# SHMS – Smart Health Monitoring System: A Study of Computerized Patient Management System with Remote Monitoring Functionality in Sri Lanka

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***Abstract*—Computerization in the health care industry has lead to the reduction of mortality rates globally. Though digital health and computerization is a growing phenomenon in the global context, in Sri Lanka still in the early stages. Thus, the primary objective of this study is to study how computerization can improve the efficiency of patient management in Sri Lankan hospitals and improve the chances of survivability of patients in critical conditions. The study ventures into explaining how the effective remote and continuous monitoring of patients and automated medication where applicable enables quicker recovery than conventional treatment methods simultaneously improving patient safety including the newly arising aspects of patient safety due to the health information technology. Furthermore, the impact of a comprehensive medical history of a patient being available to the medical staff in the emergency setting towards the successful recovery of the patient is evaluated. The study makes use of data obtained from research articles and books to understand the scope of computerization that is taking place in the health care industry globally. Studies that have been conducted with regards to technologies have been analyzed to understand the optimal data storage mechanisms for health records and the applicable technologies in the context of a Sri Lankan hospital. The results of this study will be beneficial at developing practical solutions for the computerization of the Sri Lankan health care system and the approach that should be betaken towards the general public.**

***Keywords—Remote Monitoring, IOT, Patient Management, Health, e-health***

## I. INTRODUCTION

Continuous Patient Monitoring(CPM) plays a vital part in delivering the best treatment to patients. It is very important when it comes to maintaining stable post-treatment health conditions of patients. In Sri Lankan hospitals, patient monitoring happens completely manually in the form of periodical examination by the medical staff. It would require a health worker for every couple of patients if continuous monitoring needs to be done manually, which is not feasible for a hospital with limited staff. Another downside of this is the delayed response time when a patient's health condition deteriorates and becomes unstable. The majority of Sri Lankan hospitals also lack computerized systems for managing patients. The medical history of a patient is not readily available to the staff. When responding to a health emergency, the availability of the medical history of that patient could be greatly helpful when planning treatments for the patient. Accordingly, the need for a Computerized Patient Management System(CPMS) with Remote Health Monitoring (RHM) is identified. The objectives of the systems are as follows (1) monitor multiple patients simultaneously at a given time, (2) Monitor patients remotely, (3) maintain profiles for patients that contain the personal details, medical records and vital records, (4) maintain profiles of doctors.

The scope of the proposed solution spans through a web application and an IoT based RHM device. The software is a web application that allows the system to be used by multiple hospitals with the data being stored in the cloud for a higher degree of accessibility.

## II. LITERATURE REVIEW

The advent of Information Technology is being utilized in the health care sector globally as Health Information Technology (HIT). SHMS – Smart Health Monitoring System is a product that is built with HIT putting together a patient management system and a remote monitoring system of patients for the hospitals of Sri Lanka. The concept behind this originated with the increased utilization of information technology in the global healthcare industry which seems to be lacking in Sri Lanka. In the developed world many hospitals are computerized with systems that are used to manage patients and their medical records. The hospitals utilize various forms of remote monitoring technologies for monitoring the patients and in some cases remotely providing the medications for certain illnesses with the use of electronic remote medication equipment. SHMS utilizes a device developed using IoT technologies for this purpose with a web application that acts as the interface.

Utilization of Health Information Technology comes in the form of Clinical Decision Support Systems, Electronic Physician's Orders, E-Prescribing, Electronic Medication Administration Records, Patient Data Management Systems, Electronic Medical Records, Remote Monitoring and Remote and automated Medication Administration Systems[1]. There are numerous studies conducted in the field of RHM and there are shreds of evidence on its contributes towards the improvement of the outcomes of the treatments for patients with chronic conditions such as heart failure, stroke, asthma and hypertension[1].

According to an RPM research conducted, in Japan for the management of diseases such as pulmonary heart disease and congestive heart failure discovered that RPM has reduced hospitalization of heart patients by 29% and the reduction of deaths by heart failure by 20%[2]. Under the same research, studied on the resource consumption by patients with regards to the healthcare was simulated through clinical scenarios prepared with hypothetical patients to compare the resource consumption between a patient undergoing remote monitoring and a patient undergoing regular monitoring. Two groups of patients have taken part in the study. The group that underwent remote monitoring was named RM+ (Remote Monitoring) and the group that underwent regular monitoring was named RM-. The findings of the study show that the group RM+ consumed significantly fewer resources than the group RM- [2]. The resource consumption was monitored mainly with regards to unplanned hospital visits, emergency room visits, home visits, and telephone-based communication with



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medical staff[2]. The highest impact of cost reduction associated with the utilization of remote monitoring according to the above study is for chronic obstructive pulmonary disease and congestive heart failure due to the reduced complications[2].

