Distributed personal health information management system for teledermatology

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DISTRIBUTED PERSONAL HEALTH INFORMATION MANAGEMENT SYSTEM FOR TELEDERMATOLOGY

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Table of Contents

Acknowledgements	i
Table of Contents	ii
ABSTRACT	iv
List of Figures	vi
List of Tables	viii
CHAPTER 1 INTRODUCTION	1
1.1 Motivation and Overview	1
1.2 Objectives	7
1.3 Contributions of the Thesis	7
1.4 Organization of the Thesis	9
CHAPTER 2 Telemedicine and Applications	10
2.1 Introduction	10
2.2 Definitions of Telemedicine and Associated terms	10
2.3 Telemedicine – Projects	12
2.4 Clinical Applications of Telemedicine	18
2.5 Barriers in the Acceptance of Telemedicine	18
CHAPTER 3 Distributed Personal Health Information Management System	20
3.1 Background	20
3.2 DPHIMS Architecture	21
3.3 Software and Database used for DPHIMS Development	23
3.3.1 .NET Framework	24
3.3.2 Internal Architecture of DPHIMS Server	26
3.3.3 C# Programming – DPHIMS Software Structure.....	28
3.3.4 Using ADO.NET – Querying and Accessing SQL Server	32
3.3.5 Web Service – Data Transfer between Local Server to Main Server	32
CHAPTER 4 DPHIMS & Teledermatology Module Designed for Singapore Nursing Homes	36
4.1 Software Design	36
4.1.1 Patient Web Portal	37
4.1.2 Dermatologist Web Portal	44
4.1.3 Nurse Web Portal	47
4.2 Database Design	49
4.3 DPHIMS Security Features	52
CHAPTER 5 Clinical Trials at the Nursing Home for Senior Citizens in Singapore	54
5.1 Clinical Trial Setting	54

DPHIMS for Teledermatology

5.1.1	DPHIMS Setting	54
5.1.2	Imaging Equipment and Technique	56
5.1.3	Training Sessions for Nurses and Dermatologists	57
5.2	Process Flow of Clinical Trial	58
5.2.1	Patient Enrollment Method to Register with DPHIMS	58
5.2.2	Procedure from Requesting for Referral to Receiving Diagnosis/Treatment via DPHIMS	59
5.2.3	Work Flow at Nursing Home after Receiving Diagnosis/ Treatment Report	60
5.3	Outcome Evaluation of the Clinical Trial	61
5.4	Results and Discussion	63
5.4.1	Telediagnosis Module	63
5.4.2	Distinction in Nursing Staff Attitude in Phase 1 and Phase 2	67
5.4.3	Nurse Survey	70
5.4.4	Time Difference between Diagnosis via DPHIMS and via FTF Consultation	75
5.4.5	Specialist Survey Results	77
5.4.6	System Usage Results	79
CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS		81
6.1	Conclusions	81
6.2	Recommendations for Further Research	83
AUTHOR'S PUBLICATIONS		85
BIBLIOGRAPHY		86
APPENDIX A		92
APPENDIX B		96

ABSTRACT

Teledermatology has proven to be a reliable method to provide specialist consultation for skin diseases remotely without a face-to-face visit. However, for maximum acceptance in any clinical setting, the teledermatology system must be customized to suit that setting. This is to ensure better integration of the new technology with the existing workflow. The aim of the thesis is to develop the distributed personal health information management system (DPHIMS) implementing a store-and-forward teledermatology module customized for Singapore. The thesis also aims to evaluate the effectiveness of DPHIMS with the store-and-forward teledermatology module, when used as a regular tool in a specific clinical setting. A nursing home for senior citizens in Singapore was chosen to conduct the study and a clinical trial was conducted from October 2005-July 2007.

The developed version of DPHIMS enabled the residents at the nursing home to store their comprehensive medical history in electronic form and to obtain diagnosis/treatment plan from the dermatologists without a face-to-face visit. 50 residents suffering from non-emergency skin conditions were included in the study. The nurses at the nursing home performed data entry and regular updates of patient medical records. They also captured the images of the patient's skin conditions using digital cameras with macro lenses. The outcome of the trial was based on the percentage of residents cured (as judged by the resident doctor) after obtaining diagnosis/treatment plan from the dermatologists through DPHIMS. The outcome was also based on the satisfaction of the nursing staff and the dermatologists with the system measured through online surveys. The results

DPHIMS for Teledermatology

of the study indicate that 67.6% of the residents were cured by obtaining diagnosis/treatment plan via the distributed personal health information management system. The system reduced the need for a face-to-face visit with the dermatologist, provided medical help to residents sooner than a regular clinic visit and was more cost-effective. Positive outcomes resulted from analysis of the online surveys indicating that the nursing staff and dermatologists were very satisfied with the system. The nurse aides as compared to the staff nurses were found to manage the system more effectively with greater involvement. Non-technical issues arising from within the nursing home inversely affected the usage and acceptance of the system by the nursing staff. Addressing and solving these issues enabled the system to merge seamlessly with the existing workflow of the nursing home. From this clinical trial it can be concluded that DPHIMS together with the store-and-forward teledermatology module can successfully manage the skin conditions of the residents at a nursing home. The system has improved the perceived quality of healthcare offered to the residents of the nursing home. But inferring from the various issues originating during the course of the clinical trial, it is observed that in order to implement the system as a regular tool at the nursing home, a background study has to be made on the needs of that specific clinical setting such that the system can merge with the existing nursing home workflow introducing only least disruption.

List of Figures

Figure 1. Classification of healthcare delivery2

Figure 2. Distributed diagnosis and home healthcare20

Figure 3. Distributed architecture of DPHIMS22

Figure 4. Software architecture for .NET framework24

Figure 5. DPHIMS 3-Tier server architecture26

Figure 6. Outline of web form grouping structure in DPHIMS28

Figure 7. Class structure outline for patient portal29

Figure 8. Code snippet for display of medications list on form load30

Figure 9. Class structure outline for nurse portal31

Figure 10. Class structure outline for dermatologist portal31

Figure 11. Code snippet for implementing web service34

Figure 12. Web service client authentication35

Figure 13. Registering of new patient on login page36

Figure 14. Patient portal - pre-screening page37

Figure 15. Patient portal – skin condition description page38

Figure 16. Patient portal – home page38

Figure 17. Patient portal – non-editable, printable version of health information39

Figure 18. Patient portal – other health problems40

Figure 19. Patient portal – allergies health problems40

Figure 20. Patient portal – digital image upload page41

Figure 21. Code snippet for image upload42

Figure 22. Patient portal – additional information page43

Figure 23. Patient portal – medical information upload page43

Figure 24. Dermatologist portal – home page44

Figure 25. Dermatologist portal – referred patient list for diagnosis/treatment45

Figure 26. Dermatologist portal – viewing patient medical history 45

Figure 27. Dermatologist portal – viewing patient diagnosis rendered previously46

Figure 28. Dermatologist portal – viewing selected patient information46

Figure 29. Dermatologist portal – second opinion page47

Figure 30. Nurse portal – home page48

Figure 31. Nurse portal – list of patients managed by nurse 48

Figure 32. Nurse portal – internal emailing system49

Figure 33. DPHIMS database structure in the main server50

Figure 34. Type casting data before transfer using ADO.NET51

Figure 35. Patient enrollment process into DPHIMS during Phase 258

Figure 36. Process flow of DPHIMS59

Figure 37. Work flow after obtaining diagnosis/treatment plan from dermatologists via DPHIMS in Phase 261

Figure 38(a). DPHIMS system satisfaction survey questions for nurses...61

Figure 38(b). DPHIMS user experience survey questions for dermatologists62

Figure 39. Summary of issues faced by nurses in Phase 1, solved in Phase 267
Figure 40. Phase 1 survey results on system satisfaction.70
Figure 41. Phase 2 survey results on system satisfaction.70
Figure 42. Computer skills vs. independent use of DPHIMS.....72
Figure 43. Time spent in obtaining a diagnosis during a regular clinic visit76
Figure 44. Time spent in obtaining a diagnosis using DPHIMS.....76
Figure 45. Dermatologist survey taken in the year 2005.77
Figure 46. Dermatologist survey taken in the year 2007.77

List of Tables

Table I. Nurse demographics55
Table II. Diagnosis status before DPHIMS64
Table III. Post-diagnosis status (1st July 2007)65
Table IV. Disease categories (first time diagnosis only, follow-ups not included)66

CHAPTER 1 INTRODUCTION

1.1 Motivation and Overview

Telemedicine is defined as the delivery of health care over a distance [1] [2]. It can also be delineated as the use of tele-communication technologies to provide health services over a distance [3]. In a typical setting for telemedicine, the patients have no direct contact with the doctors or nurses unless necessary or during emergencies. Telemedicine services include obtaining diagnosis/treatment plan online, communicating with the specialist via videoconferencing, general physician requesting for specialist opinion, monitoring vital signs (e.g. ECG signals) of patients etc [4]. For example people with non-emergency heart conditions will have to go for regular checkups. This may be time consuming and inconvenient especially if they are working professionals. An alternative to visiting the hospital to get their heart reading is to record the ECG signals using off-the-shelf devices and transferring it to the doctor via email. This is a typical scenario of telemedicine in practice. One such application of telemedicine is teledermatology. Teledermatology is the practice of telemedicine for dermatology using available communication and information technology [5]. It has emerged as a more prominent part of telemedicine apart from teleradiology and telepathology [1-3]. Various studies have been performed on the efficacy of teledermatology and they have concluded that these consultations are accurate and reliable as compared to live clinic or face-to-face (FTF) visits [1] [6-10].

