Professional practice and innovation: Level of agreement between coding sources of percentage total body surface area burnt (%TBSA)

Dina Watterson, Heather Cleland, Natalie Picton, Pam M Simpson and Belinda J Gabbe

Abstract
The percentage of total body surface area burnt (%TBSA) is a critical measure of burn injury severity and a key predictor of burn injury outcome. This study evaluated the level of agreement between four sources of %TBSA using 120 cases identified through the Victorian State Trauma Registry. Expert clinician, ICD-10-AM, Abbreviated Injury Scale, and burns registry coding were compared using measures of agreement. There was near-perfect agreement (weighted Kappa statistic 0.81-1) between all sources of data, suggesting that ICD-10-AM is a valid source of %TBSA and use of ICD-10-AM codes could reduce the resource used by trauma and burns registries capturing this information.

Keywords (MeSH): Burns; Trauma Severity Indices; Registries; Information Storage and Retrieval; ICD-10

Introduction
The percentage of total body surface area burnt (%TBSA) is a critical measure of burn injury severity, has been identified as a key predictor of burn injury outcome (Germann et al. 1997; Mahar et al. 2008), and is an important variable for appropriate remuneration of clinical service provision (Turner et al. 1996; Wallis et al. 2009). The %TBSA has also been identified as one of the most important burn injury measures for burn care research, quality assurance and benchmarking activities (Perry et al. 1996; Wachtel et al. 2000; Howard et al. 2007).

Following burn injury, the %TBSA can be estimated or assessed at multiple time points post-injury and by a number of clinicians. Difficulties can arise where multiple %TBSA estimates are recorded, particularly with respect to identifying the definitive or most accurate %TBSA assessment for coding purposes. Variable coding of %TBSA can have implications for the validity and reliability of burn care research and quality activities. The potential variation in assessment, documentation and resultant coding of %TBSA means caution is required when interpreting research findings and evaluating trends in burn injury (Perry et al. 1996; Wachtel et al. 2000).

The patient medical record is the primary source of %TBSA information and is used to enable routine coding and classification for hospital and health system administrative processes and capture of information for clinical databases such as burns and trauma registries. The International Statistical Classification of Disease and Health Related Health Problems, Tenth Revision Australian Modification (ICD-10-AM) and the Abbreviated Injury Scale (AIS) are standardised classifications for coding burns injury (Association for the Advancement of Automotive Medicine 2008; Commonwealth of Australia 2008). The ICD-10-AM is routinely used for coding and classifying burn injury for administrative data collection purposes and/or funding within Australian and New Zealand hospitals. The Abbreviated Injury Scale (AIS) is used by trauma registries worldwide to code injuries sustained and calculate the Injury Severity Score (ISS) for trauma patients, including burn patients. These classification systems categorise the %TBSA, while burns registries routinely record a %TBSA without categorisation. Each method relies on medical record documentation to enable retrospective coding. Given the multiple assessments of %TBSA recorded during a burn patient admission, there is the potential for disagreement in burn size coding across the datasets, but agreement between the methods has not been previously investigated.

The aim of this project was to determine the level of agreement between different sources of %TBSA, and to establish whether %TBSA is coded consistently from the medical record irrespective of the source of coded information. Improved understanding of the relationship between sources of %TBSA coding is needed to inform the development of data collection methodologies for burns, and to provide context for the evaluation and interpretation of benchmarking and research findings.

Method

Setting
The State of Victoria, Australia, has one designated adult burn care facility, the Victorian Adult Burns Service (VABS) located at The Alfred Hospital, Melbourne. All patients admitted to the VABS are recorded on the VABS registry, which is developed and managed within the VABS service and used in ‘real time’ for burn unit management and weekly case audits. Junior medical staff are responsible for registry data collection, including recording the %TBSA estimate. The Victorian State Trauma Registry (VSTR) is a population-based registry which captures data about all major trauma patients in Victoria, including those admitted to the VABS (Cameron et al. 2005). The VSTR captures %TBSA using the ICD-10-AM and AIS diagnosis codes. The ICD-10-AM codes
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are collected at discharge for burn patients through medical record review by the hospital's clinical coders. The AIS codes are assigned by VSTR data collectors through medical history review post-discharge.

Procedures

Ethics approval was obtained from The Alfred Human Research Ethics Committee. Burns cases captured by the VSTR with a date of injury from 1 January 2007 to 31 December 2008 were extracted for inclusion. The ICD-10-AM and AIS data related to %TBSA, and demographic data for adult burn cases identified from the VSTR and definitively managed at the VABS were retrieved for analysis. The %TBSA recorded by the VABS registry was merged with the VSTR data, using patient and admission identifiers to link. In addition, the individual patient medical records were retrieved for expert burn clinician review and separate coding of the definitive %TBSA. This information was then entered into the combined VSTR and VABS dataset for analysis. The expert burn clinician was blinded to the VSTR and VABS data.

