within the first 24 hours; and 2, 30 and 36 hours after symptom onset. Video examination was started from 15 to 960 minutes after admission (mean, 112 minutes).

Final diagnosis at discharge from the Department of Neurology was ischemic stroke in 53.7%, intracerebral hemorrhage in 12.2%, and transient ischemic attack in 22.0% of all cases; 9.8% had a nonstroke diagnosis. Of all stroke syndromes, 41.7% were left hemispheric, 38.9% were right hemispheric, and 19.4% were thought to be from a brain stem or cerebellar origin.

Total time for remote examination (introduction, application of NIHSS, repeated check for vital signs) was 11.4 minutes (range, 8 to 18 minutes) and for bedside examination was 10.8 minutes (7 to 18 minutes). The difference was slightly significant ($T=-2.6$; $P=0.013$).

No examination was stopped for technical reasons. In 2 cases (4.9%), there were minor problems with the video

Video examination as seen at the desktop-PC. The video appears in a browser frame. Clicking in the scan view at the top will shift the camera position to that point. At the left side camera position can be operated by mouse click as well as zoom from wide angle to close up. The view shows testing for visual field deficit, where bedside assistance is required.

image such as short stop and go or interruption of the video. In 5 cases (12.1%), we had small problems with audio technology like a voice echo or a system-induced noise. In another 3 cases (7.3%), there were more distinct problems with light, brightness, and contrast such as a very bright background provided by the hospital linen with a large white pillow and blanket. In addition, the phenomenon of light and shade in a patient's face can make evaluation tricky sometimes.

Taken together, all the technical problems required a repetition of NIHSS items in 2 cases. In all other cases, technical pitfalls had no influence on examination process or quality. Repetition of NIHSS items was also necessary in the remote examination of 5 patients (12.2%) because they were partially noncooperative (mainly aphasic patients); 3 of them were also uncooperative at bedside examination. Nevertheless, a complete examination with full scoring of the NIHSS was always possible in a reasonable amount of time. Both exams could be completed in all patients originally included in the study.

Mean NIHSS score was 4.9 points (range, 0 to 20 points) for remote examination and 4.8 points (range, 0 to 18 points) for bedside examination. Unweighted κ coefficients ranged from 0.44 to 0.89; weighted κ coefficients showed excellent interrater agreement, ranging from 0.85 to 0.99. Data for each item of NIHSS are shown in Table 1 for all patients. Table 2 shows weighted κ scores for the 12 patients seen within 6 hours of symptom onset.

Discussion

Telemedicine has been already tested in consultation for various neurological diseases[14] and in prehospital care[16] and

TABLE 1. Interrater Agreement in NIHSS Items for All Patients (n=41)

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

CI indicates confidence interval. n=41.

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

TABLE 2. Weighted κ Coefficients for the Subgroup of Patients Examined Within 6 Hours of Symptom Onset (n=12)

Coefficient	Weighted κ Coefficient (95% CI)
Consciousness	0.97 (0.91–1.0)
Questions	0.88 (0.77–1.0)
Commands	0.89 (0.72–1.0)
Best gaze	0.88 (0.77–0.99)
Facial paresis	0.62 (0.48–0.77)
Visual field	0.83 (0.70–0.96)
Motor arm	0.90 (0.83–0.97)
Motor leg	0.95 (0.90–1.0)
Ataxia	0.94 (0.86–1.0)
Sensory	0.83 (0.69–0.96)
Language	0.97 (0.91–1.0)
Dysarthria	0.93 (0.86–1.0)
Neglect	1.00 (1.0–1.0)*

CI indicates confidence interval. n=12.

*All patients received the same score by remote and bedside examiners in this item.

rehabilitation[17] for stroke patients. Only a small number of studies investigated the application of telemedicine to clinical evaluation of acute stroke patients.

Wiborg et al[13] demonstrated good to excellent agreement in testing European Stroke Scale (weighted κ, 0.72 to 0.95) and Scandinavian Stroke Scale (weighted κ, 0.70 to 0.97) in a telemedicine setting using a standard videoconferencing system. Some of their patients were examined within the first 24 hours of symptom onset. Prior work also demonstrated that the NIHSS can be reproduced with comparable results when applied via a videoconference system.[12] In their study, Shafqat et al[12] used a telemedicine link to examine 20 patients 2 to 73 days after stroke. Weighted κ coefficients ranged from −0.07 to 0.83 for the different items of the NIHSS, demonstrating mainly fair to good interrater agreement.