DPHIMS for Teledermatology

Figure 1. Classification of healthcare delivery

Teledermatology has two different delivery platforms, the synchronous teledermatology and the store-and-forward (S&F) teledermatology. In synchronous teledermatology, the patients and the dermatologists are separated by distance, and consultation takes place over live videoconferencing. This method is more costly to set up as it uses expensive video conferencing software and systems, needs reliable internet services with high bandwidth, and requires more coordination. The logistics involved is similar to a FTF consultation where the dermatologist has to set aside a specific time which is convenient for both himself and the patient. In S&F teledermatology, the consultation provided is independent of both distance and time. In the simplest case, communication between the dermatologist and the patient can be done via emails containing the medical history and with digital images sent as attachments. The dermatologist provides consultation at a convenient time (may not be immediate as is with FTF visit) without having an FTF meeting with the patient [5]. Hence, compared to

DPHIMS for Teledermatology

synchronous teledermatology, this method offers a low-cost alternative to teledermatology although the diagnosis results and treatment plan via S&F teledermatology are not available immediately. But Whited [11] reported that a greater percentage of patients in S&F teledermatology were referred back to the hospitals for a FTF consultation as compared to synchronous teledermatology. Hence in urban areas with a small geographic distribution (e.g. Singapore), where cost effectiveness is of greater concern than distance and the distance between the patients and the hospitals is small, S&F teledermatology is better suited.

Singapore is a small country as measured by its area 692.7 square kilometers. The baby boomer generation in Singapore will reach 65 years in 2012 and the proportion of the elderly will increase rapidly over the next 20 years. With the increase in the ageing population, the cost of healthcare has also been on the rise. In 2005, the healthcare cost in Singapore accounted for 3.8% of GDP, an increase from the 3% of GDP in the year 2003 [12]. Currently, it has 7% of its resident population over the age of 65 and this percentage is expected to rise to 18% by the year 2030. The old age dependency ratio for every 100 residents is estimated at 11.8 [13]. The number of people on rehabilitation from surgery, non-acute chronic diseases (e.g. chronic types of skin diseases, cardiovascular disease, rheumatism, etc.) is expected to increase significantly [14]. A major percentage of the elderly suffer from these chronic disease conditions. These conditions require frequent medical attention and subsequent visits to the doctors. This would not only increase personal healthcare costs but would also contribute to a substantial increase in the healthcare costs of Singapore.

There are 51 nursing homes in Singapore [15] with a 90% occupancy rate. Most of the nursing homes in Singapore have computerized only the

DPHIMS for Teledermatology

administrative system (billing, salary payment etc). The patient history and medical records are still recorded on paper and stored as bulky case notes. The elderly in the nursing homes have a high incidence of skin conditions [7]. They suffer mostly from infectious skin diseases like scabies and other conditions like pressure ulcers, seborrheic keratosis and xerosis [16]. Due to the inherent structural changes in aging skin, these elderly people are more vulnerable than the general population to contract significant cutaneous disorders, such as pressure ulcers and skin infections [7]. Hence, skin diseases are a common and inevitable consequence of ageing [17]. If not treated at early stages or left untreated, they can lead to significant morbidity and expensive hospitalizations [7].

A study on the residents of the nursing home [18] showed that about 75.2% could not support themselves financially. Hence getting specialist care at early stages of their skin conditions is not economically viable to this population, thus the treatment plan provided by the resident doctor at the nursing home has to suffice. The resident doctor usually comes to the nursing home twice or thrice a week for performing regular checkups on the residents. But receiving a dermatologist's care is often important for an accurate diagnosis as the management of the skin conditions performed only by a primary care physician is suboptimal [19]. Apart from their skin and financial problems, the elderly in the nursing home who are aged 65 years and above suffer from age related difficulties and health problems. A good percentage of them are bed-bound/paralyzed or suffer from dementia. Due to their old age, traveling to hospitals and waiting in the hospital queues could be quite tiresome and uncomfortable for them. Most of the time, they are not able to travel independently to the hospitals and require additional assistance. Hence, every time they travel to the hospitals, a nursing aide

DPHIMS for Teledermatology

or a helper at the nursing home would have to accompany the elderly. An ambulance would also have to be arranged by the nursing home for the purpose of this travel. Thus, this travel would also take up lot of resources and logistic support from the nursing home.

Considering the above trends associated with the aging of the population and rising healthcare costs, various initiatives are being taken to provide effective and affordable healthcare with the goal of making an improvement in the quality of life for the senior citizens without increasing the overall healthcare costs. Distributed Diagnosis and Home Healthcare (D2H2) is an initiative designed to tackle the current problems in healthcare and to accommodate future changes and trends by transforming the delivery of healthcare from a central, hospital-based system to one that is more patient-centered, distributed and home-based. D2H2 also aims to benefit patients by improving the quality and convenience of care and controlling healthcare cost thus leading to increased access to affordable and effective healthcare. The Distributed Personal Health Information Management System (DPHIMS) was developed to contribute to the realization of the Distributed Diagnosis and Home Healthcare (D2H2) vision through an international collaboration project known as Singapore-University of Washington Alliance in Bioengineering (SUWA) funded by Singapore's Agency for Science, Technology and Research (A*STAR).

DPHIMS is based on the concept of PHIMS developed at the University of Washington (UW) [20] [21]. DPHIMS customized for teledermatology has been developed for use at the nursing homes in Singapore. DPHIMS aims at providing a secure and scalable personal electronic health record management system for the nursing home by implementing S&F telemedicine to provide off-line diagnosis for

DPHIMS for Teledermatology

various non-emergency chronic diseases [22]. The key difference with the hospital electronic medical records system (EMR) is that the EMR's are owned by the providers and the patients do not have the right to access these records [20] whereas using DPHIMS, the records are owned and managed by the patients or their caretaker. The patient/caretaker can make a request to the dermatologist for diagnosis and treatment. The DPHIMS enables the patient/caretaker to store, maintain and update the comprehensive medical record of the patient. The fact that the dermatologist is purely dependent on only the images and the medical history to provide diagnosis highlights the necessity for the availability of comprehensive medical records of patients. DPHIMS achieves this by offering an extensive database of the electronic patient records enabling the dermatologist to get clear and complete information on the medical background of the patient. Giving the patient's medical history along with digital images is of importance for diagnosis as previous researchers showed that accuracy of diagnosis increased by at least 3-10% when the patient's medical history was provided along with the digital images [7][23].

Thus DPHIMS with the teledermatology module is expected to have a positive impact on the management of skin conditions of the elderly in the nursing homes. A clinical trial was performed at a nursing home for senior citizens in Singapore to evaluate the acceptance and usage of the DPHIMS system by the nursing staff, the resident doctor and the dermatologists. The study does not aim to test the accuracy of S&F teledermatology; rather it observes the need and efficiency of DPHIMS with S&F teledermatology in managing skin diseases of residents at nursing homes. The study gauges whether there is an improvement in the perceived quality of healthcare offered to these residents. It also evaluates the

DPHIMS for Teledermatology

difficulties and obstacles in introducing such a system into the everyday workflow of the nursing home.

1.2 Objectives

The objectives of this project are as listed below.

- Design and develop the DPHIMS system with the teledermatology module using a distributed architecture and customized for Singapore, enabling patients to own/update their own personal medical records and provide special permission for dermatologists to access their records for obtaining diagnosis/treatment for their skin conditions.
- Deploy the system for clinical trial to evaluate the efficacy of the system when used as a regular tool in a specific clinical setting. A nursing home for senior citizens in Singapore is chosen to conduct the study. The nursing home was considered as a test bed for this project due to the following two reasons. There is high occurrence of skin conditions among the elderly at the nursing home and most of them are unable to seek regular consultation from a dermatologist due to their economically disadvantaged status.

1.3 Contributions of the Thesis

The contribution of this thesis includes

- The developed version of the DPHIMS system with the teledermatology module customized for Singapore. Using distributed architecture which enables easy expansion of the DPHIMS network to other nursing homes and to other chronic disease conditions like telerehabilitation, telepsychiatry etc. An extensive database following the rules of the relational database management

DPHIMS for Teledermatology

system, designed to store the patient data, the digital images of the patient's skin conditions, the diagnosis/treatment reports from the dermatologists, internal emails between nurses, dermatologists and patients. Separate web-portals for the patients, nurses and dermatologists to perform data entry, upload images, check for diagnosis, provide diagnosis etc. Specific tools designed in the patient web-portal to screen the patients before registering with the DPHIMS system to ensure that they suffered only from non-emergency skin disease conditions. Security measures like using the web-portal over the secure socket layer (SSL) to protect patient data.

- Obtaining approval for the clinical trial after undergoing a full Institutional Review Board and a Domain Specific Review Board (IRB/DSRB) evaluation. The successful launch of the clinical trial for DPHIMS at nursing homes for senior citizens in Singapore on October 2005 till July 2007. The real-time usage of DPHIMS by the two dermatologists from the National Skin Centre for providing diagnosis and treatment for these residents for the clinical trial period.

The clinical trial brought out the need for a system like DPHIMS at the nursing home for senior citizens to supplement their existing healthcare model resulting in an improvement in the perceived quality of healthcare offered to these residents. The clinical trial helped to show the DPHIMS users at the nursing home the convenience of having a patient owned electronic medical record system as compared to the bulky case notes containing medical information. The clinical trial also uncovered various issues revolving around the introduction of a new system into the existing workflow of the nursing home. Solutions and alternatives to address these issues are discussed later in this thesis. An economic model which

DPHIMS for Teledermatology

may help in the introduction of DPHIMS as a regular tool at the nursing homes is proposed.

