Enhanced Home-Based Medical Care Services Through Mobile Technology

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***Abstract* — One of the fastest emerging services in healthcare is the development of home-based or home-based healthcare services. This trend has been growing in Europe, North America and Australia, especially in the last five years. However, the major challenge is the monitoring and control of the quality of the service. In this paper, we propose a set of procedures for the quality control and monitoring of the service delivered, with the workflow being streamlined using mobile technology. The proposed model was simulated on different service management models and proved an assured tendency for an accurate tracking of the practice. Simulations revealed that upon the application of these procedures up to 70 % (i.e. if 70 % of recommendations are applied), 90% of common medical errors could be avoided. In the proposed model, patients (under well defined mental conditions) are evoked and encouraged to constitute a part of the control procedure. The awareness of the patient reduces the estimated error measurement largely. The model takes care also of the quality control of certain medical devices (portable diagnostic devices) that are usually used in such practices.**

Keywords-quality control; home-based care; mobile technology; total quality management; healthcare management.

I. INTRODUCTION

Many years ago, people used to have medical care provided at their places, where "physicians" used to diagnose and treat patients at their homes. This constituted an important opportunity for the physician to take a live look at the patient's living conditions, given that these conditions were considered by that time as the most possible causes for diseases.

With the development of medical equipment and tools for both diagnosis and therapy, there was a need to gather all these equipment in a place (Hospital) where patients could come to have medical services administered. This constituted an important step in the control of diseases especially contagious ones. With such a measure, people living with the patient were no longer endangered or subjected to the disease.

As hospitals widely spread all over the world, an important issue unfolded: infection and its control. Most of the hospitals worldwide are general hospitals, which render them as places gathering a huge number of patients having different diseases, mostly infections. This leads to anticipate that a hospital is a place where we can –with a high probability– contract an infection (nosocomial infection). In order to minimize the aforementioned risk, many procedures and techniques were developed [1, 2]. One of the most common measures is to minimize the period of stay of the patient at the hospital [3]. Usually, patients having surgery procedures who are not in need for concentrated or intensive care can stay for a number of days at the hospital for the ordinary nursing tasks. During his/her stay, the patient is subjected to a non-negligible risk of infection. In cases where ordinary tasks could be performed at home, it would be better if the patient receives such a service at his/her own place. This will decrease the infection risk, liberate more space at the hospital, and in most of cases decrease the cost of treatment [4].

The development of home-based care services is widely spreading in Europe and in the United States. The services mostly ensure medical and logistic help for seniors, children with special needs, persons suffering from chronic diseases. Late studies have revealed that even some cancer cases can be followed home-based [5, 6, 7].

However, many problems are ensuing with the growth of this trend [8], the major amongst which is the lack of control of the nurse or staff delivering the service, when there is no direct supervision, as is the case in a hospital setting! In the latter case, the medical personnel are usually supervised at two levels (nurse / staff nurse and staff nurse / physician). Sometimes, a floor or ward supervisor can be added to the chain, just prior to the physician level. In this work, we will be focusing on the issues related to quality control and the quality assurance of the service. In hospitals, the staff follows well-defined and well-practiced procedures to perform daily tasks. In addition, the presence of a staff nurse or any other well-experienced staff who can ensure that technical support is available when needed decreases the risk of errors. This is not the case when it comes to home-based care services. Entities delivering these services are mostly private and they are governed by budgetary and human resources limitations. Thus, in most cases, they tend to minimize the personnel servicing one person at the time (depending of the case). The human resources limitations

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may sometimes lead to employ some staff without enough experience. At this stage, a weakness point is identified which can be restated as follows: Lack of control on – and support (technical) for – the staff performing the medical task [9].

In 2006, Koch [10] summarized the state of research on home-based healthcare from an international perspective. In their study, they reviewed all scientific literature concerned with telehealth services between 1990 and 2003. They observed a trend towards tools and services, not only for professionals, but also for patients and citizens. It could be noticed that it was difficult to determine the quality of care in the presented solutions. They stated mainly the lack of standards for the compatibility of information systems, as well as the lack of evaluation frameworks considering legal, ethical, organizational, clinical, usability and technical aspects. Added to that comes the lack of proper guidelines for practical implementation of home-based healthcare solutions. [10]

Recently, Kuo *et al.* [11] developed an information technology (IT)-mediated home-based healthcare model designed to improve the effectiveness of caring for stroke patients who require chronic home care. The developed model showed an important success; however, their system depended on a measurement device capable of monitoring certain physiologic parameters and sending them to a control room. Such dependence posed as a major limitation to the model.

Margolis and co-workers presented a design and rationale for home blood pressure telemonitoring and case management to control hypertension with a cluster randomized trial [12]. The system communicates the measurements of blood pressure to a control space, without taking into account the quality of measurement.

