A New Support System Using a Mobile Device (Smartphone) for Diagnostic Image Display and Treatment of Stroke

Hiroyuki Takao, MD; Yuichi Murayama, MD; Toshihiro Ishibashi, MD; Kostadin L. Karagiozov, MD; Toshiaki Abe, MD

Background and Purpose—With the increasing demand for rapid diagnosis and treatment of stroke, the telemedicine role of coordinating timely the efforts of the stroke team became important. We developed a system for rapidly exchanging diagnostic images and clinical and management information.

Methods—A system was created on the basis of communicating patient data and images between hospital systems and participating staff members in and out of the hospital through their standard, currently used handheld communication devices. The system is able to transfer clinical data, CT, MR, angiographic, intraoperative images, and expert opinion in real time.

Results—A pilot application of the system in our hospital showed successful information transfer, allowing medical staff to discuss patients’ diagnosis and management using a Twitter system.

Conclusions—The system (i-Stroke) may become a useful tool for acute patient management in the field of neurology and neurosurgery.

Key Words: acute stroke ■ organized stroke care ■ stroke management ■ telemedicine

Recent clinical results have demonstrated the effectiveness of recombinant tissue-type plasminogen activators in acute stroke within 4.5 hours of onset and every 5 minutes delay in receiving treatment increases by 5% the probability of a poor outcome.¹ Both time and judgment are important when treating patients with acute stroke. However, support by physicians with sufficient experience in cerebrovascular disorders is available in very few hospitals around the clock, 365 days a year. Therefore, the rapid, available at any time consultation between the on-call and the senior specialists is of great importance in deciding optimal treatment.

Recently the use of telemedicine for stroke care has expanded in a range of initiatives through Europe and the United States.²,³ In 2009, the American Heart Association recommended telestroke systems to be created in hospitals unable to provide treatment within the first 24 hours of stroke onset.⁴ Having the same demand in Japan, we established a system that is based on standard portable communication devices and their supporting systems, exchanging high-quality clinical information and imaging for “real-time” support of clinical diagnosis and treatment in these neurological emergencies.

Methods
After current mobile and handheld communication and IT devices progress, we developed the “i-Stroke” system to rapidly access diagnostic images and clinical information, whether in or out of the hospital. This pilot study was conducted in a neurosurgical department. The software was developed by the investigators. It is free software and it is already available at the Apple store. The system comprises a transmitting server and receiving Smartphones (iPhone 4; Apple Inc; Figure 1A) and allows the following functions: (1) stroke call function: informing participating medical staff involved in all aspects of patient management of an expected admission; (2) time-bar function for monitoring patients’ management course (Figure 2C); (3) image viewing function (Figure 3A–C; medical images virtually identical to those displayed in the hospital); (4) static and 3-dimensional video images available to off-site users (Figure 3D), tick-box functions for input/displaying data (consciousness level and neurological findings); and automatic calculation of intravenous medication dose (including tissue-type plasminogen activator) from body weight, diagnosis confirmation from clinical history, and findings using checklists: National Institutes of Health Stroke Scale/Glasgow Coma Scale stroke scales, and others) incorporating diagnostic and treatment functions (Figure 2A); (5) real-time video streaming of microsurgical and diagnostic images from diagnostic and operating rooms (Figure 3C); (6) Tweeting to fellow specialists (exchanging opinions on the spot); and (7) interhospital exchange of images and other information, allowing consultations for patients at other hospitals. To protect personal information, all patient information was blindly coded by the VPN system. Therefore, only patient age and gender were provided as identification. After 24 hours of stroke call initiation, all i-Stroke data for the patient are erased automatically.

Results
The i-Stroke project was approved by our Institutional Review Board and 64 “i-Stroke” calls were made between
August 2010 and March 2011. Fifty-five patients were admitted by ambulance from the central metropolitan area of Tokyo and 9 patients admitted as walk-ins. The distance of the patient transfer ranged between 1 and 20 km. The patient’s diagnosis after completion of the call and clinical management is shown on Figure 1B.

**Illustrative Case**

A 38-year-old man presented with a severe headache. Three-dimensional CT angiography revealed subarachnoid and intracerebral hemorrhage resulting from a ruptured anterior communicating artery aneurysm. Initiating a stroke call, the images were transferred to the experts on endovascular and open surgical treatment (Figure 3A–B). Monitoring real-time images on the immediately performed angiography, senior neurosurgeons and neurointerventionalists discussed treatment options using the “Twitter option.” Surgery was started immediately by the on-call residents, a junior neurosurgeon moved to the hospital monitoring the case on the way, and the senior neurosurgeon advised the team using videostream from an outside location (Figure 3C).

**Discussion**

Compared with existing systems,5,6 the i-Stroke system represents an advance in the direction of treatment support. Information sent from a fixed workstation can be received wherever there is a mobile signal (i-Phone, Android). In addition to delivering images, when initiated before admission, the i-Stroke system alerts the relevant hospital staff on the patient’s arrival condition and time, a key function considering the importance of team stroke treatment. Further on, the display of real-time diagnostic imaging results and other tests permits swift reaction to developments and physicians can objectively identify possible time savings. Clinical evaluation scales (Glasgow Coma Scale, the National Institute of Health Stroke Scale, the modified Rankin Scale) are included in the patient record options.

The real-time viewing of surgical and other procedures by senior experts outside the hospital allows the assessment of treatment progress and provides guidance, contributing to treatment safety and risk management.

The Tweet function permits adding instantly comments about clinical images and other related data. i-Stroke is therefore a novel system that enables simultaneous communication among several members and results in significant time savings on decision-making. Treatment instructions and other orders can be sent with a single touch.

For personal information protection, all mobile devices are identified and password-protected so that only the device owners can see images, and measures such as automatic
deletion of images within 24 hours of receipt are included. When images are downloaded to the physician’s device outside the hospital, to guarantee security, images are automatically rendered anonymous and simultaneously compressed to ensure rapid download, aiming for protection from information leakage.

We hope in this way eventually all emergency patients with stroke nationwide will benefit from this system through

Figure 2. Diagnostic and treatment data display and orders (A and B), including timeframe display (C).

Figure 3. Basic imaging abilities on mobile device. A, Admission CT; (B) digital subtraction angiography; (C) real-time monitoring of the procedure by consulting expert and “real-time” surgical field in display to the expert. Postoperative images: (D) digital subtraction angiography and 3-dimensional CT bone reconstruction.
the cooperation of hospitals throughout Japan who wish to participate. Furthermore, similar systems will probably also continue to be adopted worldwide in line with the American Heart Association recommendations.1,4

i-Stroke concept and functions can be adapted to other medical fields, and i-Cardiology, i-Obstetrics, and i-Gynecology are under development.

Conclusions
By facilitating the rapid diagnosis and treatment of stroke and other acute neurological and neurosurgical conditions, our system is expected to improve the outcome in many patients. The results indicate its potential to provide benefit for treatment of patients with ischemic stroke, although these series contained only 1 such case. It may also reduce extra working hours, giving physicians the opportunity to be efficient even when being on standby, away from the workplace. Hopefully misdiagnosis and unnecessary transfer of patients will be reduced, ultimately contributing to healthcare cost reduction.

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