1.4 Organization of the Thesis

This report is organized as follows.

Chapter 2 introduces and defines telemedicine and associated terminologies.

Projects in telemedicine are reviewed. Clinical applications and barriers to acceptance of telemedicine are highlighted.

Chapter 3 explains in detail the DPHIMS architecture and the supporting technologies used.

Chapter 4 describes in detail the software design and the database structure of DPHIMS and the teledermatology module designed for the nursing homes in Singapore.

Chapter 5 elucidates the launch of the clinical trial of DPHIMS customized for teledermatology at the nursing home in Singapore. The design of the clinical trial and its outcomes are analyzed in depth.

Chapter 6 concludes the report providing a summary of the clinical trial.

CHAPTER 2 Telemedicine and Applications

2.1 Introduction

The healthcare industry in most parts of the world is facing major issues including rising healthcare costs, increasing demand for hospital beds, lower accessibility to healthcare for rural and underserved population, difficulties in retaining physicians/specialists in rural areas etc [24][25]. Telemedicine has the potential to aid the existing method of healthcare delivery by improving accessibility to healthcare centers and professionals, improving quality of healthcare offered to the rural or underserved population and reducing costs of healthcare [24].

2.2 Definitions of Telemedicine and Associated Terms

There are numerous ways in which telemedicine has been defined. The American Telemedicine Association (ATA) [4] defines telemedicine as

“the use of medical information exchanged from one site to another via electronic communications to provide clinical services and to improve patients' health status.”

Bashshur [24] defines telemedicine as

“telemedicine is viewed as an innovative system of care that can provide a variety of health and educational services to its clients unhindered by space and time.”

and as

DPHIMS for Teledermatology

“telemedicine involves the use of modern information technology especially two way interactive audio/video telecommunications, computers and telemetry, to deliver health services to remote patients and to facilitate information exchange between primary care physicians and specialists at some distances from each other.”

Other definitions of telemedicine are listed below. Hu [26] defines it as

“Broadly, telemedicine refers to the use of information and telecommunication technologies to distribute information and/or expertise necessary for healthcare service provision, collaboration and/or delivery among geographically separated participants, including physicians and patients.”

and Coeria [27] defines it as

“Telemedicine is the exchange of information at a distance, whether that information is voice, an image, elements of a medical record, or commands to a surgical robot. It seems reasonable to think of telemedicine as the remote communication of information to facilitate clinical care.”

Bashshur has included educational services as a part of the definition of telemedicine but most of the other definitions provide a very narrow scope for telemedicine. Hence the term telehealth was introduced to include not only telemedicine related activities but also educational services, nursing call centers etc [4][28]. Thus the term telehealth covers a wider range of healthcare or health related services as compared to the term telemedicine.

Other terms closely associated with telemedicine are e-Health and teleconsultation. E-Health can be explained as the application of information technology where health services and information is delivered through internet

DPHIMS for Teledermatology

medium or related technologies [29]. Teleconsultation can be elucidated as providing purely consultation by a health care professional using telecommunication and information technology [30]. Thus from the definitions it is observed that the various terms are closely connected to one and other, the only distinction being in the number and type of healthcare or healthcare related services involved.

2.3 Telemedicine - Projects

The concept and practice of telemedicine has been around for more than 50 years [25] starting from the late 1960's in Nebraska Psychiatric Institute, USA [24]. Numerous telehealth, telemedicine projects were initiated but the prevalence of these projects was mostly restricted to the American, Australian and European continents. Telemedicine in Asia began with full intensity only during the latter part of 1980. At present, telemedicine projects have burgeoned all over the world and telemedicine is being used right from providing long distance diagnosis to physician-patient education and nursing informatics.

Telemedicine was initiated by the need to constantly monitor the physiological signals and other vital signs of people staffed in outer space by NASA [24][31]. Around the same time, in the early 1960s, the Nebraska Psychiatric Institute in Omaha implemented an interactive video link with the Norfolk state hospital for education and for consultation between specialists and general practitioners [24][25][31]. Also in the same year, Montreal and Quebec launched their teleradiology project enabling asynchronous transfer of images to radiologists in different parts of the continent [25]. During the late 1960's, another project was launched where patients at the Logan Airport in Boston were

DPHIMS for Teledermatology

diagnosed and medicated by a physician at the Massachusetts General Hospital (MGH) synchronously. The results of the project indicated a good accuracy of diagnosis by the remote physician but low confidence level [28]. Another project was initiated with the MGH and the Veteran's Administration Hospital in Massachusetts to provide psychiatric services via telemedicine [32].

Various other projects were established and tools were developed to address important issues with respect to telemedicine, namely, the usage of the technology for different medical specialties and in reducing healthcare costs, acceptance by provider, physician and patients, accuracy of remote diagnosis, providing education etc. The project at the New York City health services administration clustered local pediatric centers with a hospital to render remote diagnosis via two-way television. Another project offered remote psychiatric services to the City's prisons. These projects aimed at increasing the patient volume and subsequently reducing unit service costs [32]. A few projects were started or existing project scopes like the Vermont network which links two hospitals were expanded to include medical education via telemedicine [32]. There were also analysis tools developed to prove the effectiveness of telemedicine in reducing the referral rates. One such tool was the 'patient trajectory analysis' which maps the path taken by patients to receive medical care to analyze the impact of manpower/technology combination for a healthcare setting introducing telemedicine [33]. Using this tool on the target population, the researchers observed that 28.7% of referrals could be averted using telemedicine [33].

The earliest efforts in telemedicine were considered mostly unsuccessful as the projects were unable to self-sustain once the funding was withdrawn. Even

DPHIMS for Teledermatology

though results of patient and provider experience looked positive, the technology could not merge and be accepted by the organization as an alternative mode of healthcare delivery [24]. The situation was attributed to insufficient development of information technology during this period, inexperience of medical providers with usage of new technology and the impatience of funding agencies to see immediate results, resulting in their withdrawal from the program [24].

The late 80's saw an inception of a fresh set of efforts on telemedicine. With the extraordinary speed of growth of information technology and the simultaneous reduction of its costs resulted in desktops and broadband being used right from big corporations to homes. In the present day world most of the people in the medical sector including physicians and nurses are using computers on a daily basis. Computers have been integrated with the hospitals and are being used for administrative purposes like billing, for storing patient medical records and for providing medical education. Thus a lot of telemedicine projects now enjoy low cost and faster telecommunication technologies. The growth and advancement of information technology gave way to new issues relating to transfer of data, storage of medical information and internet security. Apart from teleconsultation and medical education, telemedicine started to branch out to setting up hospital appointments, developing electronic medical records to store patient records and designing and building portable medical devices which can be used from the homes of patients. For example, Hong Kong has implemented patient cards which can hold patient medical data and personal information, another form of implementing portable and accessible electronic medical records [35]. Thus the internet started to play a very prominent role in the development of the second generation telemedicine. The following paragraph denotes a few of the

DPHIMS for Teledermatology

telemedicine projects and efficacy studies performed around the world from the early 90's till 2007.

Numerous telemedicine projects were set up in the USA. In 2000, a self sustaining multisite telemedicine programs was set up by the company VISICU, INC (Maryland, USA) with the Sentara Healthcare's intensive care unit. Initial cost studies indicated a 27% decrease in hospital mortality and 17% and 13% decrease in ICU and hospital length of stay respectively. 30 more sites, each with their own remote care team were included in the program [36]. Another project in the US was from the clinical nutrition department in New York which conducted nutrition counseling for six Bassett Healthcare clinics with the aid of a registered dietician via interactive videoconferencing. The program was a good success and had resulted in increased appointments, decrease in cancellation and regular follow up along with a high degree of satisfaction among the patients due to time and travel reduction [37]. Another interesting project was a telemedicine link between USA and Japan to enable correct diagnosis and treatment for intractable epilepsy and research of higher cerebral function which concluded that with the digital EEG data, seizure patterns medical images, accurate diagnosis can be made through live discussions [38].

Australia and Japan were the next two biggest settings for telemedicine projects. In Australia, in 2000, a telepediatric service was established with the Royal Children's Hospital, Brisbane to provide pediatric services to Queensland. In addition, a routine clinical program provided outpatient treatment to 31 regional/remote hospital in Queensland for children suffering from post-acute burns via videoconferencing. The program enabled remote areas access to specialists on a regular basis and families were greatly satisfied with the service

DPHIMS for Teledermatology

[39]. Other telemedicine sites included Kuwait, the African continent, Ireland, Antarctica etc. A national telemedicine project in Africa was first set up in 2001 by RAFT and currently it has successfully been in use for over 5 years. Apart from connecting within the African continent, it also provides connection with Europe. The RAFT project enables distance learning, teleconsultation including telepathology, teleradiology and teledermatology, and personal exchanges between healthcare personals. Problems pertaining to the digital divide in using the healthcare system need for localization of medical content and improved collaboration between various countries were unearthed [40]. Antarctica which is one of the remotest parts of the world has been the test bed for various telemedicine programs. One such service involved the people at the McMurdo Station receiving telemedicine consultation from specialists situated elsewhere in the world. Telemedicine proved indispensable and helped obtain specialist care during many emergency situations and also for regular non-emergency consultations [41]. Thailand had also launched its nationwide telemedicine project in 1999 by the ministry of public health with the objective of linking major Bangkok hospitals with district hospitals and rendering medical services and education to rural areas of Thailand [35]. The north western and western health boards of Ireland have 11 telemedicine services including tele-psychiatry, tele-plastic surgery, tele-radiology, tele-neurophysiology etc. They used both the synchronous and store and forward modalities. On a survey done in 2003, the users of the telemedicine network said that motivation, support and flexibility to expand provider's work scope were important to a telemedicine project's continuation. They also mentioned that these projects had a positive impact on patients especially in reducing their travel [42]. Taiwan also has a number of

DPHIMS for Teledermatology

telemedicine projects which provide medical education and teleconsultation for various diseases. Non medical background students were provided with medical education sessions by The National Taiwan University College of Medicine using videoconferencing. They also developed a web based application in collaboration with Formosan Medical Association and Taiwan Association of Family Medicine to provide continuing medical education for the doctors. The National Taiwan University provided teleconsultation services to the Chinshan health station in rural Taipei County. The Veterans General Hospital Taipei and National Cheng Kung University Hospital connected with the hospitals of isolated islands Kin-Men and Peng-Hu and the Tri-Service General Hospital connected to the island community hospital in Ma-Tsu both provided teleconsultation services [43].

