Smartphone-Assisted Prehospital Medical Information System for Analyzing Data on Prehospital Stroke Care

Takuro Nakae, MD; Hiroharu Kataoka, MD, PhD; Shigeki Kuwata, PhD; Koji Iihara, MD, PhD

Background and Purpose—Optimizing prehospital stroke care is important because effective treatments for acute stroke require a narrow therapeutic time window. We developed a smartphone-assisted prehospital medical information system (SPMIS) to facilitate research on prehospital stroke care.

Methods—Prehospital medical information was input into the SPMIS application installed on smartphones by emergency medical staff, sent to a server through the Internet, and connected with in-hospital information. Using SPMIS, we analyzed data on 914 patients transferred to our institution by ambulance between April 2012 and March 2013.

Results—The data analyzed were the sensitivity and specificity of the prehospital diagnosis and prehospital stroke scale and the relationship between prehospital vital signs and forms of stroke. These analyses could be performed semiautomatically in a few hours.

Conclusions—SPMIS enabled us to analyze the prehospital information of patients with stroke in a short time with little effort. More large-scale studies on prehospital stroke care will become feasible using SPMIS, which may lead to advances in stroke treatment. (Stroke. 2014;45:1501-1504.)

Key Words: emergencies ▪ prehospital emergency care ▪ stroke

Because the therapeutic time window for patients with acute stroke is limited and delays in onset-to-treatment have partly been attributed to prehospital delays, several approaches have been attempted to improve prehospital stroke management. A system is needed by which we can efficiently collect and analyze information on prehospital care with little effort to assess the effect of such approaches.

Smartphones have increasingly been used throughout the world by virtue of their mobility and usability. Information can be collected, stored, and analyzed in a digital fashion with little effort and cost. Smartphones have been used in stroke care for image transfer for telemedicine or communication among members of a stroke team outside the hospital. The aim of this pilot study was to develop a system in which emergency transport records could be sent wirelessly, stored as digital data, and analyzed quickly in combination with in-hospital medical information. We discuss the use and usability of this system.

Materials and Methods

Smartphone-Assisted Prehospital Medical Information System

We developed a smartphone-assisted prehospital medical information system (SPMIS) application that could collect prehospital medical information over the Internet as digital data (Figure 1). In this study, we equipped each ambulance at the Suita Fire Headquarters with 1 smartphone in which the application was installed. Screenshots of the application are shown in Figure 2. One unique transportation identification (ID) was created for each emergency case. When emergency medical staff (EMS) arrived at the scene, in one touch, they input the time of arrival, the clinical information of a patient, and a prehospital tentative diagnosis by answering questions displayed on the smartphone. The smartphone only displayed questions that were related to the prehospital diagnosis. For example, if the prehospital diagnosis was stroke, the input field of neurological findings and Cincinnati prehospital stroke scale appeared. When EMS pressed the submit button, emergency records were uploaded to a data server at our institution, which could be viewed by medical staff at the hospital before the arrival of the patient. On arrival at the hospital, the patient was assigned a hospital ID, which was added to the prehospital medical information database by a medical clerk. The linkage between transportation ID and hospital ID enabled post hoc analyses of the prehospital medical record. A medical clerk later input information into the prehospital medical information database about whether the patient was hospitalized, and if hospitalized, the outcome and diagnosis 1 week after admission. Therefore, EMS at the fire department could view the outcome of the patient they transferred.

Analysis of Prehospital Data

We analyzed data on 914 patients transferred to our institution by Suita Fire Headquarters ambulances between April 3, 2012, and April 2, 2013, using SPMIS. The data analyzed were the reason for the emergency transportation, the prehospital medical record, and the Cincinnati prehospital stroke scale value. We categorized...
prehospital diagnoses into 9 groups (ischemic heart disease, congestive heart failure, aortal dissection, arrhythmia, subarachnoid hemorrhage, stroke other than SAH, seizure, consciousness disturbance, and others). Prehospital diagnoses were compared with in-hospital diagnoses, and the predictive values of prehospital diagnoses were calculated. The diagnostic values of Cincinnati prehospital stroke
scale for stroke were also evaluated. This study was approved by our Institutional Review Board.

Statistical Analysis
Analyses were performed using GNU R version 2.15.36 (R Development Core Team). We used Fisher exact test for categorized variables. Significance was defined as a P value <0.05.