To enable comparison of the continuous coding of the VABS and expert burn clinician %TBSA with the categorical AIS and ICD-10-AM coding, the VABS and expert burn clinician %TBSA was categorised into the corresponding six AIS %TBSA categories and the ten ICD-10-AM %TBSA categories.

Scatter plots and Bland-Altman plots were generated to visually represent the level of agreement between the expert burn clinician and VABS, as the %TBSA was recorded on the full scale from 0 to 100%. Bland-Altman plots display the mean difference between two variables with the solid line representing the overall mean difference and the dashed lines representing the limits of agreement (Bland and Altman 1986).

A Wilcoxon signed rank test, a non-parametric test equivalent to a paired T-Test, was used to test the hypothesis that there were differences in agreement between the expert burn clinician and VABS, as the %TBSA was recorded on the full scale from 0 to 100%. Bland-Altman plots display the mean difference between two variables with the solid line representing the overall mean difference and the dashed lines representing the limits of agreement (Bland and Altman 1986).

Agreement between the ICD-10-AM and AIS, AIS and expert burn clinician and ICD-10-AM and expert burn clinician was almost perfect based on the established conventions for the kappa statistic (Landis & Koch 1977),

Results

One hundred and twenty cases were included. Table 1 outlines the cases available for each coding procedure. There was an AIS %TBSA code for all cases. The ICD-10-AM, VABS and expert burn clinician %TBSA data was unable to be coded for one case where the AIS code was <10% TBSA. There were two cases where the VABS and expert burn clinician identified an inhalation injury only, while AIS and ICD-10-AM codes of <10% TBSA were reported. There were two cases where the expert burn clinician was unable to code the %TBSA; however codes from all other sources were available. There were three cases were VABS did not have a %TBSA coded when the other coding sources did. The medical histories were not able to be retrieved for seven cases for expert burn clinician coding.

<table>
<thead>
<tr>
<th>CODING PROCEDURE</th>
<th>NO. OF CASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS</td>
<td>120</td>
</tr>
<tr>
<td>ICD-10-AM-AM</td>
<td>119</td>
</tr>
<tr>
<td>VABS</td>
<td>114</td>
</tr>
<tr>
<td>Expert burn clinician</td>
<td>108</td>
</tr>
</tbody>
</table>

Figure 1 shows the scatterplot of the expert burn clinician coding of %TBSA against the VABS coding of %TBSA. Points on the line represent perfect agreement between VABS and the expert burn clinician coding. The mean (95% CI) difference between the %TBSA coding of the expert burn clinician and VABS database was -0.05 (-0.87 to 0.76). There was no significant difference ($p=0.81$) between the coding procedures, and this is confirmed in the Bland-Altman plot (Figure 2) as there is an even spread of points around the mean difference line with just a few cases near the limits of agreement (-8.453 to 8.349).

Agreement between the ICD-10-AM and AIS, AIS and expert burn clinician and ICD-10-AM and expert burn clinician was almost perfect based on the established conventions for the kappa statistic (Landis & Koch 1977),

Figure 1: Scatter plot of VABS vs Expert burn clinician

VABS %TBSA coding (X-axis), Expert burn clinician coding (Y-axis).
Points on the line represent perfect agreement between VABS and the expert burn clinician coding

Figure 2: Bland-Altman plot of VABS vs Expert burn clinician

VABS %TBSA coding (X-axis), Expert burn clinician coding (Y-axis).
Points on the line represent perfect agreement between VABS and the expert burn clinician coding

Agreement between the ICD-10-AM and AIS, AIS and expert burn clinician and ICD-10-AM and expert burn clinician was almost perfect based on the established conventions for the kappa statistic (Landis & Koch 1977),

95% confidence intervals (95% CI) were calculated for $\kappa_0$ using the Bootstrap method. All analyses were performed using Stata 11.0 (StataCorp 2009).
and substantial for the agreement between the VABS and AIS, and VABS and ICD-10-AM (Table 2).

Table 2: Agreement between coding procedures for %TBSA categories

<table>
<thead>
<tr>
<th>CODING</th>
<th>% AGREEMENT</th>
<th>KAPPA</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICD vs AIS</td>
<td>95.8</td>
<td>0.88</td>
<td>(0.78-0.91)</td>
</tr>
<tr>
<td>AIS vs VABS</td>
<td>92.0</td>
<td>0.77</td>
<td>(0.69-0.84)</td>
</tr>
<tr>
<td>ICD vs VABS</td>
<td>91.9</td>
<td>0.78</td>
<td>(0.70-0.83)</td>
</tr>
<tr>
<td>AIS vs Expert burn clinician</td>
<td>94.1</td>
<td>0.83</td>
<td>(0.77-0.87)</td>
</tr>
<tr>
<td>ICD vs Expert burn clinician</td>
<td>95.2</td>
<td>0.83</td>
<td>(0.74-0.90)</td>
</tr>
</tbody>
</table>

While not significant, the lowest levels of agreement for comparisons with the AIS were in the 10-19%TBSA category, with the burn generally considered more extensive using the AIS code. For the ICD-10-AM and VABS coding, the agreement was lowest in the 40-49% category (28%). For the ICD-10-AM and expert burn clinician comparisons, agreement was lowest in the <10% category (65%). These results were not significant.