In this paper, we propose a general control model that can be used to evaluate the quality of home-based care services. The model responds to the weakness points identified above; thus, the basic idea behind it is to ensure proper control and support for the staff, and to involve the patient in such a process. It conforms to the basics of total quality management – in general – and quality healthcare management in particular. The pillar in the proposed monitoring system is mobile technology, where the patient, the nurse, the physician, and the hospital information system are all linked in real-time.

After this introduction, the problem is detailed and laid down. The solution is then featured and characterized. Finally, future perspectives and possible ameliorations of the system are pointed out.

II. SITUATIONAL ANALYSIS

Controlling the quality of a service involves many parameters that should be evaluated and reported by the person delivering the service. Thus, it is tightly linked to the auto diagnosis methodology of the person and the system together. The identification of the problem causes reveals important aspects, as depicted in Figure 1.

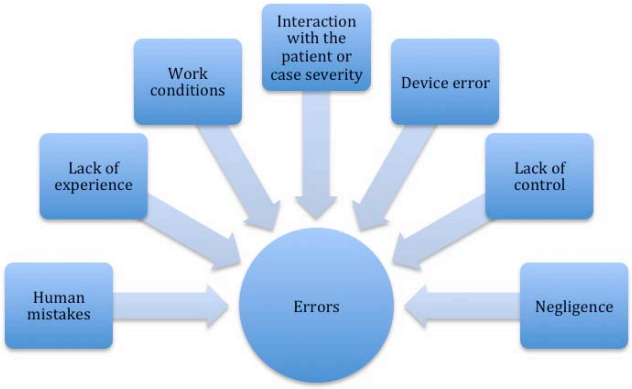

Figure 1. Roots of error.

Figure 1 shows the possible causes of error according to a deep literature research on common errors in similar cases. The query included reported cases, patient surveys, and literature works. A simulation was performed in order to define an interval for each type of error according to the other parameters.

The lack of experience was used as a testing parameter. This parameter is studied in two cases under conditions with and without control from a superior. A representation of the total error in both cases is presented in Figure 2.

The above demonstration shows the importance of the control for many reasons. Thus, a primary parameter is identified that leads to have an oversight on the staff on a permanent manner. Here, we should mention that the presence of a control mechanism or a "*permanent assistance*" as we will call it later not only provides the control but also ensures a live support in case of need for information or in any emergency situation.

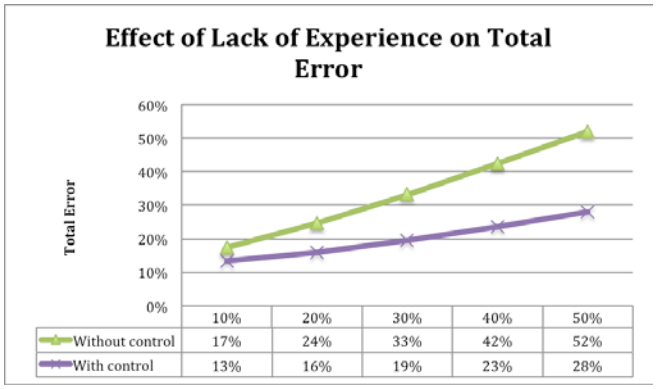

Figure 2. Total error in both cases with and without control.

One important issue can be revealed which is the importance of having a mechanism for archiving and analysis for all events that occur through the treatment process. Home-based care services are new enough that it is too difficult to find databases containing statistics or archives for incidents taking place. The presence of such databases minimizes the probability of mistake occurrence. Thus, the lack of supportive data is identified as an additional weakness point.

The two points identified show the contribution of the staff to dealing with errors; however, an important factor is added which is the interaction of the patient himself/herself. For example, a hospitalized patient who is prevented from smoking for dangerous consequences will not be able to smoke in a hospital, but this is not the case for those patients receiving care at home. The interaction and responsiveness of patients receiving home-based care services constitute a difficult challenge in the treatment process. This point will be considered as a constraint in the solution process.

Another constraint is the living environment of the patient and the respect of healthy living conditions at home. A sick person is more susceptible for infections than a normal one, which imposes giving high attention to hygiene control and to the quality of ambient air and temperature in the living place of the patient. This in turn reflects another challenge for treatment process because it depends relatively on the financial conditions of the patient.