Another aspect of ICT in health care is Patient Data Management(PDM). This may include PDM systems retrieving data from electronic medical equipment such as RPM devices and bedside medical equipment, which are then structured, stored, represented to health workers[3]. The same study discovered that these systems result in the increase of time spent on patients directly by the medical staff[1]. The study has obtained substantial evidence with regards to the improvement of the accuracy of medical records resulting in the use of Electronic Medical Records in Patient Data Management Systems which contributes to the improvement of patient safety[1]. A study conducted by Beena [4] on the effects of computerized patient records on patients identified the availability of medical data, consistency of data, and reduction of costs as benefits. The study suggests that when a medication is prescribed, a patient management system could cross-check the treatment with the medical history of the patient and alert the staff on probable side effects and complications should there be any[4] in addition to facilitating the medical staff to manually check the medical history of a patient. This with the added functionality of shared medical data across multiple institutions that uses the system would enable efficient and safe patient care[5][4]. The study has identified cost reductions that could result in the implementation of computerized patient management due to the minimization of inefficient paper-based documentation processes. Further cost improvements could result in the elimination of costly pre-tests which are conducted when there is a lack of understanding about the medical history of a patient[4]. In addition to the health-related safety improvements, the study suggests ways to improve safety within the electronic patient management system to safeguard patient data and privacy. Usage of strong user authentication measures coupled with bio-metrics and audit trails to identify the users that abuse the system, or intruders who have gained access to the system due to compromised login credentials of a user and maintaining backups are suggested[4]. Moreover, with modern technology, PDM systems can be integrated with Clinical Decision Support Systems for enhanced decision making as well.

A separate study conducted on the benefits and drawbacks of electronic health record systems has ventured into clinical outcomes, organizational outcomes, and social outcomes. Accordingly, quality of care is identified as a major outcome of electronic patient record systems in a clinical setting. Quality of care consists of three major dimensions: patient safety, effectiveness, and efficiency[5]. The study has found out that an electronic health record system with clinical decision support tools have increased the adherence to evidence-based clinical guidelines by the health workers. Researchers have observed that computerized reminders have resulted in improvements to the percentage of the usage of influenza and pneumococcal vaccination from 0% to 35% and 50% for hospitalized patients[5]. The use of influenza vaccines has increased from 47% to 65% for all patients and the use of pneumococcal vaccines has increased from 19% to 41%[5]. These studies support the theory that electronic health record systems improve adherence to clinical guidelines.

| Private or Public hospitals | | | |
|---|---|---|---|
| Private Only | Public Only | Mostly Public | Mostly Private |
| 4% | 0.2% | 50% | 45.8% |

Another research was conducted[6] on the development of a framework with open source technologies to be used for the development of clinical dashboards that are inter-operable between hospitals. The study has found out that most of the clinical dashboards used in the healthcare sector at present are custom built for a particular hospital and lack interoperability, therefore limiting the share-ability of medical data[6]. The research has identified several challenges regarding the implementation of electronic health record(EHR) systems. The most significant are the challenges associated with data that are fed from medical equipment to EHR. Fragmented vendor standards have been identified as a key barrier for the integration of data from a diverse set of devices to a common platform[6].

### *A. Benefits of Computerized Patient Management Systems (CPMS)*

A CPMS with patient profiles which contain patient details, their medical records, remote monitoring functionality with the use of electronic patient monitoring equipment that feeds vital data to the patient management system which then stored in each patient's profile, would result in following benefits :

- Improved and consistent attention towards patients.
- A higher level of preparedness for patients due to the availability of medical and vital history.
- Enhanced emergency response due to the improved preparedness.
- Reduced cost of operations at the hospital.
- Reduced cost of treatments as a result of the elimination of pre-tests due to the availability of medical history.
- Reduced cost at the facilitation of health care.
- Improved adherence to clinical guidelines that result in a higher quality of care.
- Efficient use of staff resources with the use of dashboards for mass patient monitoring.