Discussion

Percentage total body surface area burnt is routinely collected by trauma and burn registries worldwide and used widely in research, quality and benchmarking activities. The collection of the %TBSA remains a time consuming and complicated process for registry data collectors in terms of the multiple sources of data and time for data retrieval (Howard et al. 2007). This study is believed to be the first to explore the agreement between multiple sources of %TBSA. The results suggest coding procedures for hospital reporting, the local burn unit registry and the separate population-based trauma registry have substantial or near perfect agreement.

A primary function of many registries is to stimulate the use of the registry data for research. The importance of collecting data systematically to ensure data quality and reduce data collector burden is considered fundamental to the ongoing sustainability of registries (Australian Commission on Safety and Quality in Health Care 2008; McNeil et al. 2010). The retrieval of %TBSA creates additional data collection burden, given it is already routinely collected by hospital clinical coders for administrative requirements. Results of this study suggest the administrative data could be a valid alternative for sourcing the %TBSA by trauma and burn registries.

While both the ICD-10-AM and the AIS were found to agree with the other coding sources, the ICD-10-AM has greater potential to provide more specific %TBSA data for registries and clinical research. The AIS is less specific than the ICD-10-AM, with six %TBSA categories and provides no additional information, limiting its usefulness. The ICD-10-AM has 10 %TBSA categories providing more detailed data. Unless more specific burn size data is required, the use of the ICD-10-AM appears to be a valid source for %TBSA data. One limitation to using the ICD-10-AM coding for %TBSA data is the time of data collection. Clinical coding of ICD-10-AM data is routinely completed following discharge. For registries that require %TBSA data for regular caseload management or clinical audits, relying on ICD-10-AM data would be impractical.

The literature available on %TBSA coding has highlighted the importance of good documentation of burn variables, including %TBSA for accurate coding. Turner et al. highlighted the challenge with identifying the most accurate or definitive %TBSA for coding purposes and the impact this had on assignment of ICD-10-AM and Diagnostic Related Group codes related to reimbursement processes for hospital payment systems. They introduced a system of revising %TBSA diagrams to correctly depict the %TBSA and therefore obtaining optimal and accurate financial reimbursement for burn service (Turner et al. 1996).

Similarly, Wallis et al. (2009) created a document to improve the coding processes in their burns unit; the improved documentation ensured a high quality of coding which was considered to have a possible direct impact on the financial resources accrued for the burn care. At the time of data collection for this project, the VABS did not have a systematic data collection form to accurately collect burn variables used for coding. Following the identification of the challenge in retrieving the %TBSA from medical history documentation for registry coding a burn assessment form has been proposed for the VABS with plans to implement this form in the near future. This will improve retrieval of burn data for clinical coders including the %TBSA.

There are some limitations to this study. The study hospital is casemix funded and relies heavily on accurate coding for financial remuneration. There are processes and work practices in place for clinical coder and clinician consensus on %TBSA and other burn variables for ICD-10-AM codes primarily used in hospital financial reporting. This may limit the ability for generalisation of results beyond the health care system of the study.

Figure 2: Bland-Altman plot of VABS vs Expert burn clinician

Mean of the difference between the expert burn clinician and VABS coding of %TBSA (X-axis). Difference between the expert burn clinician and the VABS coding (Y-axis).

The solid line represents the overall mean difference between the expert burn clinician and VABS and the dashed lines represent the limits of agreement.
hospital if other systems do not have the same incentive for accurate clinical coding. In Australia all states used ICD-10-AM coding; however, other countries use the ICD-9 version, which is structurally different from ICD-10-AM. This also creates difficulties in generalising results. The final limitation is that the expert burn clinician who completed the retrospective data audit was a senior staff member of VABS. While at least a year had passed since the patients’ admissions, the possibility that the clinician would recall the individual cases could not be excluded. However, given that there are more than 250 admissions per year to the VABS, the potential for recall to influence the results is likely to be small. Nevertheless, this may have reduced the possibility of poor agreement between coding sources.

**Conclusion**

Results of this study suggest substantial or near perfect agreement between coding sources of %TBSA. If the specificity of the %TBSA codes from the ICD-10-AM is considered sufficient for registry and clinical research purposes, further coding by burns and trauma registry staff may be unnecessary. This would decrease data collector burden and increase registry data quality.

