Ubiquitous Healthcare Information System: Assessment of its Impacts to Patient's Information

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Abstract

In recent years, healthcare systems around the globe have undergone an increasing pressure to improve healthcare services, for chronic-disease patients as well as the general population, through effective prevention and post-operative care. Growth in governments' healthcare spending which is fuelled by an ageing population, limited financial and human resources plus an increase in the rate of chronic diseases are considered as the reasons for the increase in healthcare organisations' pressure. With advancement in technology, healthcare organisations are now moving towards Ubiquitous healthcare, which is an emerging field of technology that uses a large number of environmental and patients' sensors and actuators to monitor patient's mental and physical conditions.

Once a ubiquitous healthcare service is in place, then the ubiquitous healthcare information system will "always be on" and hence promising better health and well-being for the general population. Despite the presence of various promises that Ubiquitous healthcare brings to individuals as well as to the society, it also introduces myriad challenges potential for serious abuses such as privacy violations, staff discrimination and even threatening security attacks. Based upon extensive review of international literature, this paper investigates the impacts of ubiquitous healthcare information systems on patients, doctors, healthcare organisations and society in general. Thereafter, we analyse if these systems should be used in healthcare or not.

1. Introduction

In recent years, healthcare organisations have undergone an increasing pressure to improve healthcare services for chronic-disease patients, as well as the general population, through effective prevention and post-operative care. This has resulted in the adoption and use of Ubiquitous Healthcare Information Systems (UBHIS) which enable patients to access healthcare services anywhere-anytime [1, 2]. The move towards ubiquitous healthcare is influenced by the growth in healthcare spending fuelled by an ageing population, limited financial and human resources as well as an increase in the rate of chronic diseases such as heart failure, hypertension, obesity, mobility or cognitive impairment and chronic heart and lung diseases [3].

Joo-Hak [4] highlights three UBHIS objectives; these are (i) reducing time loss due to lag; whereby lag is the time required for human-based transmission of information which causes delays that may represent a major reason for revenue loss. Generally speaking, this means reduction in lag would reduce the gap between when data is recorded in a system and when it is available for information processing (ii) reduction in the medium cost (iii) reduction in inaccuracy as it happens in traditional medical flow.

The application and use of UBHIS is expected to enable healthcare professionals to remotely perform real-time monitoring [5, 6], early diagnosis and treatment for potential risky diseases and hence prevent terminal situation as well as assessing post-operative care and body reaction to complex therapeutic drug regimes. To achieve the abovementioned benefits of ubiquitous healthcare, sensitive patient information is collected, processed and stored using UBHIS without patients' obligation. This operation in turn affects patients' privacy, security and trust. Nam [2] argues that, if patients who use ubiquitous healthcare services knew how private, sensitive and valuable the information the devices sent was, they may not be willing to use these systems even though they provide more convenient way to get healthcare services.

Organisation of the paper: Section 2 introduces the reader to Ubiquitous healthcare, which is an application of ubiquitous technologies in healthcare. Section 3 reviews the term patients' information. Section 4 presents various technical and non-technical solutions to the protection of sensitive patient's

information. Section 5 discusses benefits of Ubiquitous healthcare information systems to individuals and the society at large while section 6 analyses and discusses issues associated with ubiquitous information systems in healthcare. Section 7 provides the conclusion of the paper.

2. Ubiquitous Healthcare

Ubiquitous healthcare is an emerging field of technology that uses a large number of environmental and patients' sensors and actuators to monitor and improve patients' physical and mental conditions [7]. The essence of ubiquitous healthcare lies in the creation of an environment where healthcare is available to everyone, everywhere without the dependence on time or location and where technologies enabling ubiquitous healthcare would not only be pervasive but also be assimilated flawlessly in daily lives [8]. With this vision of Ubiquitous healthcare then, tiny sensors, which can either be worn on (by integrating them in patient's clothing); implanted or installed in patients' homes and workplaces (such as in furniture, electrical appliances and construction), are being designed to collect information on bodily conditions such as heart rate, blood pressure and even blood and urine chemical levels. The actuators go further by triggering actions such as the release of small quantities of pharmaceuticals into the bloodstream or the electrical stimulation of brain areas.

As indicated in figure 1, where an elderly person is biochemically and physically monitored, initially these sensors and actuators were mainly used by family doctors to remotely monitor chronic-disease patients and provide general health advice while patients are relaxing at their homes. With the advancement in technology, UBHIS are expected to support greater self-monitoring and care by all individuals. An example of a system that provides self-monitoring service to its patients is HealthPal [9]. It is an intelligent dialogue-based mobile health monitoring system, which aims at supporting elderly who lack Information Technology (IT) skills into monitoring their health condition on a daily basis, in their preferred environments without relying on the assistance of their caretakers. The healthcare professionals then rely on the collected patient information to provide care to their patients. For the patient suffering from diabetes, for example, UBHIS may be used to monitor patient's blood glucose values, store the results in a database and receive feedback e.g. on success of a diet to improve blood glucose balance.

