A Comprehensive Medicine Management System with Multiple Sources in a Nursing Home in Taiwan

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SUMMARY Residents living in a nursing home usually have established medical histories in multiple sources, and most previous medicine management systems have only focused on the integration of prescriptions and the identification of repeated drug uses. Therefore, a comprehensive medicine management system is proposed to integrate medical information from different sources. The proposed system not only detects inappropriate drugs automatically but also allows users to input such information for any non-prescription medicines that the residents take. Every participant can fully track the residents’ latest medicine use online and in real time. Pharmacists are able to issue requests for suggestions on medicine use, and residents can also have a comprehensive understanding of their medicine use. The proposed scheme has been practically implemented in a nursing home in Taiwan. The evaluation results show that the average time to detect an inappropriate drug use and complete a medicine record is reduced. With automatic and precise comparisons, the repeated drugs and drug side effects are identified effectively such that the amount of medicine cost spent on the residents is also reduced. Consequently, the proactive feedback, real-time tracking, and interactive consulting mechanisms bind all parties together to realize a comprehensive medicine management system.

1. Introduction

Due to the increasing population of aging individuals [1], nursing home services are emerging in Taiwan [2]. The needs are particularly obvious and critical in Taiwan because Taiwan has been a rapidly aging society since 1993. The gross value of the industrial output of nursing home services industries is also expected to reach US$6.92 billion by 2015 in Taiwan [3], which would be double the value in 2012.

Residents living in nursing homes usually have multiple symptoms and use drugs intensively for various treatments. The major reason for this is that they visit several doctors who are more familiar with their different chronic diseases and symptoms. This situation is especially common and obvious in some countries, such as Taiwan, USA, and Canada [4]. Hence, a number of medicine management systems have thus been implemented to address these concerns and support high-quality care for elderly residents [5]. Although these medicine management systems provide identification of and notifications for inappropriate drugs, they typically lack the ability to offer proactive feedback, real-time tracking, and interactive consulting mechanisms with multiple sources.

To fill the above-mentioned gaps in nursing homes, the proposed system integrates the medical records of residents from different sources. The drug uses and doses are automatically reviewed to improve safety.

Some drugs that the residents take but cannot be acquired from the hospital information systems (HISs) of clinics or hospitals can also be integrated into the proposed system. Furthermore, the proposed system has been deployed in the nursing home of St. Martin De Porres Hospital in Taiwan to verify its feasibility. The participants include 41 residents, 10 families, 3 doctors, 1 pharmacist, 1 nutritionist, 3 nurses, and 5 care personnel.

From the evaluated results, not only were repeated drug errors and drug side effects automatically identified, but the average time for pharmacists to detect an inappropriate drug use was also reduced. With the refined automation processes and proactive notification mechanisms, the workloads and the average time for nurses and care personnel to complete a medicine record were also reduced. In other words, residents living in nursing homes usually have multiple symptoms and use drugs intensively for various treatments. Therefore, residents need to visit several doctors on the same day. As a result, the same type of drugs may be prescribed by different doctors. On the other hand, the medicines could also be the same as they had taken from their friends or families at the same period of time. The most general case on this kind of repeated drugs is the stomach medicine.

Through the drug review mechanism, the waste of repeated drugs was avoided. Consequently, the amount of medicine cost spent on the residents was significantly reduced. Moreover, with the interactive consulting mechanism, the residents can have a comprehensive understanding of their medicines.

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As a result, from the statistics from the real evaluations in St. Martin De Porres Hospital, the average time of nurses spent in detecting an inappropriate drug use per resident is described as follows steps:

1. Open the medicine records for each resident: 5 seconds.
2. Collect and print out all the medicine records for each resident, including the medicine from their friends or families: 90 seconds.
3. Manually check and verify all the medicines that each resident need to take from different sources (In general, the amount of medicine in prescriptions is within three days in Taiwan): 700 seconds.
4. Close and complete the medicine record for each resident: 5 seconds.

As the repeated drug errors and drug side effects are automatically identified by the proposed system, the average time for pharmacists to detect an inappropriate drug use was also reduced. In addition, with the refined automation processes and proactive notification mechanisms, the workloads and the average time for nurses and care personnel to complete a medicine record were also reduced.