**References**


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Professional practice and innovation:
RF-MediSys: A radio frequency identification-based electronic medical record system for improving medical information accessibility and services at point of care

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Abstract
This paper presents an innovative electronic medical records (EMR) system, RF-MediSys, which can perform medical information sharing and retrieval effectively and which is accessible via a ‘smart’ medical card. With such a system, medical diagnoses and treatment decisions can be significantly improved when compared with the conventional practice of using paper medical records systems. Furthermore, the entire healthcare delivery process, from registration to the dispensing or administration of medicines, can be visualised holistically to facilitate performance review. To examine the feasibility of implementing RF-MediSys and to determine its usefulness to users of the system, a survey was conducted within a multi-disciplinary medical service organisation that operates a network of medical clinics and paramedical service centres throughout Hong Kong Island, the Kowloon Peninsula and the New Territories. Questionnaires were distributed to 300 system users, including nurses, physicians and patients, to collect feedback on the operation and performance of RF-MediSys in comparison with conventional paper-based medical record systems. The response rate to the survey was 67%. Results showed a medium to high level of user satisfaction with the radiofrequency identification (RFID)-based EMR system. In particular, respondents provided high ratings on both ‘user-friendliness’ and ‘system performance’. Findings of the survey highlight the potential of RF-MediSys as a tool to enhance quality of medical services and patient safety.

Keywords (MeSH): Electronic Health Records, Health Services Accessibility; Radio Frequency Identification; Access to Health Care; Health Information Technology; Safety

Introduction
The healthcare environment is constantly changing and becoming ever more complex. At the same time, it is vitally important to ensure that high quality patient care is maintained. One way to improve the quality of patient care that has received considerable attention from researchers is the potential for integrating information technology into medical practice (Bates & Gawande 2003; Jamal, McKenzie & Clark 2009; Parente & McCullough 2009). When healthcare professionals make medical decisions they generally rely heavily on their knowledge of the patient’s medical history. Better and more effective use of this information can enhance patient safety (Al-Azmi, Al-Enezi & Chowdhury 2009). However, most medical organisations in Hong Kong still rely on paper-based medical records (which document demographic data, diagnoses, medications, and radiological results) and which, according to Abd Ghani et al. (2008), present three major challenges for current medical practice:

The first challenge involves the huge collection of paper-based medical records that currently exist. In a typical healthcare environment in Hong Kong it is often difficult to retrieve these records and to share a patient’s medical information because records can easily be misplaced (Ting et al. 2010). Consequently, relying on the patient’s medical history contained within these records to support diagnoses can be problematic.

The second problem relates to the difficulty of sharing medical information across organisations that have their own individual patient databases, and sharing paper-based medical information is not easy. Rarely do patients visit only one medical organisation in their lifetime, and they might also visit other medical service providers. Patients cannot be expected to recall all details of their past medical history and/or previous medication regimes during each new consultation; yet inaccurate information supplied to the attending physician can adversely affect the quality of medical decisions taken and treatment provided.

A third challenge is the potential for medical errors due to poor visibility of medical processes. Numerous researchers have studied the use of RFID technology to ensure that correct medicines are administered to the right patients, to alert nurses or pharmacists when they select the wrong medicines, and to prevent the use of medicines beyond their expiry date (Tam et al. 2008; Ting et al. 2010). However, these previous studies focused on item identification, which provides only limited information on the medical process itself. Even when physicians identify the correct patient, mistakes can still occur if the wrong processes (surgical operations, examinations or therapies) are applied. These errors can occur because healthcare professionals do not usually have the means to track the medical process that the patient has, or is supposed to have, undergone.
These three issues clearly present problems to both physicians and patients and in complex cases (e.g. Alzheimer’s disease) information about the assortment of drugs that patients may be taking or the existence of multiple drug allergies will be extremely difficult to access (Meadows 2006). With missing or limited information, physicians may not be able to provide the required standard of care. Establishing an effective medical information sharing and retrieval environment will help to address this issue.

Combining radio frequency identification with an electronic medical record system

RF-MediCard
A basic RFID medical card (known as an RF-MediCard) coupled with a software package to manage all the medical information of card-holders through the Internet has been developed (EPCglobal Inc. 2005). This system supports the delivery of fast and appropriate care, especially for those who are unable to communicate with physicians. The RF-MediCard employs RFID technology and the industrial numbering standard (termed the Electronic Product Code [EPC]), to format the dynamic patient data stored in the patient card in a unique and consistent manner. As in product identification applications, the RF-MediCard guarantees not only the uniqueness of patient identification but it also has the additional capability of recording simple medical information relating to the card holder (Ting et al. 2009).

RF-MediSys
The aim of RF-MediSys is to integrate the RF-MediCard and electronic medical records system (EMRS) concepts. It was designed to enhance the effectiveness of medical information retrieval and other routine healthcare delivery processes (e.g. patient registration, prescription and location). Design of the system as well as evaluation of its fulfilment of design objectives are presented in subsequent sections of this paper.