## III. METHODOLOGY

The effect of computerization on safeguarding the lives of patients is studied in the research to propose a solution in Sri Lanka utilizing Health Information Technology (HIT) to improve health care. The study focuses mainly on CPMS and RHM under HIT.

Researches that have been conducted on various implementations of HIT internationally are reviewed for the purpose of investigating the extent of applications. The study has identified the technologies that are feasible for the application of HIT in Sri Lanka.

A survey was conducted with the use of Google forms for identifying the facilities offered by Sri Lankan hospitals and their extent of computerization. The following results were obtained.

## IV. Results & Discussion

Table 1: Frequency of hospital visits

| Frequency of hospital visits | | | |
|---|---|---|---|
| <5 times a year | > 5 times a year | 1 times per month | >1 times per month |
| 70.8% | 20.8% | 0.1% | 8.3% |

Table 2: Hospital visitation public vs private

Table 3: Usage of CPMS in the visited hospitals

| Encountering CPMS | | | |
|---|---|---|---|
| Manual only | Mostly file based | Mostly CPMS | All CPMS |
| 12.5% | 41.7% | 37.5% | 8.3% |

Table 4: Feedback on whether the CPMS system supports patient profiles and medical history

| Availability of patient profiles and medical history in the above CPMS | | | |
|---|---|---|---|
| Yes | No | Only admins operate the system | Access only available for staff |
| 21.7% | 69.6% | 4.3% | 4.4% |

Table 5: Availability of Remote Health Monitoring in the visited hospitals

| Availability of RHM | |
|---|---|
| Yes | No |
| 22.7% | 77.3% |

Table 6: Feedback on whether the hospital allows obtaining past medical records

| Ability to obtain past medical records | |
|---|---|
| Yes | No |
| 37.5% | 62.5% |

Table 7: Feedback on whether the patient has undergone Remote Health Monitoring

| Whether undergone RHM or not | |
|---|---|
| Yes | No |
| 87.5% | 12.5% |

Table 8: Patients' perception of RHM and whether it contributes to better survivability or not

| Perception on whether RHM increases the chances of survivability | | |
|---|---|---|
| Yes | No | May be |
| 62.5% | 0% | 37.5% |

Table 9: Perception of the importance of accessibility to medical history and patient profiles

| Whether the access to patient profiles and medical history across hospitals is important or not | | |
|---|---|---|
| Yes | No | May be |
| 75% | 0% | 25% |

According to the results of the survey, the majority of the hospitals in Sri Lanka do not have a CPMS with integrated RHM functionality that gives the patient access to their profile details and medical history. Furthermore, there is no universal platform available that could facilitate the creation, maintenance, and accessibility to the medical history of a patient across hospitals. The results of the survey indicate that patients have a positive perception of the benefits of a CPMS with RHM.

## V. SHMS

When introducing a new system in an environment of a developing nation, it is important to focus on the availability of funds, resources, and the overall feasibility of the system. If the system needs technologies that are not available at the time, there is a higher probability of the project being unsuccessful. SHMS is developed with technologies that are readily available for the ease of implementation of the system in Sri Lanka. SHMS is consisted of the following components.

### 1. Web Application

When introducing a new system in an environment of a developing nation, it is important to focus on the availability of funds, resources, and the overall feasibility of the system. If the system needs technologies that are not available at the time, there is a higher probability of the project being unsuccessful. SHMS is developed with technologies that are readily available for the ease of implementation of the system in Sri Lanka. SHMS consists of the following components :

- Administrator
  - Creates, Updates, Deletes patient and doctor profiles
  - Assigns doctors to patients
- Doctor
  - Creates and Updates medical records
  - Views vital data, patient details, and location
- Patient
  - Views patient details, medical and vital history

The web application has been developed with JavaScript technologies. JavaScript-based frameworks are quite popular for web development and server-side scripting and are heavily being used in the Sri Lankan IT industry. This has made it an abundant resource when it comes to the availability of developers. The utilization of existing and available technologies may contribute to future maintainability.

NodeJS has been used for the REST API and VueJS has been used for the front end. VueJS is based on Angular but is community developed and has a higher degree of efficiency and performance. It's relatively simple yet has the complete functionality expected from a web development framework.