Figure 3 summarizes the different weaknesses and constraints of the treatment process and the cause-effect relationship between each of the contributors. As presented in the figure, there are many parameters that influence the treatment process and are considered as limiting aspects. Besides, the quality control of the medical equipment used should eventually be addressed in some cases. For instance, a non-stable blood pressure measurement device can provoke a lot of disturbance for a non-experienced staff who may not doubt the measured value and further investigate it. Troubles and panic evoked by non-controlled or non-maintained devices can lead to dangerous decisions in certain cases ultimately increasing risk. Such a probability of errors in portable medical equipment may be higher because such devices are usually kept either with the staff or at the patient's place. In a hospital, medical devices are usually maintained almost on a daily basis and the availability of a biomedical engineer or a technician on site decreases the risk. The biomedical department in a hospital performs periodic checks on the functioning conditions of devices (humidity, temperature, electricity and grounding, electric safety, etc.). In home-based care, neither the staff nor the patient are trained or qualified to perform such a task.

Figure 3. Cause-effect relationship influencing the treatment process in home-based healthcare.

III. MODEL AND MANAGEMENT OF THE SOLUTION

A. *Controls and Support*

The proposed management model for the service contains steps and procedures in order to minimize the risk and errors provoked by each of the above-mentioned issues. The model is based on the use of information and communication technology facilities in order to maintain acceptable working conditions, thus improving the quality of the service delivered.

Nowadays, portable touchpads and smart devices can establish a bidirectional communication process where data is transferred rapidly and processed in a very short time. The design involves pre-defined mobile devices that connect through a secure application to a central system/database hosted at the hospital or at the company offering the service.

The mobile application, installed on a mobile smart device (Touchpads, tablet PCs, smart phones, etc.) will have two different versions; one for the patient, and another for the physician. The mobile application can be modified or adapted depending on the case requirements that are defined through a well-traced procedure.

The goal of the application will be:

Physician's version:

1- Send instructions to the control room.
2- Establish communication between the physician and the patient at home.
3- Show critical medical information of patients (patient's file, medical measurements, etc…)
4- Show needed reports/trends about patients
5- Receive emergency reports/alarms from the system

Patient's version:

1- Send medical readings/measurements to the control room (example: blood pressure measurements).
2- Establish communication between physician and patient.
3- Receive instructions/alarms from control room.

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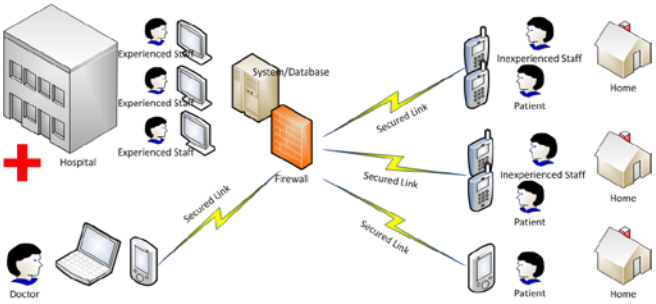

Figure 4. Home-based care system sample diagram.

In the control room, the system will be managed by the experienced staff member(s) to control and manage the communication processes between the control room, patients, and physicians; as well as follow the treatment processes between the staff and the treating physician who may be situated inside or outside the hospital.

The system itself will:
1- Collect medical readings from patients.
2- Collect instructions from physicians.
3- Host maintenance information about mobile medical equipment.
4- Ensure on-time connectivity to mobile devices.
5- Analyze data based on intelligence.
6- Trigger alarms

A sample diagram of the system is illustrated in Figure 4.

The created mobile application contains multiple steps where at the end of each routine to be performed by the staff, an outcome is required. The outcome will be presented as a value to be entered by the staff/patient. The value entered is transferred directly and shown on the server's screen in the 'Central Control Room". The transfer of data to the control room enables online verification by the control room officer. The importance of this step comes from the fact that the control room officer, who in turn ensures the technical support and the control for the staff, can verify any procedure. A screenshot of what is displayed to the staff is shown in Figure 5.

Figure 5. Screenshots of the mobile application. An example of the initial pad navigation screen (left) showing two potential patients. A summary of a measurement (blood pressure in this case) is shown to the right.

The software enables to create a visible history of any parameter of the patient. This history can be connected with the control room directly. This can even be done through videoconferencing, where the control room officer can in turn talk to the patient.

Transferring the information all the time to the control room permits to create huge databases where all events are added using neural archiving methodologies. This data can ensure an important support for the staff and builds an expert system that will always be available in case it is needed. A key bonus of this feature is traceability, where all events are recorded along with respective timestamps.

B. Patient Responsiveness and Awareness

Improving patient responsiveness and awareness has been shown to increase when patients are involved in the treatment process. A developed version of the model and the application proposes that two touch devices be used, where one of them will be kept with the patient. On the patient's device, a patient application is installed permitting the interaction and the communication with the control room and with the staff concerned if available. In her/his dedicated application, the patient will be asked to enter all the parameters measured by the staff as the latter does on his/her own application. The staff will be asked to approve the data entered by the patient through the mobile application. Some alerts are programmed so that when a measured value approaches the safety limits or thresholds, a sign attracting the patient's attention is launched. However, this should be applied in a limited number of cases, depending on the patient's alertness and/or – probably – their psychological aptitude. Such a dual system is exemplified in Figure 6.

