Original Paper

Effectiveness of Near-field Communication Integrated with Mobile Electronic Medical Record System in Terms of Physician Turn-around Time in an Emergency Department: Simulation Study

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Abstract

Background: Mobile electronic medical record (EMR) systems are widely used based on the wide availability of smartphones; their ability to improve efficiency in medical practice has been demonstrated. However, the quantitative effectiveness of mobile EMR systems has rarely been measured.

Objective: The aim of this study is to determine the effectiveness of near-field communication (NFC) integrated with a mobile EMR system in terms of physician turnaround time in an emergency department (ED).

Methods: A simulation study was performed in an ED. 25 participants working in the ED participated in two scenarios, using mobile or a PC: one is locating randomly designated patients in the ED from the ED entrance, and the other is looking up the laboratory results of an ED patient at the bedside. Upon accomplishing the scenarios, participants responded to a 10 question questionnaire using a system usability scale (SUS). The main metric was turn-around time for each scenario. The secondary metric was the usability of the system, graded by the study subjects.

Results: Locating patients from the ED entrance took 93.0 s (mean) using the mobile scenario, whereas it took 57.3 s (mean) using the PC scenario, which is significantly faster \((P < .001)\). Searching for laboratory results of the patients at the bedside took 25.2 s (mean) using the mobile scenario, and 61.5 s (mean) using the PC scenario, which is significant \((P < .001)\). Sensitivity analysis comparing only the time for login and looking up the relevant information also found mobile to be significantly faster. The mean SUS score of NFC-mobile EMR was 71.9 points.

Conclusions: NFC integrated with mobile EMR helped physician practice to be more efficient, with good usability.

Trial Registration: IRB File No - SMC 2018-01-144-001

Keywords: near-field communication, electrical medical records, emergency department
Introduction
An emergency department often exhibits chaos and inefficiency [1]. Patient severity varies and changes unpredictably. The location of patients also changes based on the clinical process and test results, which arrive at different times. Physicians often waste a substantial amount of time walking back and forth to check relevant information such as a patient’s current location and laboratory results. ED providers strive to improve the efficiency of the work flow.

Electronic medical record (EMR) systems have achieved remarkable advances in recent years. Mobile EMR systems are receiving increasing attention as mobile devices and mobile applications become more common. [2, 3]. The ubiquitousness of mobile technology is known to be helpful to health care providers for increasing efficiency of workflow, resulting in better quality of care [4, 5].

Near-field communication (NFC) is widely used in various communication applications. In the field of healthcare, usage scenarios include patient identification [6], blood transfusion [7], drug administration [8], medical staff tracking [9], and medical record access [10]. The wave of NFC technology in the healthcare field has been combined with Internet of Things (IoT) technologies [11]. Through combination with mobile EMR systems, NFC technology can reduce medical errors and improve workflow using bedside technology [12].

However, the effectiveness of mobile EMR has rarely been measured. To date, only subjective usefulness and volume of utilization have been considered [13, 14]. Even more vigorous quantitative elementary studies are required to develop and adopt such systems in practice. Additionally, it is important to determine system effectiveness in real-life clinical environments.

The aim of this study is to determine the effectiveness of an NFC-integrated mobile EMR system in terms of physician turn-around time in an emergency department.
Methods

Study Setting
This is a simulation study that took place in an emergency department. The study was reviewed and approved by the Institutional Review Board (IRB) (IRB no. SMC 2018-01-144-001).

The study was carried out in an academic ED in Seoul. The ED is part of a tertiary academic teaching hospital with approximately 9,000 daily outpatients and 2,000 inpatient beds [15]. The ED holds 69 treating beds. The number of annual visits is approximately 79,000. Although the ED is equipped with PCs at each station (84 PCs total) there are no PCs at bedsides. Most of the beds are not in private rooms, but are open to stations.

The proposed mobile EMR system was developed by the hospital; it operates on the institution’s EMR system, which was also developed within the hospital. The overall system had a major update in July, 2016. The mobile EMR uses an Android-based application that gives physicians access to inpatient, outpatient, and emergency department information. Users can log into the system with their fingerprint and search for locations, clinical notes, vital signs, laboratory results, and medical images. The NFC function was implemented in April, 2017. Figure 1 shows the general view and architecture of the mobile EMR system.

Study Participants
ED physicians who were working in the ED during the study were asked to participate. Participants were recruited from April 1st to 20th, 2018. Among 35 ED physicians, 25
doctors agreed to participate in this study.