Design of the RF-MediCard
Each patient is issued a RF-MediCard (a RFID-tagged smart card), which stores the holder’s personal and medical information. The function of the RF-MediCard is to store basic medical information (e.g. drug allergies, major or chronic diseases, medical history, blood type), for quick and easy access when the patient presents the card. It is particularly useful when the patient visits another organisation that does not have the patient’s medical record on hand. The entire medical treatment schedule can then be uploaded to the central database and updated accordingly. Thus, healthcare professionals can check before they perform any examination or therapies on a patient and avoid taking inappropriate action.

Design of the RF-MediCard is depicted in Figure 1. Basically, the RFID tag is embedded in the RF-MediCard and a barcode is printed on the front. The barcode, that stores the same unique code of the RFID tag, will be used when the RFID does not work properly. By presenting the RF-MediCard to an authenticated RFID reader, all the information stored in the card can be retrieved and used in the RF-MediSys.

System Architecture of RF-MediSys
The RF-MediSys system comprises six modules, namely RFID Registration Module, Knowledge Representation Module, Medical Diagnosis Module, Prescription Module, Risk Surveillance Module and Information Services Module (See Figure 2). The design philosophy of this architecture is to separate the major functions of the system into logical sections of display, processing logic and data services.

RFID Registration Module
Upon entering the clinic, the patient registers by presenting the card to an RFID reader. The RFID Registration Module is used to verify and collect the captured RFID information for use in other modules. If the card is authentic, patient information and the physician booking schedule will be displayed. Through the user-friendly interface, the patient can view the schedule of physicians and conveniently make an appointment to see a specific physician. A digital display board which displays the patient list is located in the waiting area, indicating their current status (either consulting the physician or waiting) so that patients are able to estimate their waiting time more easily than with the traditional approach of asking the receptionist for such an estimate. These self check-in functions help streamline the physician booking and consultation processes.

Knowledge Representation Module
This module is designed to represent the knowledge that will be taken into consideration by the physician in performing medical diagnoses. In each diagnostic process, the physician can retrieve the patient’s medical informa-
tion stored in the RF-MediCard and, if necessary, extract the patient’s records of past medical treatments via the information sharing network using the unique EPC code assigned to that patient. As a result, these records will provide the physician with significantly richer contextual information for understanding and treating the patient.

**Medical Diagnosis Module**

The Medical Diagnosis Module is so designed that physicians can easily communicate with RF-MediSys via the software that is compatible with Extensible Markup Language (XML) and the Internet. With the user-friendly graphical user interface, even physicians who are casual users can access the system effortlessly. In particular, this module can help the medical organisation in three ways:

- to review the medical information collected from the RF-MediCard
- to streamline the medical diagnostic process
- to enhance efficiency of the medical prescription and treatment processes.

**Therapy Determination Module**

With the diagnostic results generated by the Medical Diagnosis Module as input, the Therapy Determination Module is designed to facilitate therapy (by selecting suitable medication or recommending additional tests). For medicine selection, the Case-Based Reasoning (CBR) technique is used to retrieve the prescription decisions of previous cases with similar evidence to support an intelligent and dynamic approach to medication prescription. By using appropriate decision parameters to evaluate similarity with the case under consideration, CBR will rank the past medical records and present the top ten medicines with corresponding probabilities that measure the extent of matches with prescriptions for similar cases in the past.

After the physician has determined the medicines to be prescribed or additional examinations to be conducted, these results will be stored in the RF-MediCard automatically. For example, while a patient is waiting to collect prescribed medicines following registration and consultation the status stored in the RF-MediCard is indicated as: ‘Registration (1) → Consultation (1) → Drug (0)’. In this way the state of the entire medical process is recorded, (1) and (0) being codes indicating respectively whether a specified process has been completed or not. To ensure the nurse collects the correct medication, information relating to medication as well as patient information is recorded in the RF-MediSys system. During the dispensing of drugs, the nurse can use the RFID reader to scan the RFID-tagged drug containers of the prescribed medicines to make sure that the correct drugs are collected. In addition, for double checking the patient should present the RF-MediCard for scanning when the medicines are collected.

**Risk Surveillance Module**

This module is used to monitor the healthcare process so as to ensure that the correct medical procedure is applied to the right patient. At each care-giving point, healthcare professionals need to scan the RF-MediCard to read the medical processes that are to be applied to the patient, and track which of them have been completed, or to determine whether the current process is indeed the correct one to be applied.