Besides alerting the patient and involving her/him in the process, another purpose of having the data entered by the patient is to have a second reading of the parameter to be measured. This minimizes the risk of the human error and allows the staff to have a second look at the measured value.

Certain features for the entertainment of patients might be incorporated in the application thus improving the healing process. A psychic follow up can be also ensured through this application.

C. Patient Living Conditions

In the proposed model, a primary step is added to the patient incorporation procedure. This step is to perform an evaluation for the patient's living place at the very beginning of the treatment process. If the patient's living conditions are not adequate, the service might not be offered and the patient will be kept at the hospital. Eventually, some modifications might be required so that the living place stays in conformity with the defined norms. This can lead to

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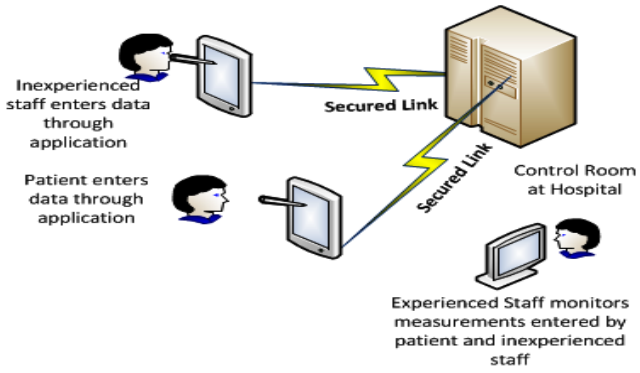

Figure 6. Communication scheme between the various key players.

the identification of some parameters that will be added to the mobile application and measured on an hourly, daily, or weekly basis depending on the parameter.

D. *Devices Maintenance*

In the dedicated program, a tab is designated for the device history. For any measured parameter, the application will ask the staff to enter the tag number of the device used. The tag number is an identification code that permits the system to check in the database for the device history. In the device history, all device maintenance records and control data are archived. The staff will be alerted if the device was not maintained or checked on time. In addition, when an abnormal value is measured, the system will directly check the maintenance date, and it might ask the staff to perform the test once or more, as shown in Figure 7.

IV. CONCLUSIONS AND PERSPECTIVES

As home-based medical services are becoming a reality in today's society, innovative solutions are needed to help offer such services safely and efficiently. Technology plays an important role in ensuring this and in guaranteeing the quality of offered service. This is all the more so when the

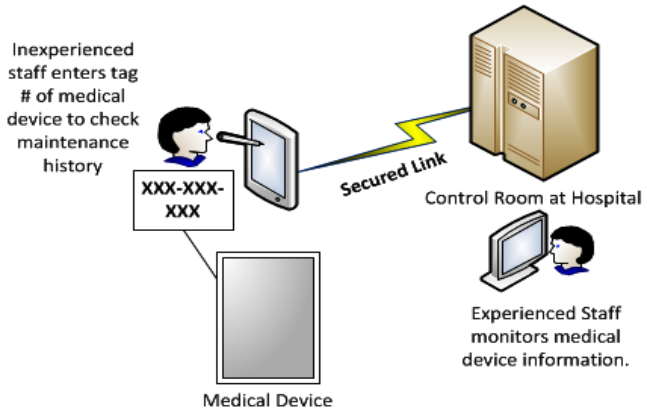

Figure 7. Equipment maintenance tracking system.

services are rendered in a country that markets itself as a destination for health tourism [13]. The proposed model enhances the home-based care service in a rapid and non-expensive manner taking into account key quality considerations. The preliminary implementation of the system – in cooperation with a Lebanese private hospital and a one-day-surgery polyclinic – involved the collection of data comprising vital signs (body temperature, blood pressure, pulse rate), blood glucose, general appearance, and – in limited cases – urination frequency and volume. The collected data produced seed information that was further used to extrapolate into more quasi-real settings. Current raw data (not shown) is in complete accord with the proposed model based on the simulation data shown above.

The use of information and mobile communication technology permits the instantaneous control and support of the medical services rendered at home. Future advanced versions of the application may contain more features designed for people with special needs so that a permanent assistance is ensured. Other features may include tracking of the staff and patients, probably through the usage of global positioning system (GPS) capabilities in the device and an active subscription-based service to broadcast geographical locations. Both technical and geographical tracking can be performed at the same time through this software-based model.

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