**Study Scenarios and Sensitivity Analysis**

After a brief introduction, participants went through two sequential scenarios. Subjects were randomly assigned to follow either mobile or PC protocols. An independent observer recorded the activities with a camera and completed a case report form with time stamps during the process.

The first scenario was locating patients in the ED from the ED gate. Subjects were given the name of a patient in the ED and were requested to locate the patient using either PC EMR or mobile EMR. After locating the patient, the subject was guided to reach their bedside.

The second scenario was to look up a laboratory result from the bedside. Subjects were brought to a patient’s bedside and were requested to determine a specific laboratory result at the bedside, using either mobile or PC interfaces. Because there was no PC at the bedside, subjects had to take a few steps to reach an available PC and return with the report. The steps in each scenario are shown in figure 2.

![Figure 2. Schematic view of simulation scenarios. (a) Locating the patient. (b) Looking up laboratory results for the patient. (ED: Emergency Department)](image)

We performed a sensitivity analysis with the data without considering movement intervals. This test was performed to determine whether there was a consistent outcome if the condition allowed more available PCs, which are at the gate and at the bedside.

**Survey**

After completing all scenarios, participants responded to 10 questions using the System Usability Scale (SUS). The SUS is composed of a five-point Likert scale that investigates the usability of the NFC-integrated mobile EMR system [16].
Measurement and Outcome
The main metric was the length of turn-around time for each scenario. The secondary metric was the usability of the system, graded by the study subjects. We collected demographic data from each subject and recorded the time intervals of each step of the process for both scenarios. Afterward, the SUS questionnaires were collected.

Statistical Analysis
Continuous variables are expressed in terms of averages and standard deviations, whereas categorical variables are expressed in frequencies and percentages. Time average difference was examined using a paired t-test. $P < 0.05$ was considered to be statistically significant.
Results

Main Outcome
Among 25 participants, 11 were male and 14 were female. The general characteristics of participants are shown in Table 1.

Table 1. Characteristics of participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%) / mean(SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>30.6 (4.9)</td>
</tr>
<tr>
<td>Sex, male</td>
<td>11 (44)</td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
</tr>
<tr>
<td>Intern</td>
<td>4 (16)</td>
</tr>
<tr>
<td>Resident</td>
<td>15 (60)</td>
</tr>
<tr>
<td>Specialist</td>
<td>6 (24)</td>
</tr>
<tr>
<td>Service year</td>
<td>4.6 (4.0)</td>
</tr>
</tbody>
</table>

It took 93.0 s (mean) to locate the patient from the entrance of the ED in the mobile scenario, whereas it took 57.3 s (mean) in the PC scenario, which was significantly faster ($P < .001$). Looking up laboratory results at the patient’s bedside took 25.2 s (mean) in the mobile scenario, whereas it took 61.5 s (mean) in the PC scenario, which is significantly different ($P < .001$). A schematic comparison is shown in Figure 3.

Sensitivity Analysis
Sensitivity analysis was performed. We compared time for login and time for finding relevant information for each scenario (mobile and PC). Login using mobile EMR took
13.1 s (mean) for the first scenario and 12.5 s (mean) for the second scenario. Login by PC took 36.2 s (mean) for the first scenario and 30.5 s (mean) for the second scenario. There was a significant difference in times (P < .001). Finding the location of patients after login took 6.8 s (mean) using mobile, whereas it took 18.9 s (mean) using a PC. Looking up a specific laboratory test result took 12.8 s (mean) using mobile and 26.5 s (mean) using a PC, which is significantly different (P < .001). The results are shown in Table 2.

Table 2. Comparison of time spent on specific tasks.

<table>
<thead>
<tr>
<th>Task</th>
<th>Mean time (SD)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mobile (s)</td>
<td>PC (s)</td>
<td>P-value</td>
</tr>
<tr>
<td>Scenarios</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-in</td>
<td>13.1 (2.9)</td>
<td>36.2 (15.2)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Looking up relevant information</td>
<td>6.8 (3.6)</td>
<td>18.9 (16.9)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Total</td>
<td>19.8 (4.7)</td>
<td>55.2 (29.0)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Scenarios</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log-in</td>
<td>12.5 (2.1)</td>
<td>30.5 (7.7)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Looking up relevant information</td>
<td>12.8 (5.3)</td>
<td>26.5 (8.0)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Total</td>
<td>25.2 (5.3)</td>
<td>57.0 (11.6)</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Survey

The mean SUS score of NFC-mobile EMR was 71.9 points. The results are shown in Table 3.

Table 3. Scores of system usability scale.