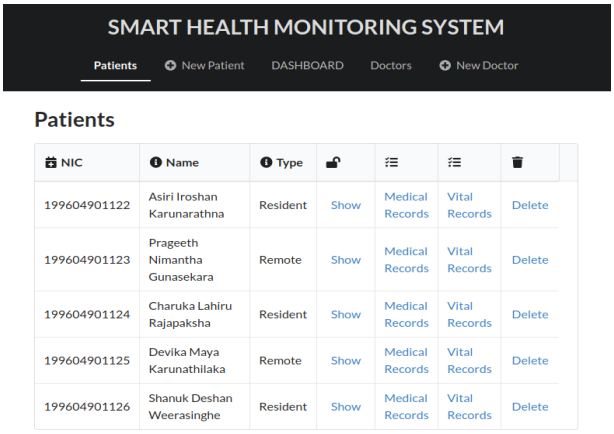


Fig 4: SHMS dashboard



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2. Cloud Database (NoSQL)

- Stores profile details of users.
- Stores medical records
- Stores vital records

MongoDB has been used as a database system. The reason for using a NoSQL database was the horizontal scalability. NoSQL databases are ideal for storing a stream of data dumped by the RHM systems. NoSQL databases follow a shared-nothing architecture[7] which eliminates a single point of failure and bottlenecks.

3. REST API

- CRUD operations between web application and database

4. IoT based RHM device

- Measures pulse rate
- Measures body temperature
- Obtains latitude and longitude values of the location
- Emergency mode status (button pressed or not)
- Periodically sends the above data to the cloud database

### *A. System Architecture*

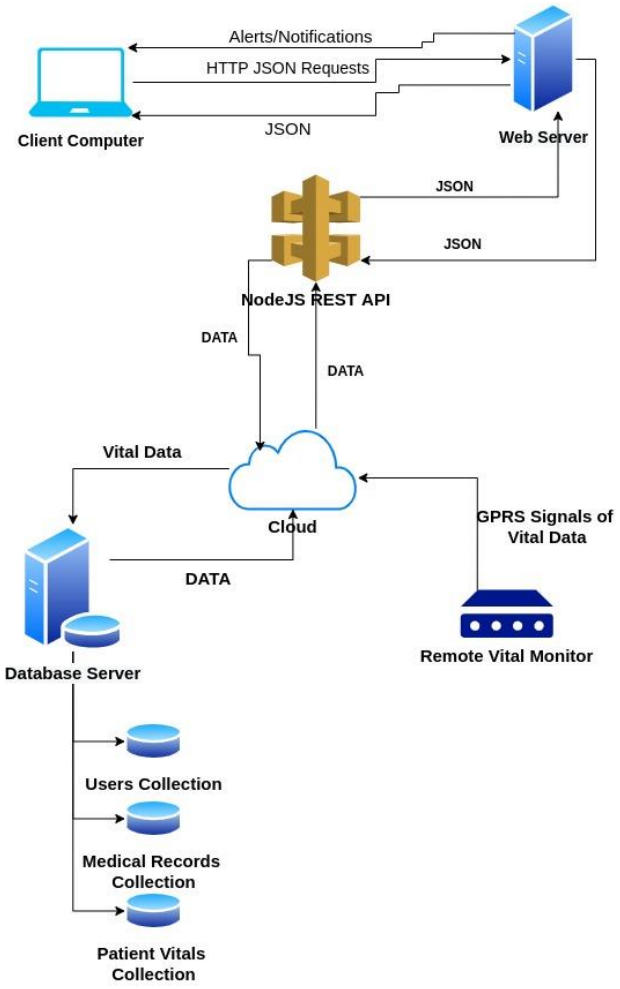


Fig. 5: System architecture

## VI. Conclusion

The paper presents a CPMS with RHM functionality which utilizes a Web Application and an IoT device. The context of the system is a hospital and the system works as a platform that is accessible across multiple institutions. The application has the flexibility to be integrated with any RHM device that is capable of transmitting data to the cloud due to the separation between the front end and the back end. The application requires a panel of admins from each medical institution for managing. Patients can view their profile details, medical records, and vital history while doctors are responsible for the creation of medical records and observing vital data. The RHM device provides warning and critical alerts based on the vital parameters obtained. The system can be improved by implementing the logic of offering warning levels on the web application instead of on the device and adding different modes such as sleeping, exercising, walking that would adjust the parameter ranges considered for issuing warnings for better accuracy.

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