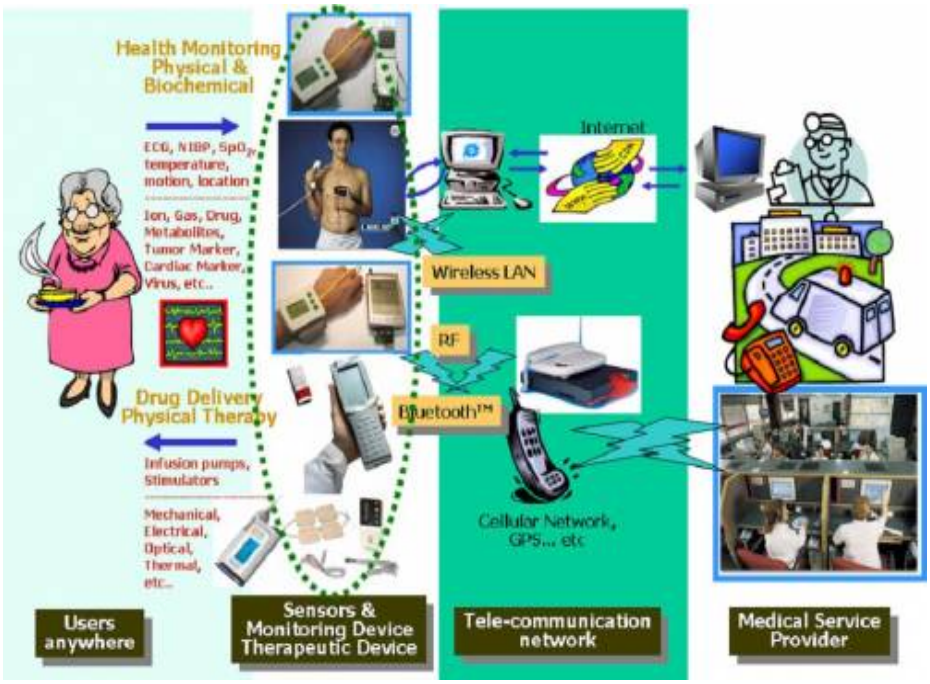

Figure 1. Concept of Ubiquitous Healthcare [10]

These systems may also be used to warn patients as well as healthcare professionals of the vital signs that a problem may occur and therefore help healthcare professionals to provide early diagnosis [11]. Additionally, they may be used to collect data for trend analysis and medical research and hence increasing

efficiency, accuracy and availability of medical treatment [12]. The patient information collected is considered to be highly private and sensitive which requires protection. To ensure that privacy and security of this information is maintained, different technical and non-technical solutions have been proposed and used. In section 3, a review of sensitive patient's information is provided.

3. Patients Information

The advances in mobile devices, wireless networks and context-aware technologies are bringing ubiquitous healthcare into reality. With the help of wireless Personal Digital Assistants (PDAs) and portable computers, for example, healthcare professionals will be able to better communicate with their patients and access updated patient information anywhere and anytime. They can also communicate with their fellow healthcare professionals who are geographically separated while providing care to patients. In Ubiquitous healthcare, these benefits, among others, may only be achieved with the help of collected electronic patients' information.

Although, there is no single agreed definition of the term electronic patient information, which is also referred to as Electronic Healthcare Record (EHR) in Ubiquitous computing, the World Health Organisation (WHO) [13] defines the term, in electronic healthcare's perspective, as the longitudinal health record with entries by healthcare practitioners in multiple sites where care is provided. This definition, however, is insufficient for the ubiquitous healthcare environment, as electronic patient information is automatically captured and sent to UBHIS using sensors which can either be worn, implanted or installed on patient's homes or workplaces. Healthcare Information and Management Systems Society (HIMSS) [14] defines the term further as the longitudinal electronic record of the patient health information generated by one or more encounters in any care delivery setting. As HIMSS does not specifically indicate how the record is captured or gathered then this definition is considered appropriate for our work.

As UBHIS process information in electronic form; by digitising, processing, transmitting and storing this information, then we are making patients vulnerable if accessed by unauthorised users. Therefore, based on the nature of information involved then privacy, security and trust must be maintained as any breach to patient's sensitive information may result in patients' mistrust of the systems, patient harm, social embarrassment or prejudice and may even affect patients' insurability. In addition, with the sensitivity of information involved then there is a need to create policies and laws regarding ownership of user information in ubiquitous healthcare environment. In section 4 we provide a thorough discussion on various legislations as well as access control models proposed for protecting patient's information in ubiquitous healthcare.