Results
Of 914 cases, an invalid patient ID was recorded in 40 cases. Of the remaining 874 cases (511 men and 363 women; mean age, 70.8±14.7 years), prehospital diagnoses were recorded in 867 cases (94.9%). Because our institution specializes in cardiovascular and cerebrovascular diseases, cardiac disease accounted for 23.2% of all reasons for transportation, whereas cerebral disease accounted for 57.8%. Ischemic heart disease was the most common cardiac disease (9.5%), followed by congestive heart failure (7.0%) and arrhythmia (4.3%). Stroke other than SAH was the most common cerebral disease (46.9%) and SAH accounted for 2.2%.

We analyzed the predictive values of prehospital diagnoses (Table), the diagnostic values of Cincinnati prehospital stroke scale (Table), and correlations between vital signs and forms of stroke (data not shown) using SPMIS. Of the 417 cases diagnosed with stroke by EMS, 126 were diagnosed with cerebral infarction and 73 were diagnosed with intracerebral hemorrhage by radiological examinations. These analyses were performed semiautomatically in a few hours.

Discussion
Use of SPMIS
Prehospital diagnosis and care in patients with stroke is of vital importance. However, few studies have examined prehospital data, and the sample size in these studies was generally small. The analysis of paper-based data from a large number of patients requires much effort regardless of whether it is performed prospectively or retrospectively. In particular, it is sometimes difficult to obtain accurate data in emergencies comprehensively. The difficulties encountered in studies on prehospital stroke data have been attributed to the collection of prehospital data, which are not typically documented in medical records. Although this pilot study was conducted at 1 hospital and 1 fire department, >900 emergency patients could be analyzed in 1 year. If we applied SPMIS to multiple hospitals and multiple fire departments, >10,000 patients could be analyzed. Data automatically accumulated in the server, and the data analyses described above could be performed in a short time. SPMIS can be used as a powerful tool in a large-scale study on prehospital stroke care.

The time course of prehospital care can greatly influence the prognosis of patients. In SPMIS, in one touch, the time of the emergency call, arrival at the location of the patient, departure to the hospital, and arrival at the hospital were accurately recorded. We could easily assess whether some revisions to the rules for emergency transportation may reduce prehospital delays and improve the outcomes of patients with stroke using SPMIS.

Usability of SPMIS
The SPMIS application was designed so as not to place unnecessary burden on EMS. Keyboard input was generally avoided. For example, number wheels in which the present time was set as the default appear on the display to input a time record. We arranged the layout of the application to be clear and simple. Questions were divided into several layers and only 1 or 2 questions appeared on 1 display. These features made the input easier and quicker and save the time of EMS for other important tasks. Moreover, EMS can view the in-hospital diagnoses and prognoses of the patients they transferred through the SPMIS system at any time, which raises their motivation. To demonstrate the advantages of SPMIS, it is necessary to compare it with the conventional paper-based system, which was not analyzed in this study. This is a limitation of this pilot study.

Conclusions
We developed a novel SPMIS. Data were sent to the server for real-time analysis. SPMIS was designed to reduce the burden on EMS. More large-scale studies on prehospital stroke care will become feasible using SPMIS, leading to advances in stroke treatment.

Table. Diagnostic Values of Prehospital Diagnosis and Cincinnati Prehospital Stroke Scale

<table>
<thead>
<tr>
<th></th>
<th>In-Hospital Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(+)</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>0.33 0.99</td>
</tr>
<tr>
<td>Prehospital diagnosis</td>
<td>11 11</td>
</tr>
<tr>
<td>Stroke (infarction/TIA/hemorrhage)</td>
<td>0.90 0.68 0.51 0.95</td>
</tr>
<tr>
<td>CPSS</td>
<td>0.62 0.64 0.57 0.68</td>
</tr>
<tr>
<td></td>
<td>≥1 137 102</td>
</tr>
<tr>
<td></td>
<td>0 83 179</td>
</tr>
</tbody>
</table>

TIA indicates transient ischemic attack.
Acknowledgments
We thank the Suita Fire Headquarters for collaborating with us on this study. Smartphone-assisted prehospital medical information system was developed in partnership with Nippon Electric Company.

Sources of Funding
This study was supported by a research grant from the Fire and Disaster Management Agency and Intramural Research Fund (23-4-6) for Cardiovascular Diseases of the National Cerebral and Cardiovascular Center.

Disclosures
None.

References
Smartphone-Assisted Prehospital Medical Information System for Analyzing Data on Prehospital Stroke Care
Takuro Nakae, Hiroharu Kataoka, Shigeki Kuwata and Koji Iihara

*Stroke*. 2014;45:1501-1504; originally published online March 25, 2014;
doi: 10.1161/STROKEAHA.114.004872

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2014 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/45/5/1501

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Stroke* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Stroke* is online at:
http://stroke.ahajournals.org//subscriptions/