Efficacy studies on various clinical applications of telemedicine were also performed. One of them involved the outpatients attending the diabetics clinic of Grenoble University Hospital and Toulouse Rangueil University Hospital, France. The outpatients were coached rigorously through a GlucoNet system using SMS during their follow-up period. The result of the study showed that patients enrolled in the SMS sequence tended to improve glycemic control compared to patients following conventional follow-up [44]. Another study was performed on patients attending clinics in Meekatharra, Mount Magnet, Cue and Wiluna, in the Mid-West region of Western Australia for diagnosing ear diseases in children using digitized still images of the eardrum. The study concluded that there is good agreement with diagnosis made via telemedicine if high quality digital images along with comprehensive patient medical information are provided [45]. In a study done in Kuwait, published in 2003, a fundus camera was used to capture digital images of the retina and the images were used by retinal specialists to

DPHIMS for Teledermatology

diagnose eye defects. The study showed that digital imaging can be used to diagnose specific eye defects [46].

2.4 Clinical Applications of Telemedicine

Clinical applications of telemedicine describe the usage of telemedicine techniques to perform consultation/diagnostic services for specific areas like radiology, dermatology, pathology, psychiatry etc. The applications of teleradiology and telepathology include providing consultation to rural areas, requesting and obtaining expert/second opinion and continuing medical education. But these are more of a hospital based service as the equipments involved in teleradiology (e.g. MRI machine) and telepathology (e.g. light microscope) are very expensive and need expert handling. On the other hand the equipment used in teledermatology (e.g. digital or web camera), telepsychiatry (e.g. web camera), telerehabilitation (e.g. video camera) etc are inexpensive and can be operated by laymen. Hence these applications are not restricted to only hospitals but can be used to provide home based consultation and diagnostic services.

2.5 Barriers in the Acceptance of Telemedicine

In the present day world, there is a steep increase in the number of telemedicine programs and projects set up around the world. Even though certain aspects of telemedicine like teleradiology have become accepted as part of the healthcare delivery system, telemedicine is still not used as an alternative to traditional healthcare. Providers are very much concerned about interstate and inter-country licensing and about the medico legal issues arising when providing consultation via telemedicine. Insurance companies have not come up with a

DPHIMS for Tele dermatology

standard policy for reimbursing diagnosis/treatment taken through telemedicine and any complications arising from that. Policies for reimbursing physicians and nurses who provide medical services via telemedicine have to be standardized for all telemedicine projects. With the aid of the government, insurance companies and clear medico-legal law, telemedicine would be more appealing to healthcare providers and patients. This would also enable telemedicine projects to become more profitable and thereby self sustaining.

CHAPTER 3 Distributed Personal Health Information Management System

3.1 Background

Distributed Diagnosis and Home Healthcare (D2H2) is a new paradigm for healthcare delivery. The aim of D2H2 is to decentralize the delivery of healthcare from a hospital based system to more of a home based system. The realization of D2H2 includes development of home-usable and portable medical devices like Electrocardiogram (ECG) capture devices, telecommunication technologies like the broadband and world wide web, intelligent decision support systems and single platform to integrate these various components [47].

Figure 2. Distributed diagnosis and home healthcare

PHIMS was developed by UW as part of an effort to actualize the D2H2 vision. The generalized PHIMS is defined in [20] as “A web-based repository that contains patient medical information, such as their general information, insurance, family health history, allergies, surgeries *etc.*” PHIMS provides a platform to store your personal data and health records. But unlike the hospital medical record

DPHIMS for Teledermatology

system, it is patient-oriented and is developed to enable each individual to own and have access to their own personal medical records [20]. PHIMS and the associated Facilitated Accurate Referral Management System (FARMS) were initially tested at the Orthopedics and Sports Medicine's Bone and Joint Center at UW in 2002 [21] and were deployed as a regular clinical tool in 2004. Later in 2004, PHIMS/FARMS were deployed at the Everett Housing Authority, Seattle; a low cost housing board to conduct another study on the usefulness of the system to its residents [48]. The system was deployed as a clinical tool at the Regional Heart Center, UW Medical Center for conducting specialist referrals [49] and at the Mental Health Clinic, Seattle for providing an alternative method for students at UW to obtain psychiatric care [50].

DPHIMS was adopted from the concept of PHIMS and is customized for the Singapore context [51]. DPHIMS was also tailored for use at the local nursing home for senior citizens. As per the requirement of the nursing home, a teledermatology module was designed to be used along with DPHIMS to perform diagnosis and treatment for the skin conditions of the home's residents.

3.2 DPHIMS Architecture

DPHIMS uses a distributed architecture-based approach. DPHIMS is distributed in the sense that certain modules run on local servers and the rest runs on the main servers. The main server and the local servers are placed at different physical locations. The advantages of implementing the distributed architecture are illustrated using Figure 3. Scalability is one of the major advantages of this type of architecture. Scalability is described in [52] as the "ability of an application server, such as a Web server, to grow to support a large number of

DPHIMS for Teledermatology

concurrent users without degradation of performance and to how well a hardware or software system can adapt to increased demands”. Scalability also implies the ease with which an existing system can be expanded to include new applications.

Figure 3. Distributed Architecture of DPHIMS

Let each of the local servers shown in Figure 3 be placed at individual nursing homes and the nursing homes be at different locations. With this architecture, additional nursing homes can be included with ease and the nursing homes can run more than one application of telemedicine, say teledermatology and telerehabilitation. The nursing home can also access the local server through workstations through their Local Area Network (LAN) and they need not walk to the server room to perform the necessary operations. As the number of nursing homes increases, extra servers can be connected to the main server to balance the

DPHIMS for Teledermatology

load. In this manner the entire network can be expanded and extra load can be handled thus ensuring that the system is scalable.

The other advantage of this architecture is that it can prevent direct access to the local server by external users (e.g. users not within the nursing home LAN). This is achieved by transferring the necessary data (e.g. resident medical information etc.) from the local server to the main server. The external users (e.g. specialists) can access the main server to view this information for a specific period of time after which the data is purged from the main server. This process flow allows information from the local server to reside in the main server only for a temporary period, thus enhancing protection of local server data.

3.3 Software and Database used for DPHIMS Development

The DPHIMS system is implemented on a Dell PowerEdge 1750. The servers run on the Microsoft Windows 2003 operating system with Internet Information Service (IIS) version 6. The web portals are designed and developed on the .NET platform using ASP.NET and the programming language C#. The database used by DPHIMS for storing medical records and other details is the Microsoft SQL 2000 server technologies. The Microsoft web service is used to transfer data using HTTPS, i.e. Hypertext Transfer Protocol (HTTP) over a Secure Socket Layer (SSL) between the local server and the main server. Though the encryption increases the size of the data to be transferred, it is highly secure compared to using separate File Transfer Protocol (FTP) servers. The web pages can be best viewed using Internet Explorer.

3.3.1 .NET Framework

The .NET framework is an extensive programming platform which is a part of the Microsoft Windows component. ASP.NET, ADO.NET etc are parts of the .NET framework which have to access the .NET framework classes to develop web applications and web services. The .NET platform was chosen as it provides a managed environment for developing, deploying and integrating as many as 25 .NET languages including C#, VB.NET, and Jscript.NET. It also allows web applications to integrate seamlessly with the database server. The software architecture of the framework is shown in Figure 4.

Figure 4. Software architecture for .NET framework

The .NET framework is the middle layer between the programs and the operating system. The core advantage of this framework is the Common Language Infrastructure (CLI) which enables applications to be written in any language preferred by the programmer. This allows easy project management and future

DPHIMS for Teledermatology

development by different programmers. The CLI also performs tasks pertaining to memory management, threading, enforcing thread safety etc. There are two components to the CLI, the Common Intermediate Language (CIL) and the Common Language Runtime (CLR). Together they translate the program codes to machine readable code. The Base Class Library (BCL) serves as the building block of .NET applications and includes functionalities like networking, database access, security, multi-threading etc. BCL also consists of a rich client side and server controlled client-side classes for developing the Graphic User Interface (GUI). The classes in ASP.NET are used to provide a scalable sever side environment for the codes which need to be executed during runtime. These codes are also termed as managed codes. Managed Codes target the runtime whereas unmanaged codes do not. The classes in ADO.NET are used for providing access to RDBMS like SQL server and interfaces to extensible markup language (XML). Apart from the CLI, the framework offers other benefits relevant to the development of the DPHIMS application. These are listed below.