This module also supports the Therapy Determination Module by raising alerts of drug contraindication (such as drug-drug interaction and food-drug interaction) and, if necessary, suggests alternative drugs for the physician’s consideration. All related drug information is captured from various trusted medical databases and then automatically decoded as sets of interaction rules that are stored in the system’s database. These rules are validated by authoritative medical practitioners before they are adopted as decision support information in the Therapy Determination Module. An example of such an interaction rule is ‘IF Drug₁ = Epiklor and Drug₂ = Lomotil THEN Interaction=YES’. Supported by these drug interaction rules, alerts of drug contraindication are generated upon completion of the selection of medicines. If an interaction exists, information, such as degree of interaction (i.e. major, moderate, and minor), cause of contraindication, and mitigation of the risk, are displayed. Otherwise, the message ‘No Interaction is Found!’ is shown.

**Information Services Module**

The Information Services Module contains the system databases that maintain all the information of the RF-MediSys system. Physicians can retrieve patient data from this module and turn them into useful information. Five databases storing different types of information serve
different purposes. Each record in the Patient Information database is associated with a registered patient with his/her unique identification number and personal information, for example patient name and contact information, whereas the Medical Records database stores information on the medical cases (such as the symptoms and diagnosis made, and the treatment and/or medicines prescribed) associated with individual patients. These two databases will provide input to the Knowledge Representation Module. The Drug Information database stores all the validated interaction rules to facilitate detection of drug contraindication. In order to help the physician to gain access to a wide variety of data in support of an investigation (i.e. in the CBR process), the relevant data extracted from the Medical Records database can be transformed into the Cases database through instructions written the Structured Query Language (SQL)\(^1\).

**Research aims**

The aim of the current research was to evaluate the RF-MediCard and RF-MediSys system from the perspective of users of the system in terms of user-friendliness, system performance and system maintenance.

- **User-friendliness**: to provide a universal, collaborative and effective real-time medical information sharing platform to assist healthcare professionals who practice in different organisations in monitoring and retrieving patients’ medical information.
- **System performance**: to reduce human errors (since a mistake can result in disability or death) in clinical operations.
- **System maintenance**: to visualise real-time information of medical processes so as to detect potentially hazardous situations, thereby enhancing patient safety and quality of medical services.

The authors propose that RF-MediCard and RF-MediSys, which adopt the automatic identification capability of RFID to facilitate medical information sharing and retrieval, will reduce medication errors and streamline the registration process.

**Method**

**The research setting**

A Hong Kong based medical organisation, Humphrey and Partners Medical Services Limited (HPMS)\(^2\), was selected as a test site to study the feasibility and practicality of transforming the medium for medical information sharing from traditional paper-based medical records to the use of RF-MediCard. The aim of this pilot study was to investigate the ability of the proposed system to track full medical records of card holders in order to demonstrate the ability of the system to (i) visualise medical information without time and location constraints, and (ii) identify the point at which errors had been made under the existing/current communication environment.

HPMS is one of the largest multi-disciplinary medical services providers in Hong Kong, with 20 medical experts providing medical services in various specialties. The challenges of utilising the previous paper-based medical record system have plagued HPMS for many years. In an attempt to address these challenges, HPMS accepted the authors’ invitation to collaborate as a test site of RF-MediSys.

Based on the generic architecture of the system shown in Figure 2, several subsystems featuring different functions have been built:

- **Patient Registration System (PRS)**: PRS provides a platform to patients for registration and for making an appointment to see a physician in an automatic and self-service manner (Figure 3a).
- **Medical Diagnostic and Therapy Selection System (MDTSS)**: MDTSS is responsible for retrieval of particular medical information for medical diagnosis and therapy selection (Figure 3b).

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\(^1\) SQL is a standard database language designed for managing data in database systems.

\(^2\) HPMS is a multi-disciplinary medical service provider operating a large network of medical clinics and para-medical service centres throughout Hong Kong Island, the Kowloon peninsula and the New Territories. Services include general practice and specialist care, pathology services, dental services, and primary health care services. Currently, there are more than 370 such clinics in operation, covering approximately 20,000 member clients.

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**Figure 3:**

(a) Patient registration system (PRS): Patient enters the clinic and places the RF-MediCard for registration;

(b) Medical Diagnostic and Therapy Selection System (MDTSS): Physician makes a diagnosis and records the result in RF-MediSys.
Medication Management System (MMS): MMS ensures medication safety by alerting both the physicians and nurses during the drug prescription process if errors are detected (Figure 4).

Medical Process Monitoring System (MPMS): Similar to the concept of EPCglobal Network [4], the MPMS monitors and verifies the end-to-end medical care process for detection of abnormal procedures being taken (Figure 5).

Timeframe for the study
Evaluation of the project took place over the period of one month, starting on 1 October 2010 and concluding on 31 October 2010.

Design of the study and sample selection
The study used a questionnaire survey design. Users of the RF-MediSys system (including patients3, nurses, and physicians) were surveyed to determine their opinions on the performance of the system. A stratified random sampling method was used to select participants in this study. System users aged between 15 and 60 years were randomly selected from the total population of current patient, nurse and physician users, to ensure that equal proportions of users from each category of user were included in the sample. Physicians and nurses were further stratified by type of expertise.