The remainder of this paper is organized as follows. Section 2 contains a review of related systems in nursing homes. Section 3 outlines the requirements and the detailed design of the proposed medicine management system. Section 4 describes the implementation of the proposed system. Section 5 discusses the evaluations of the proposed system, and Sect. 6 presents the conclusions of the study.

2. Related Works

HISs[6] have been introduced into the fields of health and biomedicine since the early 1950s. A HIS is an integrated information system to manage all hospital processes. HISs can also be applied to a wide range of health care environments and various subsystems are developed around HISs, e.g., medication information systems (MISs)[7], electronic medical record systems (EMRs)[8], and nursing home systems[9]. Nevertheless, most subsystems are developed independently such that several concerns of integrating these subsystems can be solved.

Therefore, a MIS is a key part of medicine management systems. MISs can help with medication monitoring[10] and the use of medicine databases[11]. Although the integration of medical information is accomplished, the medicines that residents take by themselves, i.e., that are not prescribed by doctors, are not examined. In addition, consulting mechanisms are not mentioned in previous studies.

A number of systems are proposed for care services in nursing homes. For instance, some nursing home systems focus on emergency services[12] and the needs of elderly residents[13].

Nevertheless, most residents living in nursing homes in Taiwan have established their medical histories in multiple hospitals and clinics. Therefore, the prescription of the same medication from multiple sources is a critical issue that should be supported by a medicine management system. Moreover, the existing nursing home systems do not provide feedback mechanisms.

Some clinics continue to use handwriting-based medical records[14], which may introduce additional human errors. In contrast, the integration of multiple EMRSs for medicine management is implemented[15].

Although EMRSs have been used to integrate prescriptions, a medicine management system in a nursing home that detects inappropriate drug errors with proactive notification and consulting mechanisms and integrates multiple sources has not yet been constructed.

Moreover, methods to reduce the workloads of nursing home staff, e.g., to reduce the average time to complete a medicine record, and to detect inappropriate drugs have not been reported in previous studies.

Several medication systems have been developed by the Taiwanese government, e.g., the Healthcare Cloud Medication Record System[16] and the Medical Record (EMR) Exchange Center[17]. Using the Healthcare Cloud Medication Record System, each citizen can check his/her medication records for the past 3 months by using their personal healthcare smart card, but the most recent medication records available are from the previous day.

Conversely, with the realization of the EMR Exchange Center, people can apply for online medical records and medical resources are shared with every doctor in Taiwan.

Although the EMR Exchange Center may be used to detect repeated and side-effect drug errors in advance, the issues of real-time tracking, proactive feedback, and interactive consulting mechanisms have not been addressed.

In other words, the Healthcare Cloud Medication Record System[16] and the EMR[17] are only able to share online medical records and medical resources. Nevertheless, the medicine from the sources that without these two systems is not able to be tracked, e.g., drugs given by their families or friends. Thus, a medicine management system with real-time tracking functions is needed to be developed. In addition, a consulting mechanism is critical to be implemented to offer proactive feedback functions, so that a comprehensive survey of medicine use for each resident is constructed by the proposed medicine management system.

3. The Requirements, Considerations and Its Designs of the Proposed Medicine Management System

Figure 1 shows the architecture of the proposed medicine management system and the new modules with predefined APIs enable medical data exchange between multiple sources. In addition, an interface is designed to allow users to input the medicine information manually. If a drug error is detected, the system automatically notifies the related parties. The system also allows all parties to trace and provide feedback with the drug review, notification, and consulting mechanisms to ensure the safety of drug use for the residents.

As shown in Fig. 2, the proposed system incorporates
The proposed medicine management system has 5 objectives:

1. To collect medical information from different sources and allow users to enter the medicine information manually.
2. To be able to identify repeated drug use and side-effect(s) between drugs and alert the related parties.
3. To reduce the workloads of staffs in a nursing home.
4. To have real-time tracking and a comprehensive survey of medicine use for each resident.
5. To reduce the medicine cost spent on residents in a nursing home.

The relationship of the five objectives in this paper is described as follows.

Figure 3 indicates the result of objective (1) to collect medical information from different sources and allow users to enter the medicine information manually.

Figure 4 shows the result of objective (2) to be able to identify repeated drug use and side-effect(s) between drugs and alert the related parties. As mentioned in Sect. 1, residents living in nursing homes usually have multiple symptoms and use drugs intensively for various treatments. Thus, a medicine management system with inappropriate medicine use and an alert system are needed to be developed to identify repeated drug use and side-effect(s) between drugs and alert the related parties.