- The object-oriented programming allows the reuse of developed modules and APIs. The problem with DLLs where older versions of applications do not run properly on newer versions is also avoided. Here, each version of the application uses components from that version enabling co-existence of older and newer versions.
- Unauthorized access by clever guessing of passwords through buffer overruns is prevented by verifying the type safety of the codes at the CLR stage, i.e. an 8 byte cannot be accessed as a 16 byte value. This is achieved by checking the start address of the code execution during CLR thus preventing execution of codes from arbitrary locations.

DPHIMS for Teledermatology

- There is an automatic memory management where the objects are automatically disposed at the end of their scope. This ensures that the problems like memory leaks and invalid memory references which were major issues while coding with C or C++ languages are completely resolved.
- The consistent handling of errors and exceptions irrespective of the coding language or database used.
- The ease of integration of third party components with the .NET classes enables expansion of the application to other domains. For example, Video streaming API's for telerehabilitation or mobile devices like tablet PCs or PDAs could be easily integrated with the existing application.

The framework also provides a wide variety of classes for web page development with user and role based access, session remembrance, input validation etc.

3.3.2 Internal Architecture of DPHIMS Server

The DPHIMS web server is built using the 3-Tier architecture as shown in Figure 5.

Figure 5. DPHIMS 3-Tier server architecture

Tier 1 represents the presentation layer of the architecture. The user interface of DPHIMS is coded using ASP.NET. The ASP.NET controls and Hypertext

DPHIMS for Teledermatology

Markup Language (HTML) are used to design the interface. For example, consider the scenario of an existing patient providing username and password at the login page. The patient accesses the DPHIMS hosted web pages through the internet via HTTPS. HTTPS transmits the entered information in a secure, encrypted format. Tier 2 represents the application layer of the architecture. Here the compiled code, the customized library for the DPHIMS applications etc reside. Manipulation of data, including numeric calculation, interpretation etc, accessing the database for data retrieval and storage is performed in this layer. Continuing with the example scenario, Tier 2 receives and decodes the information. The password pertaining to this username is retrieved and stored from the data base as a SQL DataReader object, using ADO.NET features. If the password entered and the password from the database match, the patient is successfully redirected to the home page; else the web page displays an error message. Tier 3 represents the data layer where all the information is stored using a RDBMS system like MS SQL server 2000. As per the features of the database, this layer may also store Stored Procedures which can be activated by Tier 2. The database structure is elucidated later in this section.

The 3-Tier architecture implemented by DPHIMS has many advantages over a 2-Tier architecture. In a 2-Tier architecture application codes and execution including database access (the application layer in 3-Tier architecture) is performed by the client. This means that any change in the codes would necessitate all the clients to modify at the same time otherwise wrong data is stored in the database. Also there would be heavy network traffic with clients establishing simultaneous database connections. These issues are avoided in the 3-Tier architecture by separating the client from the Application layer.

3.3.3 C# Programming - DPHIMS Software Structure

The DPHIMS application is developed using the C# programming language which supports object-oriented programming (OOPS) concepts like inheritance, polymorphism, classes etc. and interface, and component based programming. Components can be viewed as a collection of smaller objects which perform a specific function or task. For example a function which takes the physical path of an image in a directory as the input and uploads it into the database can be seen as a component or an image upload control. This can be reused for as many applications that require this functionality.

The DPHIMS software structure groups its classes inside the main project according to every class's functionality. Taking the example of a patient, the web forms pertaining to health records like allergies, health history, social history, medications etc. are grouped under the health record management of the role 'Patient'. Likewise, forms pertaining to providing diagnosis and similar functions are grouped under the role of 'Specialist'. Common functionalities pertaining to internal emailing which is used by all users are grouped under 'Common'. The outline of the grouping inside DPHIMS is depicted in Figure 6.

Figure 6. Outline of web form grouping structure in DPHIMS.

DPHIMS for Teledermatology

Figure 7. Class structure outline for patient portal.

The class structure outline for the patient is as depicted in Figure 7. For example, if a new user is trying to register with DPHIMS, after gathering the details from the user, the user authentication class refers to the class which performs the actual task of verifying and registering a new patient. The database is then accessed by this class to store the information of the newly registered patient. If the user is already registered, then the class flow is modified slightly as explained in Section 3.3.2.

From Figure 7 it can also be seen that the web forms which serve as the interface for obtaining user input refers to the class files in the ‘Health Record’ group to access the database. Each class file inside the library queries the database for existing records (e.g. medications history), adds, deletes and modifies patient information residing in the database. For example, if the patients want to view their past medication history, they access the ‘CurrentMedications.aspx’ form

DPHIMS for Teledermatology

from the browser after user authentication. The form then accesses the Load() method in the Medications.cs class file by creating a new instance of the Medications.cs. The code snippet that performs this functionality is shown in Figure 8.

```

/// <summary>
/// Find all medications currently prescribed to a patient and display in a DataGrid control in the web form
/// </summary>
private void Page_Load(object sender, System.EventArgs e)
{
    if (!IsPostBack)
    {
        Medications medication = new Medications();
        MedicationList.DataSource = medication .MedicationList;
        MedicationList.DataBind();
    }
}

```

Figure 8. Code snippet for display of medications list on form load.

The MedicationsList property as seen in Figure 8 returns back the list of medications after querying the database. This list is bound to the data grid of the 'CurrentMedications.aspx' for display. The process of retrieving data from the database is explained later in this section under ADO.NET. Apart from storing and maintaining their medical records, the patients can refer to the webservice (DataUploadDownload.asmx in Figure 7) hosted by the server side to transfer their medical records while requesting for a diagnosis from the specialist. They could also use the webservice for sending emails to the specialists. To view the comprehensive list of their medical information in printable and non-editable format, the patients can also use the forms and controls under the display group. This display functionality can also be used by the nurses and specialists to view the patient medical information.

The class structure outline for the nurses and the specialists are shown in Figures 9 and 10 respectively.

DPHIMS for Teledermatology

Figure 9. Class structure outline for nurse portal.

Figure 10. Class structure outline for dermatologist portal.

3.3.4 Using ADO.NET – Querying and Accessing SQL Server

The DPHIMS application uses the features of ADO.NET like DataSet to access the SQL server. When a .NET application connects to the database, the query results are stored in a DataSet through the DataAdapter. DataSets can be viewed as small relational databases which allow inter-table relationships, constraints etc. Once the DataSet is populated, the connection to the database is closed. The data tables in the DataSets can be manipulated as per the application's requirement and a new database connection is made to update these changes in the DataSet into the main database via the DataAdapter. Compared to earlier models the data access model offered by the framework is more efficient. For the previous models, once a database connection is made, that particular table which is accessed is locked till the entire query execution as required by that application finishes. But for the model used by DPHIMS application, query execution is performed on the DataSets after the database connection is closed. This leaves the database resources free for other users during query execution.

3.3.5 Web Service – Data transfer between Local Server to Main Server

Web service developed for the DPHIMS application is hosted by the main server to transfer data to and from the main server. Web services are essentially brief application codes which perform a specific task where data is transmitted over HTTPS using the XML format (Simple Object Access Protocol, SOAP). These are independent of operating systems and programming languages and can be invoked by any application which uses SOAP over HTTPS instead of HTTP. The usage of HTTPS to transmit data offers a highly secure environment which is

DPHIMS for Teledermatology

essential to protect the patient medical data. Though the encryption process increases the size of the data to be transmitted by a substantial figure, it is accepted as a nominal tradeoff for improving data security.

The usage scenarios for the web service are described below.

- Patients log into the DPHIMS application from the local server: On pressing the 'Login' button, the web service at the main server is invoked to check if there are any new, unread diagnosis report, email from the specialist. These data are then downloaded from the main database to the local database.
- Patients perform a referral request from the local server: On pressing the 'Upload' button, another web service is invoked in the main server which queries and accepts data from the local database and stores it in the main database. While performing the upload, the web service also checks if the patient data already exists in the main server, if the patient has received diagnosis reports during that week etc. If the patient performs the upload operation incorrectly or accidentally, they can press the 'Delete' button which invokes another web service to delete that patient's records from the main server.
- Nurses' log into the DPHIMS application from the local server: Similar to the patient login process, the same web service that checks for unread email for the patient is invoked from the main server to check and download new email for the nurses from the specialists.

Snippets of code explaining web service authentication and implementation is provided in Figures 11 and 12. The web services are stored using the .asmx file extension and not as the normal .aspx extensions. Figure 11 shows a sample of the

DPHIMS for Teledermatology

code behind the .asmx file. The DataTransferWS object takes the property of the System.Web.Services.WebService class offered by the .NET framework. This class can hold various individual web methods which can be designed to perform the necessary tasks.

```
[WebService(Description="webservice")]
{
    public class DataTransferWS: System.Web.Services.WebService
    {
        [WebMethod(Description="Patient Medical Data Upload")]
        {
        }
        [WebMethod(Description="New email Download")]
        {
        }
        [WebMethod(Description="New diagnosis report download")]
        {
        }
    }
}
```

Figure 11. Code snippet for implementing web service

For a client to make a connection and use the Web service offered by the main server, a new web reference must be added to the client side program codes. Figure 12 shows the pop up window when 'add new web reference' is clicked. Under the URL, providing a link like 'https://main_server_name/client_side_project_name/web_service_name.asmx' would immediately prompt the client to provide the server user name and password. Only upon authentication would a connection be established.

DPHIMS for Teledermatology

Figure 12. Web service client authentication

These web services can be reused by any new local server added to the expanding DPHIMS network. New web services can also be programmed into the main server without affecting the existing model. One important aspect to note is that only the main server is programmed to control data transfer to and from the local server. Each local server when added to the network has to be authenticated and accepted by the main server as a legitimate server before starting to perform data transfer. The stringent authentication method prevents stray computers or servers from being able to use this web service through the internet and thereby inject junk data. Another measure implemented in this project to protect data from harmful code injections during data transfer will be explained in Section 4.2.