To facilitate generalisation of results, the sample selection covered a broad range of respondents from different backgrounds in each of the three groups. Participants included those who were youths, middle-aged and elderly, junior and head nurses, junior and senior physicians, and specialists.

Participants
The study included 201 participants, drawn from the three categories of users of the system: nurses, physicians and patients. Of 300 questionnaires distributed in the first instance (278 to patients, 15 to nurses and 7 to physicians), 201 valid responses were returned (186 patients, 10 nurses, 5 physicians). This represents a response rate of 66.9% for the patients’ group, 66.7% for the nurses’ group, and 71.4% for the physicians’ group.

Measures and procedure
A questionnaire consisting of 10 items designed to measure user-friendliness, performance, and maintenance support was administrated to the three groups of system users. Responses to these questions were provided on a 5-point Likert scale ranging from highly dissatisfied to highly satisfied (1 = highly dissatisfied, 2 = satisfied, 3 = no strong view, 4 = satisfied, 5 = highly satisfied). Criteria embedded in these items were designed by the authors in consultation with healthcare IT consultants at HPMS (see Table 1). Cronbach’s alpha was used to check the inter-item reliability of questionnaire items. In each case Cronbach’s alpha coefficient was greater than .70.

Questionnaires were distributed to selected respondents by surface mail sent in late October 2010. A pre-paid, pre-addressed envelope was included to facilitate the return of completed questionnaires. Unique control numbers known only to the researchers were used on survey forms to ensure anonymity of respondents. Recipients of questionnaires who had not responded within two weeks were followed up by means of a reminder letter.

Figure 4: Medication management system (MMS)
Nurse picks out required medications and places them on an RFID reader. Results (success or failure) are shown on a display.
The nurse will be alerted instantly if wrong or missing medicines are detected.

Figure 5: Medical process monitoring system (MPMS): If patients are required to undergo medical tests (e.g., x-ray or blood sample), they are required to wait in another area. The nurse scans the patient record to check identity and to ensure the patient follows the correct process.

3 Patients self-register for medical appointments via the system.
Data analysis

Data collected from returned questionnaires were analysed using SPSS software. Statistical analyses performed were based on descriptive statistics (means, standard deviations and frequencies). Because the sample size for two categories (nurses and doctors) was small, no inferential statistics were applied.

Results

System evaluation

The outcome of the evaluation showed a medium to high level of user satisfaction with the RFID-based EMR system for all three user groups. In particular, potential users gave high ratings on both the user-friendliness and system performance of the RF-MediSys in general, with a mean score of at least 3.9 on a five-point scale. Results show that RF-MediSys can provide a universal platform for sharing medical information across settings with a simple, easy-to-use interface and collection and display of high quality information. Results also highlight that the majority of human errors (e.g. dispensing medicines to the wrong patients) are significantly reduced because of the automatic alert function provided by the identification capability of RF-MediSys. Furthermore, real-time access to the medical processes can be easily visualised because of the effective detection of potential hazards. On the other hand, regarding system maintenance, although the mean values ranged from 3.8 to 3.9, both the physicians’ and nurses’ groups suggested that the provision of a user guide with frequently asked question (FAQ) would be helpful to their understanding of the use of the system and errors handling. To confirm that the mean values of the system evaluation were statistically different from the neutral values of the scale (i.e. 3 = no strong view), a sample t-test using the test value 3 was conducted. Results showed that the mean values of all the questionnaire items were larger than the neutral values of the scale at 5% level of significance. This suggests that RF-MediSys can improve both the medical information retrieval and operational efficiency (See Table 2 for details).

Discussion

Results of this survey indicate that RF-MediSys can enhance performance and enrich the capabilities of traditional medical information sharing, errors detection and medical processes visualisation by using RFID technology (with a mean score of at least 3.9 on a 5-point scale based on the criteria in the form of user-friendliness and system performance).

The authors contend that RF-MediSys has the potential to make a significant impact on the management of health information and the quality of health care in a number of ways:

1. Uniqueness and innovativeness

In recent years, a variety of research works on the use of RFID technology to augment information systems have been undertaken to reduce medical errors and improve patient safety (Tam et al. 2008; Parente & McCullough 2009; Ting et al. 2009; Ting et al. 2010). The use of RFID in asset tracking and management is already a popular application in many medical organisations. However, those applications focus on using RFID for item identification, whereas RF-MediSys is concerned with turning the data captured from RFID tags into meaningful and useful information to support the work of nurses and physicians in the entire medical process by retrieving critical patient medical information. This enhances the quality of medical services and reduces medical errors.