The results of “average time to complete a medicine record per resident (from 600 seconds to 20 seconds)” and “average time to detect an inappropriate drug use per resident (from 800 seconds to 10 seconds)” in Table 1 represent the result of objective (3) to reduce the workloads of staffs.
Table 1  Final evaluated results in this study.

| Items                                                                 | Before                          | After                          |
|-----------------------------------------------------------------------|---------------------------------|---------------------------------|
| Proportion of detecting side-effect drug errors                       | -                               | 0.082% (1/1,214)               |
| Proportion of detecting repeated drug errors                          | -                               | 25.45% (309/1,214)             |
| Proportion of drug errors that are not in prescriptions               | -                               | 7.4% (24/310)                  |
| Amount of medicine cost spent on the residents                        | USS 129.5K                      | USS 103.9K (−19%)              |
| Average time to complete a medicine record per resident               | 600 seconds                     | 20 seconds                     |
| Average time to detect an inappropriate drug use per resident         | 800 seconds                     | 10 seconds                     |

Fig. 5  Feedback mechanism of the proposed system.

Fig. 6  Tracking mechanism of the proposed system.

in a nursing home.

Figures 5 and 6 present the result of objective (4) to have real-time tracking and a comprehensive survey of medicine use for each resident. Moreover, the most recent medication records are not available in the existed systems, e.g., the Healthcare Cloud Medication Record System [16] and the EMR Exchange Center [17]. Hence, a real-time tracking with a comprehensive survey of medicine use for
each resident is essential to be achieved.

Since the most medicine cost is spent from the 2nd Generation National Health Insurance (NHI) by the Taiwan government, the medicine cost is thus important to be reduced. Through the drug review mechanism, the waste of repeated drugs was avoided. Consequently, the amount of medicine cost spent on the residents was significantly reduced. The result of “amount of medicine cost spent on the residents (from US$ 103.9K to US$ 129.5K)” evidence the result of objective (5) to reduce the medicine cost spent on residents in a nursing home.

To address functional requirements, prescription collection from different hospitals and clinics is necessary because one of the essential requirements is to ensure the safety of medicine use for residents. A repeated drug error may be found when combing prescriptions from various sources. Therefore, the proposed system needs to automatically detect not only repeated drug errors but also side-effect drug errors while integrating multiple sources. Prior to the introduction of the proposed medicine management system, the medicines taken by residents were recorded manually by nurses and care personnel and were checked manually by pharmacists.

However, in the proposed system, the medicine uses are automatically transferred to the proposed medicine database, and pharmacists must only reconfirm the medicine use after the drug review process. Consequently, the system reduces the workloads of the staff in reviewing prescriptions.

An interface to input medicine information manually is also needed for a comprehensive survey of medicine use. Some predefined formats are applied to record the medicine uses for interoperations. For the medicines taken by residents that are not prescribed by doctors, e.g., drugs given by their families or friends, the users would create a new medicine use in the medicine database, including the drug name, dosage, and treatment dates, and other optional information. Doctors or related parties are thus able to review all of the medicine uses and have a comprehensive survey of each resident.

Inappropriate drug use is avoided by the medicine consulting function. The users of the medicine consulting function are residents, nurses, pharmacists, and doctors. The consulting system is treated as a platform for the residents to understand more details about the medicines that they take by sending a query to their doctors or pharmacists online.

Since the residents living in nursing homes usually have multiple symptoms and use drugs from different doctors, the doctor first prescribes the medicines can describe the situation of residents and identify the side-effect drugs by the medicine consulting subsystem, i.e., describing the current situation and symptom of the resident, or identify which drugs that the residents are took, so that the following doctors could see the related information and understand the situation of the resident well from the medicine consulting subsystem. Consequently, several inappropriate drug uses can be avoided with the medicine consulting subsystem.