CHAPTER 4 DPHIMS & Teledermatology

Module Designed for Singapore Nursing Homes

4.1 Software Design

The screenshot shows a web interface for the 'eMedicine' system, specifically for the 'Singapore - University of Washington Alliance Dermatology Center'. The page has a blue header bar. Below the header, there is a 'Login' section. It includes two input fields: 'E-Mail Address' and 'Password'. Below these fields is a 'Log in' button. A red oval is drawn around a text link that says 'If you are a new user, click [here](#) to register.' A red arrow points from this link towards the right. At the bottom of the page, there is a footer with copyright information: 'Copyright © 2005-2006 Singapore-University of Washington Alliance. All rights reserved.' and a 'Contact Us' link.

Figure 13. Registering of new patient on login page

Web portals are designed to cater for the three kinds of roles played by the users of the DPHIMS system namely the residents of the nursing home, the nursing staff and the dermatologists. The web.config file is used to store authorization information for the above roles and to deny access to random users. The system follows a simple and consistent web design pattern to enable quick learning and easy usage. The dermatologists and the nurses are assigned a login ID and a password by the administrator of the system with which they can enter the DPHIMS system. New patients are registered via the system using a link provided in the login page as shown in Figure 13. On successful registration, they are also assigned a user name and password for subsequent log-ins into the system.

DPHIMS for Teledermatology

4.1.1 Patient Web Portal

4.1.1.1 New Patient Registration

A new patient registering with DPHIMS is presented with a pre-screening page. The pre-screening page as shown in Figure 14 contains a list of dermatologic conditions which ensures that the patient suffers from non-emergency, chronic skin diseases only. The list of the skin conditions in this page was as recommended by the dermatologists. If the patient registering with the system suffers from conditions not included in this page, the registration is aborted.

Current Health Problem

Please answer the following questions and then click Next.

In general, what is the problem you are seeking a referral for related to (check all that apply)?

☐ Acne

☐ Eczema Dermatitis

☐ Itching with rash

☐ Itching without rash

☐ Leg ulcer

☐ Nail problem

☐ Pigmentation

☐ Rashes

☐ Rosacea and Rhinophyma

☐ Seborrheic keratosis

☐ Skin infection

☐ Tumour/growth

☐ Vitiligo

☐ Warts

How many surgeries have you had on this problem or condition?

When did the problem start?

How are the symptoms progressing?

Less than a week ago

Staying the same

Next

Figure 14. Patient portal - pre-screening page

A patient having completed the pre-screening page as per the requirement provided with a set of web pages which request for a summarized version of the details on the patient’s skin conditions, personal information, allergies to medications, primary care physician information etc. The details on the patient’s skin conditions include the time the condition started, the reason why it started, any previous treatment or surgeries performed pertaining to this condition etc. The aim of these pages is to provide the dermatologists with an overview of the

DPHIMS for Teledermatology

patient’s skin issues and also to highlight important points such as any allergies to medications. Figure 15 show example screen shots of the skin condition description page.

Current Health Problem

Please answer the following questions and then click Save.

If you would like to go back to the previous page, click Back to Referral Problem at the bottom of this page.

Please check all that apply. The problem:

☐ Started with an injury

☐ Was related to your job

☐ Was present from birth

Please give a brief description of the problem you would like our help with, and any diagnoses other doctors have provided you with (if any).

Have you tried any interventions (e.g. skin treatments, exercise, diet control, pills, etc...) to try to improve the symptoms?

What effect(s) have those treatments had, if any?

Figure 15. Patient portal – skin condition description page

4.1.1.2 Existing Patient Log-in

On successful registration, the patient is redirected to the home page shown in Figure 16. The home page is designed to have three links.

eMedicine

Singapore - University of Washington Alliance
Dermatology Center

Log Out

My Home Page

John Doe 's Home Page

Thank you for your interest in the SUWA Dermatology Center. You can view your recent referral here:

[View My Referral Request](#)

To best use your time when you come to the clinic, we would like to have your health record on file. Your health record will include information such as your contact information, insurance, allergies, medications, past surgeries, and any chronic conditions you may have. Please fill in as much information as you can here:

[Fill In My Health Record](#)

This section will display all your diagnosis reports recieved till date. The latest report will be displayed by default and if you scroll down to the bottom of the page, you will have a listing of all your diagnosis reports. Kindly note that this page is for viewing only. You cannot make ammendments to the diagnosis reports.

[View My Diagnosis Reports](#)

Patient Survey

The link to the patient survey is provided below. Kindly spare a few minutes of your time to fill in the survey form and to submit it. This will be a huge help to the clinical trial study conducted by SUWA. Thank you for supporting us in this study.

[Patient Survey](#)

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Contact Us

Figure 16. Patient portal – home page

DPHIMS for Teledermatology

The ‘view referral request’ link displays the un-editable, printable form of the existing patient medical information as shown in Figure 17. The patient can choose to take a print out and store the information in a hard copy form or show it to his/her physician during regular visits.

The screenshot shows a web interface for a patient portal. On the left is a blue sidebar with links: 'My Home Page' and 'Upload Patient Records'. The main content area has a header 'Medicine Singapore - University of Washington Alliance Dermatology Center' and a 'Log Out' button. Below the header, there are two sections: 'Patient Information' and 'Insurance'. The 'Patient Information' section contains a table with personal details for John Doe. The 'Insurance' section contains a table with insurance details for Medicare.

Patient Information			
Name	John Doe	Age	24
Date of Birth	11/10/1980	Blood Type	
Gender	Male	Height	
Weight			
Language	English		
Address	54 Yew Mei Green north 6		
Area	West		
City	Singapore	Postal Code	689876
Country	Singapore		
Home Phone	65-90876785	Work Phone	65-88987890
Hand Phone	65-87869098	E-Mail	jdoe@yahoo.com
Emergency Contact Name		Emergency Contact Number	

Insurance			
Primary			
Type of Insurance	Medicare		
Insurance Company Name	Great Eastern	Group Number	9
Subscriber Name	John Doe	Subscriber ID	78
Address	66 woodlands avenue		

Figure 17. Patient portal – non editable, printable health information version

The ‘fill in my health record’ link redirects the patient to a list of web pages which acquire the comprehensive medical information from the patients. This includes general information, primary care physician information, other diseases for which the patient is undergoing treatment, hereditary diseases like diabetes, current medications of the patient and information on the past medication if available, any allergies or surgeries, lab tests, social history like smoking/drinking habits etc. These web pages can be updated easily to ensure that the patient does not hold outdated medical records. There are two ways by which medical information can be entered and updated.

- A ‘SAVE’ button provided at the end of the web page when pressed would store new information entered in the text boxes or the existing information

DPHIMS for Teledermatology

which is currently updated. Only upon pressing this button will the information be saved or updated into the dataset.

- An ‘ADD’ button provided on the web page adds the information entered in the text boxes and appends it to a growing list at the end of the web page. A ‘remove’ link is provided at the right side of each entry to enable deletion of that entry.

Health Problems
☐ Vision problems
☒ Ear, nose, throat problems
☐ Heart problems
☐ High blood pressure
☐ Lung/chest problems (e.g., abnormal chest x-ray, asthma, emphysema, pneumonia, TB)
☐ Gastrointestinal/stomach problems
☐ Arthritis/gout
☐ Genito-urinary problems (kidney, bladder)
☒ Skin problems
☐ Nerve problems
☒ Anxiety/depression
☐ Diabetes
☐ Hepatitis/liver disease
☐ Thyroid problems
☐ Blood problems (anemia, leukemia)
☐ Bleeding problems
☐ Cancer

Figure 18. Patient portal – other health problems

Allergy Type	Allergy Name	Type of Reaction	When it Happened	
Food	Dairy Products	vomitting	1998	Remove

Figure 19. Patient portal – allergies health problems

DPHIMS for Teledermatology

Figures 16 to 19 show a tool bar on the left side of the screen for easy navigation from one page to another. Though the contents of the toolbar changes as per the web page viewed, the position of the navigator is constant. This ensures that the user does not get confused when looking to navigate across web pages.

The most important web page for this teledermatology application is the image upload page as shown in Figure 20 which allows users to enter compressed digital images of the patient’s skin conditions. Currently for this teledermatology application, still images in JPEG, GIF and PNG formats are accepted. This page lists the images in chronological order starting from the latest set of uploaded images.

Insurance

Primary Care Physician

Health Survey

Family Health Survey

Medications

Surgeries

Allergies

Herbals & Supplements

Lab Tests

Social History

Patient Data ▶

Additional Information

View My Information

My Home Page

Upload the digital photographs of your skin condition (in compressed format) that you think might be helpful in the evaluation of your consultation request. When you are done uploading the images, please proceed to Add Additional Information.

We can accept documents and files up to 1 MB in size in JPEG, GIF or PNG format.

Dermatology Data Category

Digital Image of Patient's Skin Condition ▼

Description

(e.g. Digital images of affected area of skin near ear lobe)

Body Site

(e.g. Ankle/Feet)

File

Browse...