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean of score (SD) (n=25)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1. I think that I would like to use this NFC-mEMR frequently.</td>
<td></td>
</tr>
<tr>
<td>Q2. I found NFC-mEMR unnecessarily complex.</td>
<td></td>
</tr>
<tr>
<td>Q3. I thought NFC-mEMR was easy to use.</td>
<td></td>
</tr>
<tr>
<td>Q4. I think that I would need the support of a technical person to be able to use this NFC-mEMR.</td>
<td></td>
</tr>
<tr>
<td>Q5. I found that the various functions in NFC-mEMR were well integrated.</td>
<td>71.9 (7.61)</td>
</tr>
<tr>
<td>Q6. I thought there was too much inconsistency in NFC-mEMR.</td>
<td></td>
</tr>
<tr>
<td>Q7. I would imagine that most people would learn to use NFC-mEMR very quickly.</td>
<td></td>
</tr>
<tr>
<td>Q8. I found NFC-mEMR very cumbersome to use.</td>
<td></td>
</tr>
<tr>
<td>Q9. I felt very confident using NFC-mEMR.</td>
<td></td>
</tr>
<tr>
<td>Q10. I needed to learn a lot of things before I could get going with NFC-mEMR.</td>
<td></td>
</tr>
</tbody>
</table>

*NFC-mEMR: near field communication-mobile emergency medical record*
Discussion

Principal Findings
Various measures have been implemented to cope with ED frustrations. Improving work efficiency of the ED is one in-hospital factor. In terms of physical structures, ideal structures for work have been demonstrated [17]. Several studies have shown the positive effect on efficiency of developing clinical guidelines and protocols for effective evaluation [18, 19]. Newer technologies such as radio frequency identification (RFID)-integrated point-of-care testing (POCT) [20], triage kiosks [21], and dashboards [22] have been well studied. Our study aimed to improve physician efficiency by saving time in walking to check patient information with the help of new technology. Ubiquitous near-patient access to EMR via NFC is found to be useful in this regard.

In this study, we demonstrated the effectiveness of NFC integrated with mobile EMR in terms of consumption of physicians' time. Mobile EMR connected by NFC was significantly faster than PC-integrated EMR in terms of login time and checking laboratory results. Because the proficiency of the physicians with mobile EMR integrated with NFC was different, we evaluated the usability using a questionnaire. SUS was used after the respondent had had an opportunity to use the system being evaluated [16]. Based on the score of over 70 on the SUS questionnaire (ranging from 0 to 100), NFC-integrated mobile EMR was proven to be easily usable.

Similar technologies such as RFID-based or beacon-based technologies have shown promising results. At the ward, RFID tags were placed in wearable wristbands at the time of admission, and were used for identification and ward nursing based on integration with a developed smartphone application [12]. Most previous studies explored the possibility of NFC in healthcare applications and proved the positive effects of its use. However, the quantitative attribution of efficiency in real practice has rarely been measured. This study showed the efficiency of an NFC-integrated mobile EMR application in the field in an ED deploying an NFC system by comparing time consumed.

However, to enhance emergency physician performance, a multi-dimensional method is required, rather than a single tool. ED processes are complicated, with multiple steps from various providers, often coming from outside the ED.

Limitations
First among the limitations of this study is that this study was conducted at a single center. Further studies conducted at multiple centers or EDs are needed to improve generalizability of our conclusions.

Second, participants had different levels of familiarity with smartphones and NFC tags. Because the NFC system was built over a year ago, only some participants were familiar with NFC, which might cause bias.

Third, because this study was conducted in an actual emergency room, each participant had different circumstances. For example: 1) In the middle of the scenario, when locating a patient, the nearest PC was occupied by another staff member, which led to the subject being forced to use a PC that was further away. 2) While moving to a patient’s bedside, there was an occasion when a participant was forced to stop because a
moving stretcher cart or medical staff member blocked the aisle. 3) Some of the PCs used were comparatively slow. As mentioned above, unpredictable circumstances might influence the overall time measured for each scenario. We adjusted this bias by performing sensitivity analysis.

Fourth, the usability estimation for NFC-mobile EMR via SUS could be overrated because responses were filled out immediately after performing scenarios, which in most cases, resulted in the superiority of NFC-mobile EMR. Further studies could investigate usability over a longer period of the physician's working practice.
Conclusion
NFC-integrated mobile EMR is effective for reducing turnaround time of physicians when practicing in the field and has good usability.
Acknowledgement
This study was supported by Samsung Medical Center.

Conflict of interest
None declared.

Abbreviations
ED: emergency department
EMR: emergency medical record
NFC: near-field communication
RFID: radio-frequency identification
SUS: system usability scale
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