Furthermore, the proactive feedback mechanism is constructed using the design of the pharmacist suggestion function and is based on the medicine alert service. As shown in Fig. 2, the medicine alert service subsystem is one of the subsystems in the proposed medicine management system. The medicine alert service subsystem is utilized to notify the related parties after detecting suspicious treatments, e.g., repeated drugs or drug side effects. Once a drug error is notified by the medicine alert service, the information about the inappropriate drug error in the prescriptions appears in the pharmacist suggestion table. Additionally, the pharmacists can review the history of pharmacist suggestions for each resident via a query. In addition, to improve the quality of care, the proposed system allows the nursing staff to review the history of the pharmacist’s suggestions for each resident.

Other system requirements include the collaboration and interoperability between legacy subsystems. First, legacy subsystems have existed for a long time, and collaborative integration is thus important.

The proposed solution must be able to exchange/share data with other systems. Second, some formats must be predefined to facilitate the better integration of intermittent data from various sources. The last requirement is interoperability among multiple sources.

Some application programming interfaces (APIs) and modules are well defined to coordinate two distinct types of medical systems. All participating hospitals and clinics must follow the specifications of interoperability, i.e., the common medical vocabulary dictionary and the predefined APIs, to be integrated into the proposed system.

The proposed system flow is described as follows. After a resident receives a new prescription from a hospital or clinic, a transaction from the HIS of the hospital or clinic is subsequently sent to his/her nursing home to update his/her medicine records in the medicine database within the hospital service subsystem. Users may also report the medicines taken by the residents that are not in their prescriptions to the medicine database via the online web service subsystem. Next, the comprehensive medicine management system analyzes all of the active or in-use records and prescriptions stored in the medicine database.

A number of supportive subsystems are developed in the hospital or clinic to realize the proposed system. A HIS agent is developed in the participating institutions to handle communication between the HIS and the hospital service subsystem and share the prescription information between the nursing home and other institutions.

The prescription processor, which is the key part of the HIS agent, is primarily responsible for receiving the prescriptions from HISs in hospitals or clinics and transferring the prescriptions to a pre-defined format. The converted data are subsequently recorded in the medicine database of the nursing home. Moreover, the medicine processor of the HIS agent synchronizes the hospital’s pharmaceutical database with the medicine management system.

The HIS agent is highly portable because it is developed with the Java language. The code size is 87 Kbytes,
which is suitable for porting to other platforms and does not affect the original performance. All participating hospitals and clinics will install the HIS agent to interoperate with the proposed system. Doctors are recommended to identify the format and definition for their prescriptions, which have been well defined in the hospital’s pharmaceutical database.

After discussing with the Management Information Systems (MIS) team in the St. Martin De Porres Hospital during the development time, the main risk of this type of medicine management system is connected to Internet. Finally, a virtual private network (VPN) is constructed between the hospital service subsystem and the HIS agent to establish a secure communication channel. On the other hand, the internal data access is managed under an account/password mechanism which is the same as other information systems in the St. Martin De Porres Hospital. The above two mentioned approaches in terms of VPN and the account/password management achieve a security and reliable access communication for this work.

4. Implementation of the Proposed System

The system was implemented in the nursing home at St. Martin De Porres Hospital, Chia-yi, Taiwan. The nursing home contains 258 wards distributed throughout 6 floors. The proposed system was deployed to manage 46 wards on the 6th floor. The prototype connected to the St. Martin De Porres Hospital, its nursing home, and 2 local clinics. The total participants were 41 residents, 10 families, 3 doctors, 1 pharmacist, 1 nutritionist, 3 nurses, and 5 care personnel. The system took one year to be completed, and the evaluation was performed over 6 months.

The key parts of the user interfaces of the proposed system are shown from Figs. 3 to 6. Figure 3 contains a portion of a resident’s medical information. The record demonstrates that the medicines come from different sources, i.e., the divisions of urology and neurology. Note that some sensitive information is redacted in the following figures to protect the privacy of the related parties.

The basic functions of the medicine alert are illustrated in Fig. 4. Both life-threatening drugs and drugs that cause individual allergies are emphasized by highlighting cells in colors, such as the third and fourth items in Fig. 4, respectively. Moreover, the proposed system identifies the repeated drugs and side-effect alerts using the capital letters R and S, respectively.

The feedback mechanism allows pharmacists to issue their feedback and recommendations, as shown in Fig. 5. Pharmacists need to indicate the description of the problem and whether the problem is classified as an adjustment or a side-effect event. For example, an interaction warning for two drugs is raised, cyclosporine and metoclopramide, which have a side-effect. The pharmacists are also able to give some recommendations to residents, such as asking the healthcare professionals to check the drug use before the resident takes the medicines.