Add

Click Here To View Image Archives

Date	Image no.	Image	Enlarge Image	Image Type	Size (kb)	Dermatology Data Category	Description	Body Site	
10/3/2005	2		Enlarge	JPEG	517	Digital Image of Patient's Skin Condition	full view of both hands palm	palm	Remove

Figure 20. Patient portal – digital image upload page

The images are uploaded individually using the HttpPostedFile class. This class attributes provides the byte size of the file to be uploaded, the file path, extension and contents. With the information provided by these attributes, content length check, extension type check etc are performed before uploading the image. The image content is then stored in the database as a Binary stream. Figure 21 displays the code snippet used for image upload.

```

Int32 imagelength = System.Convert.ToInt32(httpFile.ContentLength);
Stream imgStream = httpFile.InputStream;
byte[] imgBinaryData = new byte[imagelength];
imgStream.Read(imgBinaryData, 0, imagelength);

```

Figure 21. Code snippet for image upload

Images which are more than a month old from the date of access are placed in the image archives and are not displayed in the main page. Placing the older images in the image archives helps faster loading of the web page. The 'click here to view image archives' link opens a separate web page within the same session and displays the complete set of images of that patient. An enlarge image option is also provided for the specialist to view the images in full size to obtain a clearer, close up view for diagnosis.

Along with the rest of these pages, an 'additional information' page is designed as shown in Figure 22. The function of this page is to provide a platform for the patients to record updates on their health and also extra information considered useful for the dermatologists. The information entered in the text box could be something verbal, something personal like *'I started using this medication as per your directions. But unfortunately I seem to lose appetite after every course and the rashes seem to grow worse'*. This page was used especially when the patient was referred for follow-ups and a detailed update on the patient's progress had to be provided. The free text box provided for this page is considered very valuable as this allows the dermatologists to get a feel of the patient's psychological state, problems, and issues like aversion towards external applications [53].

DPHIMS for Teledermatology

Figure 22. Patient portal – additional information page

Figure 23. Patient portal – medical information upload page

As per the architectural design of the system, for the dermatologists to be able to view the patient information, the records have to be transferred from the local server to the main server. The ‘information upload page’ as shown in Figure 23 offers this functionality. As elaborated in Chapter 3, pressing the upload button transfers data from the local server to the main server using the .NET web service. In the event that the uploaded information is incorrect, the delete button can be

DPHIMS for Teledermatology

used to purge the transferred information from the main server and then the correct information can be re-uploaded.

4.1.2 Dermatologist Web Portal

The web pages accessed by the dermatologists are hosted from the main server. The home page of the dermatologist after logging in is shown in Figure 24.

Figure 24. Dermatologist portal – home page

The home page is designed to have a toolbar on the left side of the screen for easy navigation. A set vacation option is also provided for the dermatologist to let the patient or nurses know that they are on vacation and would not be able to render diagnosis. If the ‘out’ is chosen, when a patient or the nurse request for a referral or send email to the dermatologist, an automatic email is sent to them informing them of the vacation and the length of the vacation. The ‘patient list’ link provides a list of all the patients registered with the DPHIMS system at the local server side and the ‘referred patients’ list gives the number of patients currently waiting to obtain diagnosis and treatment. The ‘referred patients’ page is as displayed in Figure 25.

DPHIMS for Teledermatology

Figure 25. Dermatologist portal – referred patient list for diagnosis/treatment

The referred patients’ page links dermatologists to all the necessary patient information including medical history and uploaded digital images of skin conditions as presented in Figure 26. The information is listed in a sequential manner and can be completely viewed by simply scrolling down the web page. The ‘patient diagnosis’ link allows the dermatologists to give the diagnosis and treatment report. This is a simple yet comprehensive report as displayed in Figure 27, which is in an easily readable and printable format. The diagnosis report was designed based on the suggestions and guidance of the dermatologist.

Email Address		Phone		Fax	
		65-62875466			
Patient Health Problems					
Patient Health Problems		Description			
Vision problems		Impairment of both left and right eye.			
Heart problems		1 - Ischemic heart disease.			
Gastrointestinal/stomach problems		viral gastritis(06/12/02)			
Skin problems		Psoriasis.			
Diabetes		Diabetes Mellatus.			
Other		1 - Renal Impairment. 2 - Old Cerebral Vascular Accident with vascular dementia.			
Family Health Survey					
There are no family health problems.					
Current Medications					
Problem	Medication	Dosage	Doctor	Helpful?	Reason for Stopping
Ischemia	Persantin	25 mg tds	Dr. Chia Kiat Swan	Effective	No
Ischemia	ISDN	5 mg bd	Dr. Chia Kiat Swan	Effective	no
Ischemia	Aspirin	100 mg om	Dr. Chia Kiat Swan	Effective	no
General Health	Vitamin C	100 mg om	Dr. Chia Kiat Swan	Effective	no
Constipation	Lactulose	10 mls tds	Dr. Chia Kiat Swan	Effective	no
Bone Strength	Calcium and Vitamin D	2 om	Dr. Chia Kiat Swan	Effective	no

Figure 26. Dermatologist portal – viewing patient medical history

DPHIMS for Teledermatology

Figure 27. Dermatologist portal – viewing patient diagnosis rendered

Web pages like ‘view selective information’ and ‘second opinion’ were designed to create functionally more user friendly portals. The selective information link as presented in Figure 28 allows the specialists to select the patient information they deem necessary to make a diagnosis unlike the web page shown in Figure 26 where the specialist have to scroll down to view the complete information.

Figure 28. Dermatologist portal – viewing selected patient information

DPHIMS for Teledermatology

The second opinion page is shown in Figure 29. This page permits the dermatologist to obtain a suggestion and discuss with other dermatologists registered with the system on a particularly tricky or difficult diagnosis.

Figure 29. Dermatologist portal – second opinion page

4.1.3 Nurse Web Portal

Nurses play a very important role in patient care. For patients who do not have the ability to use computers or are unable to do so due to their physical condition, the nurses act as their caretakers. The nurse portal was mainly developed to give a platform for each nurse to manage the patients who are under their care. This portal is hosted in the local server. Managing the patients includes requesting for diagnosis and follow-up, updating patient records and images and administering the suggested medications. The nurse home page is as shown in Figure 30. A ‘patient list’ link redirects the nurse to a web page which contains a list of all registered patients and also the list of patients managed by that nurse. This is as shown in Figure 31. A check mark against each patient name managed by them

DPHIMS for Teledermatology

indicates that a referral request has been sent out to the dermatologist recently. The patient’s medical records can also be uploaded via the nurse portal by pressing the icon next to each patient’s name.

Figure 30. Nurse portal – home page

Figure 31. Nurse portal – list of patients managed by nurse

Common to the three web portals is the internal emailing system included in the software design of DPHIMS. This was to aid the dermatologists, nurses and patients to ask questions, clarify any doubts or to request for extra information. The internal emailing system is especially used for the dermatologists to convey to the patients or the nurses that a report diagnosing their skin condition and providing treatment is ready. Also in cases where the pictures are not clear or the dermatologist needs more digital images for diagnosis, he/she can send an email to

DPHIMS for Teledermatology

the nurse or the patient to request for more or better quality images. Figure 32 depicts the internal email as viewed from the nurse web portal.

Figure 32. Nurse portal – internal emailing system

4.2 Database Design

DPHIMS database design follows the relational database management concept as it uses the Microsoft SQL server 2000. The structure of the DPHIMS database remains the same in the local server and main server except for some modifications with the KEY constraints like foreign key. The local server uses the tables necessary for storing the information pertaining to nurses and patients and the main server uses the tables necessary for the dermatologists. Similar structure is maintained in the local server and main server to enable smooth transfer of data between the two databases. The structure of the database taken from the main server is shown in Figure 33. The concepts of RDBMS including normalizations, primary key constraints, and foreign key constraints were implemented in the

DPHIMS for Teledermatology

database design to protect against data redundancy, isolated data and other such errors.

Figure 33. DPHIMS database structure in the main server

The design of the DPHIMS application is such that for the specialist to view the patient data, data has to be transferred from the local to the main server database. The data then resides in the main database for a brief period of time. The

DPHIMS for Teledermatology

data must be safeguarded from SQL injections of harmful code during transfer. SQL injections occur when a hacker inserts additional query via the input data from the client with the intention of accessing sensitive data or modifying/inserting/deleting data. DPHIMS applications perform typecasting or type safe parameter encoding using datasets, a feature allowed by ADO.NET. It is implemented by providing the exact data type of the value which is being transferred. Figure 34 shows an example of how the above mechanism is coded in the DPHIMS system. It can be seen that while adding parameters to the query, the type whether it is an integer or string etc is included. This would prevent malicious query additions as ADO.NET specifically string encodes each parameter along with its data type.

```

public DataSet DataSetPatientDiagnosisDownload(Int32 SpecialistId, Int32 ReferralId)
{
    SqlConnection sqlConnDiag = new SqlConnection(Configuration.ConnectionString);
    SqlCommand sqlCmdDiag = new SqlCommand();
    DataSet dataSetPatientDiagnosis = new DataSet();
    sqlCmdDiag.Connection = sqlConnDiag;
    sqlCmdDiag.CommandText = "SELECT TOP 1 UserID, ReferralID, DateCreated, DateSubmitted, Diagnosis, Category,
    Description, Assessment, Medications, Diet, Comments" FROM PatientDiagnosis WHERE (ReferralID = @ReferralID
    AND UserID = @UserID AND PatientDiagnosis.DateSubmitted IS NOT NULL) ORDER BY
    PatientDiagnosis.DateSubmitted DESC";
    sqlCmdDiag.Parameters.Add(new SqlParameter("@ReferralID", System.Data.SqlDbType.Int)).Value = ReferralId;
    sqlCmdDiag.Parameters.Add(new SqlParameter("@UserID", System.Data.SqlDbType.Int)).Value = SpecialistId;
}

```

Figure 34. Type casting data before transfer using ADO.NET

Patient data transferred outside the nursing home can reside in the main server only for a brief period of time. Here the DPHIMS database uses the SQL server agents feature offered by SQL server 2000 to activate a trigger at 2.00 AM every Sunday to purge all patient data in the main server which has been residing for more than 1 week.