2. Practicality and user-friendliness

RF-MediSys provides nurses and physicians with medical information on demand. By using RF-MediSys, nurses and physicians can easily retrieve the required information for diagnosis and therapy determination. RF-MediCard can also bring benefits in automating patient registration, which will significantly improve the daily operation of the nurses. With the use of medical information stored in the card, RF-MediSys's capability can be extended to assure the right medication is administered to the right patient, and to allow for visualisation of the entire medical process so as to facilitate detection of anomalous medical procedures. RF-MediSys has been developed and pilot implemented in a real situation (i.e. the case company – HPMS) and the results demonstrated the system's feasibility and its user-friendliness in supporting delivery of superior services at critical points of care to the patients. In the case study, it is also observed that user training is a critical issue for the successful introduction of the system. User resistance to change is another challenge in the
implementation of the system, and significant support is required to earn trust in adopting the new technology.

3. Extensibility and scalability
With sound system design architecture, RF-MediSys can accommodate the extension of new functions or enhancement of existing functions without impacting on other parts of the system. The modular design of each function facilitates customisation of RF-MediSys to fit the needs of specific companies. For example, the medical information stored in RF-MediCard can be tailor-made to cater for specific medical information which the physicians would like to access. Additionally, the user interfaces for medical diagnosis and therapy determination can be modified so that they will work seamlessly with traditional paper-based patient records. Indeed, RF-MediSys maintains good performance even in situations with heavy use. For example, when the system was tested with numerous physicians and nurses concurrently using the system, it still responded (e.g. visualised the medical information and detected anomalous medical processes) almost instantaneously. However, one of the critical issues is the readability of RFID tags. If more than 100 tags are read at the same time, the current hardware may not be able to cope. With improvement of the related hardware, the tag readability performance can be upgraded progressively.

4. Social responsibility
It has been the norm that user-friendly solutions to monitor and locate all the entities (such as medicines, patients, nurses, physicians and medical equipment) involved in a single medical process are not available. Medical errors are likely to occur when irregularities exist in the process. However, with the help of RF-MediCard and RF-MediSys, it becomes significantly easier to locate entities and retrieve valuable medical information. Problematic cases can be brought to the attention of the healthcare professionals (such as the nurse) in real time. A typical example relates to the collection of incorrect medicines after the prescription process. Through the adoption of RF-MediSys, correct medical services can be provided by assuring the availability of accurate medical information for diagnostic and therapy determination, as well as medicine safety at point of care. In this way, medical errors, such as incorrect medication, can be avoided. In addition, RF-MediSys speeds up the medical processes, helping to reduce operation expenses.

5. Security and privacy
Since the RF-MediSys is capable of storing large quantities of patient information, such as their demographic information, past medical history and current health conditions, security audit and user authentication must be adopted to ensure confidentiality and security of the data. Since Internet-based communications are used for data transfer between modules of the RF-MediSys, data protection during transmission would be a critical issue of RF-MediSys in protecting the privacy and integrity of patients’ information. RF-MediSys makes use of electronically stored health information to facilitate sharing of medical information. In this system, a patient’s basic medical information (e.g. drug allergy) is recorded in the RF-MediCard, and other information (i.e. past medical history) is saved in the EMR system. Since this information is stored in different databases, a unique patient ID number serves as a key to map and combine the information, thereby transforming it into an intelligible form for the use of the physician. It is claimed that data encryption and the encoding scheme are important in protecting the information stored in the RF-MediCard, as well as in supporting the secure exchange of medical information among the authorised medical institutions.

Limitations of the study
There are some limitations to the present research. This study included participants from one medical organisation only, which limits generalisation of findings to other healthcare institutions such as hospitals. The small sample size for two of the user groups in particular (nurses and physicians) further limits generalisation of findings from these two groups to other clinicians in the same organisation as well as in other medical settings. Further research is needed with larger sample sizes to enable more robust validation in the area of measurement as well as the use of inferential statistics. It would be useful if future studies examining user satisfaction with an RFID-based system could be broadened to include other medical facilities and larger proportions of clinicians in the sample.

Conclusion
This study has demonstrated respondents’ satisfaction with the RFID application to better retrieve and share medical information, facilitate a reduction in human errors, and the enhancement of medical process visibility. Medical practice is a highly skilled and complicated process that demands several processes be performed flawlessly for the delivery of safe medical treatment. A seemingly minor mistake or human error may lead to serious consequences. Therefore, medical organisations must be able to guarantee patient safety and the quality of their medical services. This study demonstrates that RF-MediSys offers a cost-effective solution to meet such expectations.

RFID embodies an evolving technology that allows medical organisations to monitor and control the sharing and retrieval of medical information in real time. Although the application of RFID technology in healthcare services is still in its infancy, this research points to the considerable potential for the system to enhance patient safety and improve medical services in this environment.

This study demonstrates how RFID technology can be deployed to meet the needs and practice of medical services in a particular clinic. Although these findings cannot be generalised beyond the medical organisation.
involved in the study, these results do suggest that this innovative approach could be usefully applied in other healthcare settings such as hospitals.

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