4. Accessing Patient Information

Several measures, both technical and non-technical, have been proposed and applied in different countries around the globe to control access to sensitive patient information. For non-technical solutions, different regulations have been formulated. European countries, for example, enacted the Fair Information Practice Principles (FIPP) from 95/46 European Union (EU) Directive to protect privacy of individuals [15]. Among other principles, the FIPP requires healthcare organisations to collect information for specified, explicit and legitimate purposes only and also to obtain patient's consent for the disclosure of such protected information. However, these principles contradict with what really happens in ubiquitous healthcare where patient has no obligation on what information should be collected and what should not be collected (opt-in, opt-out). Again as technology becomes very complex and the need to protect patient's privacy through consent arises; then the question is what will the informed consent look like in Ubiquitous healthcare? [16]

In addition to aforementioned non-technical solutions with their related challenges, different access control models have been proposed. Role-Based Access Control (RBAC) is considered as a consensus of various models proposed to date to protect patients' information. The model's central idea is to use roles to organise access privileges and hence simplifying security administration. Generally speaking in RBAC, roles are considered as the only contextual attribute to control access in these systems. Despite its popularity, RBAC is criticised for its difficulty in setting up an initial role structure and for its inflexibility in rapidly changing environments like healthcare. A pure RBAC solution may provide inadequate support for dynamic attributes such as time of the day and location, which might need to be considered when determining user permissions in a dynamic healthcare environment where users enter and leave abruptly. Currently, researchers are enhancing RBAC with contextual information to support dynamic nature of the environment [17].

Hansen and Oleshchuk [18] propose a Spatial Role-Based Access Control (SRBAC) model, which is an extension of the existing RBAC, to be able to specify spatial constraints on enabling and disabling user roles in ubiquitous healthcare. The SRBAC can be used to constrain the set of permissions available to roles that a

user may activate at a given location. In a similar way, Shin et al. [19] also propose location as contextual information to be considered when controlling access to sensitive patient information in UBHIS. Considering Dey and Abowd's [20] consideration on relevant contextual attributes, the proposed models lack important attributes such as activity and resource which might need to be considered when controlling access to sensitive patient information.

Lee et al. [21] propose the Activity-Oriented Access Control for Ubiquitous Hospital Information and Services. The model's central idea is based on using user's activity to authorise access permissions. A user is allowed to perform an activity if he/she holds a number of satisfactory attributes that is role and assignments under a specified condition such as time and location. This work complies with what Dey and Abowd [20] proposed. Nevertheless, healthcare environment is very rich in context and these are not the only contextual attributes, therefore more work is needed to identify contextual information appropriate for the healthcare environment.

In section 5, positive impacts brought by the adoption and use of ubiquitous systems in healthcare will be discussed.

5. Impacts of Ubiquitous Systems in Healthcare

As highlighted in the introductory section, UBHIS provides various benefits ranging from an individual patient level to the whole society in general. In this section advantages of these systems will be discussed.

One of the main purposes of Ubiquitous information systems in healthcare is to monitor patients at the comfort of their homes [3]. Contrary to Electronic healthcare (e-healthcare), which aims at applying Information and Communication technologies in healthcare, where a patient has to move to the healthcare centre in order to receive care [22], in Ubiquitous healthcare, where ubiquitous healthcare system is considered to always be "on"; working anywhere and anytime [1], patient receives healthcare services at the comfort of their homes. This act then reduces cost, increases efficiency, and ensures availability of medical treatment without considering location of the patient. At the level of the healthcare organisation, ubiquitous healthcare will lead to a change from doctor-centric systems to individual patient-centric operational models.

Technologies are also being developed to support activities of the healthcare professionals, in hospitals and other critical and primary care settings. Examples of these systems include, patient record systems that modify information presented to healthcare professionals based on their current context whereby instead of jotting down notes and entering them later into a computerised system, the use of a Personal Digital Assistant (PDA) allows nurses and doctors to instantly update medical records and files of patients [23]; support for improved information flow between nurses during shift changes [24] and collection of pre-transmission of information from accident scenes to the hospital, as indicated in figure 1. There have also been systems developed for training healthcare professionals in the healthcare environment [25].

Apart from providing the abovementioned benefits to both patients and healthcare professionals, ubiquitous technologies used in healthcare are also being used to improve the performance of patient support devices – such as helping cognitively impaired wheelchair users avoid impact with objects, and especially with other people in the crowded areas, and to provide feedback such as verbal description of objects for visually impaired users.