Figure 6 introduces the tracking mechanism of the proposed system. Doctors and nurses can enter and edit the corresponding reply and check whether a feedback item has been followed up. For instance, the fourth item in Fig. 6 indicates that the corresponding nurse or doctor has not replied yet, and the “track to complete” field thus shows No. In contrast, the “track to complete” field for the other items in Fig. 6 are changed to Yes automatically because the doctors or nurses have replied to the corresponding questions.

5. Evaluation and Discussion

Table 1 summarizes the evaluated results of the proposed system. A total of 1,214 prescriptions were tracked for 41 residents for 6 months. From the final evaluated results, only one side-effect drug error was found that required manual input by the users, and the proportion of the prescriptions triggering side-effect drug errors was thus approximately 0.082%. This excellent result is due to the excellence of Taiwan’s health care system. The Healthcare Cloud Medication Record System [16] and the EMR Exchange Center [17] developed by the Taiwanese government have been used to check medication records for the past 3 months and integrate prescriptions for each resident, respectively. With these two medication systems, doctors in Taiwan could detect repeated and side-effect drug errors in advance. This is the main reason that why the side-effect drug error was extremely low in the result of this work.

Furthermore, the proportion of detecting repeated drug errors was 25.45% because 309 repeated drug errors were automatically discovered. Note that 23 of the drugs were manually entered by the users. This result is because the residents often like to visit different doctors with a long-term relationship and prefer to take tonics by themselves. Conversely, the results indicate that the manual input mechanism is necessary because 24 (7.74%) of the drugs that resulted in drug errors were not contained in prescriptions.

The amount of medicine cost spent on the residents decreased by approximately 19%, as the total cost was reduced from US$129.5K to US$103.9K after the evaluation. Note that the payment of the medicine cost for each resident was calculated from the 2nd Generation National Health Insurance (NHI) in Taiwan. One of the major reasons for the cost reduction is because most of the repeated drugs were verified and the pharmacists and doctors were notified; thus, the waste of repeated drugs could be avoided in the nursing home.

Prior to the establishment of the proposed system, the care personnel had to manually enter the information for all of the medicines taken by residents into the medicine database.

With the refined automation processes, the information for the prescriptions was automatically transferred to the medicine database. The care personnel only needed to reconfirm the medicines and add the drugs that were not in prescriptions. Thus, the efficiency of the medicine recording process has been significantly improved, and the average time required to complete a medicine record per resident
was reduced from 600 seconds to 20 seconds. 
Moreover, the average time to detect an inappropriate drug use per resident was reduced from 800 seconds to 10 seconds. Note that the above two measured times have been evaluated 50 times in the nursing home.

6. Conclusions

In this work, a comprehensive medicine management system is achieved through the avoidance of problematic prescriptions, real-time tracking, proactive feedback, and interactive consulting mechanisms. All of the recent medicine uses by each resident can be tracked online, and pharmacists are able to issue requests for suggestions on medicine use.

The proposed system also allows users to input information about medicines that residents take but were not prescribed. With the interactive consulting mechanism, the residents are able to have a comprehensive understanding of their medicine use.

After a real implementation in the nursing home, the evaluated results show that both the average time to complete a medicine record and detect an inappropriate drug and the amount of medicine cost spent on the residents were obviously reduced. Moreover, repeated drug errors and drug side-effects can be identified automatically. Consequently, the proposed system is still in use today.

In the future, the Healthcare Cloud Medication Record System and the EMR Exchange Center plan to cooperate with the proposed system, e.g., instead of the HIS agent, such that the proposed system is expected to be integrated with more clinics or hospitals in Taiwan and will become a global paradigm for medicine management systems.

Acknowledgments

This work was partially supported by Ministry of Science and Technology (MoST), Taiwan, under grants, MOST-104-2220-E-110-001, MOST-104-2220-E-110-002, and MOST-104-2220-E-110-007. The authors would like to thank all colleagues who contributed to this study in the nursing home of St. Martin De Porres Hospital for providing valuable suggestions. We also appreciate all of the support from the residents and their families in the nursing home of St. Martin De Porres Hospital. With their participation and feedback, we were able to gather substantial information and conduct a quality research study.

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