The present study is the first attempt to test the feasibility and validity of remote video examination using the NIHSS in acute stroke patients shortly after symptom onset in a time frame when the most relevant therapeutic decisions are made. It is the first study of telemedicine in stroke carried out in the setting of an emergency room. Video examinations were done in the normal scenario of our acute stroke admission protocol, with all patients lying on a stretcher or bed and connected to standard monitoring of vital signs.

Within this setting, all examinations were done completely without major problems in a very short time. Because camera control was rather quick and exact, we did not need to group the items of examination, and NIHSS was administered in a standard sequence like that given in Table 1, which is very similar to the recommendations of Berger et al.[15] The time required for video and bedside examinations was rather short. However, the small difference (0.6 minutes) was still significant. The main explanation is that in a small number of the video examinations, there were minor technical problems or patients were partially uncooperative, requiring repetition of single items of the stroke scale. Most patients were satisfied with the examination setting, even though the remote examiner was not visible to the patient.

Interrater agreement was good to excellent in all items of the NIHSS for all patients and for the subgroup of hyperacute patients (<6 hours) only. κ Coefficients were higher than in the prior study.[12] This could be due to differences in video and audio quality; Shafqat and colleagues[12] used a standard personal computer–based videoconferencing system connected by three ISDN lines, whereas in our study, focus, color, and contrast of the video image presented on the monitor were probably higher with the high-speed multimedia system.

Weighted κ coefficients were lowest in testing for facial paresis, especially in the 6-hour subgroup. We believe that these results are due partially to regulations of the NIHSS protocol that still leave much room for individual judgment. The κ coefficient was also lowest for facial paresis (weighted κ, 0.62) in the original study validating the German version of NIHSS[15] and in a validation study of the original version (weighted κ, 0.22).[18]

Overall results of video examination were almost equal to those at bedside. From our results, it seems possible that an experienced expert in the stroke center does a reliable examination and takes part in the diagnostic process and treatment decisions such as administration of tPA or in differential treatment of hemorrhage. In a recent randomized trial,[14] use of telemedicine produced additional tests and was less accepted compared with face-to-face consultation. Thus, facing the expert may be still superior to remote contact. In many instances, however, transferring the patient or expert is impossible within the appropriate time windows. In a prior article, it was concluded that neurological examination is possible through an audiovisual link and is as good as face-to-face examination of a junior doctor.[19] In our study, remote examination in the emergency room was equal to bedside testing by an expert with the same level of experience. Accordingly, teleconsultation over an audiovisual link may be a clear improvement to smaller hospitals. Experts from the stroke center will interfere not only with initial assessment but also with the in-hospital course of the patient by repeated consultation. In addition to mentoring inexperienced colleagues in the local hospital, a telemedicine-based network will have an educational effect over the long term and will help to raise common standards in stroke care that are not always established.[5]

In this context, our data may help to generate more confidence in the use of telemedicine because its acceptance still seems low. Recently, however, first experiences with routine use of telemedicine in stroke care have been published,[20] with thrombolysis a result of teleconsultation in some cases. For making decisions on thrombolysis and interacting with emergency personnel, the expert in the stroke center needs additional information besides a clinical evaluation of stroke type and severity. In the present trial, the remote examiner just used an audiovisual link and was able to view the vital signs on the monitor. It might be possible to view films of CT scans through the video link. To provide additional information about imaging or text and laboratory data, the multimedia system used in our study could also handle other data sources like DICOM data or HTTP connections via a computer network and thus could be the cornerstone of a larger telestroke network. It also seems to provide better video quality and remote-control mechanism but requires quite higher bandwidth compared with standard videoconferencing systems.

Before telemedicine will reach more widespread use in stroke care, technology should be optimized, especially with regard to data compression algorithm and data speed. Moreover, there are some basics like light, background, and acoustics in the examination room that need to be addressed when a telemedicine service is begun. For examination of patients lying on a hospital bed, which is most suitable in acute care, optimal camera position and angle are necessary. Subsequently, the size and shape of the examination room must be taken into account. Finally, a clear description and high grade of standardization of the whole process are crucial, and bedside assistants must receive good training.

In summary, telemedicine is a promising technology that can help to get modern stroke care to more patients. Our data suggest that remote video examination of stroke patients is feasible even in the acute care situation at the emergency room and provides valid clinical information comparable to bedside testing. A multimedia system like that used in this study may provide advantages over standard technology but is only the first step in the development of an integrated telestroke system. Its value in clinical routine and its cost-effectiveness must be proved in further studies.

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