In addition to specific benefits of Ubiquitous healthcare to different groups, Joo-Hak [1] highlights general benefits of these technologies once ubiquitous healthcare service is in place as

- Availability and accessibility of healthcare knowledge and expertise. The access involves knowledge about the health status of respective person while knowledge may involve the current personal situation, possible relevant past diseases/operations/ therapies, current symptoms or already available diagnosis [3]
- Availability and accessibility of quality healthcare on a more equitable basis to underserved rural and urban areas
- Comprehensive availability of ubiquitous clinical services, regardless of time, specialty, and geographical location
- Availability of ubiquitous healthcare services for new and alternative (non-invasive) medical procedures
- Cost savings for ubiquitous healthcare service providers and patients in procedural, travel, and claim processing costs
- Reduced use of traditional emergency services
- Improved non-emergency services
- Decreased time for non-emergency services
- Timely accessibility of critical information in the event of emergencies
- Increase of service process efficiency [3]
- Increase and improvement in patient relationship management[3]

6. Ubiquitous Healthcare Issues: Analysis and Discussion

Despite the presence of positive impacts of Ubiquitous Healthcare Information systems to the society, as highlighted in section 5, the technologies used also brought various negative effects. This section presents issues pertaining application of ubiquitous technologies in healthcare.

Privacy: Collecting and storing sensitive patient information electronically without patient's obligation increases the potential risk of breaching patient's privacy as well as security and trust. Agranoff [26] defines privacy as "*the claim of individuals, groups or institutions to determine for themselves when, how, and to what extent information about them is communicated to others*".

Clarke [27] highlights several dimensions of privacy, these are:

- **Privacy of the person**: This is concerned with the integrity of the individual's body. Issues include compulsory immunisation, blood transfusion without consent, compulsory provision of samples of body fluids and body tissue, and compulsory sterilisation;

- **Privacy of personal behavior:** This relates to all aspects of behaviour, but especially to sensitive matters, such as sexual preferences and habits, political activities and religious practices, both in private and in public places;

- **Privacy of personal communications:** Individuals claim an interest in being able to communicate among themselves, using various media, without routine monitoring of their communications by other persons or organisations; and

- **Privacy of personal data**: Individuals claim that data about themselves should not be automatically available to other individuals and organisations, and that, even where data is possessed by another party, the individual must be able to exercise a substantial degree of control over that data and its use.

By considering the four dimensions of privacy in ubiquitous healthcare then we can conclude that it is difficult to ensure privacy in ubiquitous healthcare environments. Consider the fourth dimension, for example, in ubiquitous healthcare, patient has no obligation on what information should be collected or not-collected by the sensors, and who should access that information and therefore breaches patient's privacy when accessed by unauthorised user. Again, in ubiquitous healthcare, even personal behaviour of the person is monitored by UBHIS in that case the question to ask ourselves is, in the near future will these systems reshape and modify personal behaviours? If not then why do these systems collect all the information from patients?

Insurance: In the industrialised world, although healthcare is provided on an insurance basis, its funding mechanism varies substantially. Both public and private health insurance companies face some challenges in dealing with new patients' information as they are gathered by the UBHIS. Reflecting on private insurance companies, they often require a physical examination before insuring individuals. The collected information, from physical examination, will determine if an individual will be insured or not. With UBHIS which collects patient's information without his/her obligation then there is a big chance these systems may lead to insurance discrimination [28].

Medical errors: Unlike in electronic healthcare information systems where a healthcare professional can enter records into wrong patient's records and resulting into medical errors propagation [29], in ubiquitous healthcare the case is different. As UBHIS gathers data automatically then what happens when these systems go wrong and provide harm results to patients? Who is to blame and how will the consequences cost be covered in already financially stretched systems? In general when these systems go wrong they can result into patient's mistrust to the systems and hence affecting their adoption and use to the general population.

Equity: In many countries around the globe, the health gap between rich and poor, with its associated expectancy gap, is already significant. For the year 2010, for example, in the United Kingdom, the gap between rich and poor differed by 7% for men and 14% for women [30]. Government responses have suggested the poor to take healthier lifestyle to make up for their economic disadvantage. Apart from taking healthier lifestyle, also there exists more advanced healthcare, in terms of ubiquitous healthcare. With these two options then it is clear that ubiquitous healthcare increase the inequality level in the society as poor people will never afford to opt for the latter alternative.

7. Conclusion

The impacts of Ubiquitous Healthcare Information Systems (UBHIS) to patients, doctors and society in general, are many and varied. Although UBHIS provide many positive impacts, their negative effects should not be ignored as they directly affect patient's privacy and data security.

Since there is no other domain where the importance of obtaining the right information at the right time, irrespective of time and location dependency, is more critical that the healthcare sector then the impacts of these systems need to be valued carefully and consideration should be made to ensure the privacy of patients is maintained. Generally speaking, healthcare organisations should value on what their motive is regarding their move to ubiquitous healthcare against expected benefits.

Additionally, as these systems generates massive amounts of data, which goes hand-in-hand with the increase in life expectancy of rich people then, the question to raise is how will the storage of these records be maintained when this data is rarely transformed into useful strategic decision support resources. All these and other issues need to be clearly highlighted before adopting and using ubiquitous information systems in the healthcare environment.

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