4.3 DPHIMS Security Features

All the information that is transmitted is encrypted and sent over the SSL. All the pages hosted by DPHIMS are accessed using the encrypted HTTPS layer. Access to the information on the web site is limited to the users registered with the system and the investigators who will act as the site administrator. The .NET authentication and authorization measures are implemented. Only the logon page is available to unauthenticated users, and DPHIMS validates all input for in-range values. There are four user roles available and resources are restricted appropriately for each role. The roles are patient, dermatologist, nurse and system administrators. Patients can register new accounts on their own. Each user is allocated a user ID and password and is given levels of site privilege that will limit the files they have access to. This implies that each user will have access only to his/her own health information, but he/she will not have access to the health information of others. The DPHIMS web site also has automatic logging out features if left unused for a certain time period. DPHIMS keeps an application-level audit trail of logins, record views, and record updates. OS and web server-level logs and audit trails are also retained indefinitely.

The physical security measures taken which are external to DPHIMS are described in the following paragraph. The local server and main server will be protected from external intrusions with the IP address filter. A firewall with complete layer 7 protection is incorporated to secure the servers to the application level. The firewall with layer 7 protection filters incoming packets and would only allow authorized programs to be executed. The exposed ports are SSH, HTTP and HTTPS. The SMTP email server is also disabled as it is likely to become a target for hackers, spammers and the patient data might be in the danger of getting

DPHIMS for Teledermatology

exposed. Hence only an internal emailing system within the DPHIMS application is implemented.

CHAPTER 5 Clinical Trials at the Nursing Home for Senior Citizens in Singapore

The clinical trial was granted approval by the Institutional Review Board/Domain Specific Review Board (IRB/DSRB) of Singapore. The approval and extension forms are attached to Appendix A of this document. The trial was launched in October 2005. As per the protocols of the IRB/DSRB, the residents or their legal guardian gave a written informed consent in either English or in Mandarin for participation in the clinical trial. The data from the clinical trial is collected from the period of October 2005 to February 2007. The trial was categorized into Phase 1 (October 2005 to July 2006) and Phase 2 (August 2006-1st July 2007).

5.1 Clinical Trial Setting

5.1.1 DPHIMS Setting

As discussed in Chapter 4, DPHIMS follows the distributed architecture. The local server was placed at the nursing home and the main server was placed at the BMERC server room in NTU. The local server network with an ADSL 512K internet connection was set up independent of the existing LAN at the nursing home. This separation of DPHIMS network from the exiting nursing home network was in accordance to the IRB/DSRB protocols. The main server was set up within the NTU network with a 100 Mbps connection speed.

5.1.1.1 Nursing Home Setting

The nursing home has a total of 350 residents with an average age of 80 years. The target population of the clinical trial is the residents with chronic, non-emergency skin conditions. A majority of the residents do not speak English and Mandarin is the popular language. Also most of the residents are not computer literates. As for the staff count at the nursing home, there are 10 staff nurses, 44 nursing aides, one resident doctor and one matron. The nurse demographics are provided in Table I.

Table I. Nurse demographics

Description	Phase 1	Phase 2
System Users	Staff Nurse	Nursing Aide
Total population	10	44
Sample size for DPHIMS	5	9
Age Range	30-50 years	20-30 years
Nationalities	Myanmar – 3 , India – 1, Philippines – 1	Myanmar – 7 , Philippines – 2

For this clinical trial, the nursing staff performed the data entry and uploaded the digital images of the resident’s skin conditions into the DPHIMS system. They also performed the referral requests for skin conditions on behalf of the residents. During Phase 1 of the clinical trial, the staff nurses executed the above tasks and during Phase 2 the nursing aides performed the above activities. The resident doctor is not present at the nursing home full time. He visits the

DPHIMS for Teledermatology

nursing home three times a week to perform regular check-ups on the residents. The matron manages the entire scheduling and supervising of the nursing staff at the home.

5.1.1.2 Dermatologist Setting

Two dermatologists from the National Skin Centre (NSC), Singapore consented to be involved in this clinical trial. They volunteered to give free diagnosis to the residents of the nursing home during the period of the clinical trial. They also have an excellent command over the English and have advanced computer skills. During Phase 1 of the clinical trial, both the dermatologists were located in Singapore whereas during Phase 2, one of the dermatologists shifted to UK but continued to provide diagnosis and follow-ups for his existing/new patients from UK.

5.1.2 Imaging Equipment and Technique

A Sony DCRTRV940 Digital Video Camera Recorder with a 3.6- 43.2 focal length was used to capture the digital images of the patient's skin conditions. An image resolution of 1152x864 was used and the images were stored in a compressed JPEG format. The compression was lossy with a compression ratio of 3. The skin lesions were consistently imaged using three views, the far view, mid view and close up view, all taken at an angle perpendicular to the lesion from the top. The far view was captured to help dermatologist identify the place of the lesion and the overall distribution of the lesion. The mid view describes the localized lesion distribution apart from morphological details of the lesion and the close up view describes the minute details like pus formation etc. For growths like

DPHIMS for Teledermatology

tumor, along with the top angle, a right angle view was also shot to provide a 3 dimensional view. A few distinct lesions were photographed with a centimeter scale to depict the original size of the skin condition [6] [54]. Apart from the above techniques, standard, approved methods of imaging of various body parts were followed [54]. The photographs were taken using the normal lighting inside the resident wards to study if the images obtained under such conditions would suffice for the dermatologists. The nursing staff at the nursing home performed the image capture with the aid and guidance of the researcher.

5.1.3 Training Sessions for Nurses and Dermatologists

On the inception of the clinical trial, the concept of tele-dermatology and DPHIMS was explained to the nursing staff, matron, the resident doctor and the management at the nursing home through presentations and live demonstration. Individual training sessions on the hands-on usage of DPHIMS were conducted for the nurses and the dermatologists. Each session lasted for 60 minutes per nurse and 30 minutes per dermatologist. The nurses were provided with hypothetical patient cases to practice and understand the system. An additional 30 minute training session was conducted for the nurses on the techniques of photography of the patient skin conditions. Posters explaining the photography techniques and DPHIMS were put up inside the server room. User manuals explaining in complete detail the working of DPHIMS and its usage were also given to the dermatologists and nurses. During Phase 2, when the group of nursing staff involved in the clinical trial changed, the new group of nursing staff was not given formal training as most of them were computer literates. They were asked to

DPHIMS for Teledermatology

directly start performing data entry and image capture under the guidance of the researcher.

5.2 Process Flow of Clinical Trial

5.2.1 Patient Enrollment Method to Register with DPHIMS

The recruitment process of residents was divided into Phase 1 and Phase 2. During Phase 1, the residents were referred to DPHIMS by the resident doctor when he noticed any skin abnormalities during regular check-ups. During Phase 2, apart from the method in Phase 1, the nursing aides also referred the residents to the resident doctor when they noticed skin abnormalities. This work flow process is depicted in Figure 35. The resident doctor then reviewed the patient and subsequently referred them to obtain diagnosis/treatment from dermatologists via DPHIMS.

Figure 35. Patient enrollment process into DPHIMS during Phase 2

The target population consisted of residents who were

- Neither diagnosed nor provided with initial treatment plan for their skin conditions.
- Diagnosed with skin conditions and provided initial treatment by the resident doctor prior to the clinical trial.

DPHIMS for Teledermatology

- Diagnosed with skin conditions by dermatologists and underwent a treatment plan prior to the clinical trial.

This target population thus represents the various types of referrals that need to be handled by such a system at a nursing home setting. The aim of this study is not to test the accuracy of a teledermatology system, but to observe the need and efficiency of such a system in handling the skin disease management of elderly residents at nursing homes. Once referred to DPHIMS, the resident goes through an online pre-screening page (Figure 14) hosted in DPHIMS to ensure that the skin conditions fall under the non-urgent category. Only after clearing the pre-screening page is the resident allowed to register with the system.

5.2.2 Procedure from Requesting for Referral to Receiving Diagnosis / Treatment via DPHIMS

Figure 36. Process flow of DPHIMS

Figure 36 depicts the procedure for the DPHIMS system from requesting for a referral to obtaining diagnosis/treatment from the dermatologist.

Stage 1: The nurses use the userID and password of the residents and perform data entry of the patient medical records or update the already entered medical

DPHIMS for Teledermatology

records of the patient. They also capture and upload the digital images of the patient's skin conditions into the local server hosting DPHIMS.

Stage 2: The nurses then request for a diagnosis or a treatment plan from the dermatologist by uploading the patient medical records and the digital images from the local server into the main server. An internal email is automatically sent to the dermatologists notifying that a new patient is requesting for diagnosis.

Stage 3: The dermatologists regularly log into their web portal hosted by the main server using their own UserID and password to check for new patient referrals. The dermatologists view the medical records and the uploaded digital images of the referred patients using Internet Explorer 6.0 and enter their diagnosis into the diagnosis page. An internal email is automatically sent to the nurse informing them that diagnosis/treatment plan has been provided.

Stage 4: The nurse logs into the nurse portal at the local server regularly to check for emails from the dermatologists. Once they receive an email from the dermatologists confirming that diagnosis has been provided they log into the respective patient's portal. On successful log-in, the latest diagnosis of that particular patient residing in the main server is automatically downloaded into the local server database.

5.2.3 Work Flow at Nursing Home after Receiving Diagnosis/Treatment Report

Once the diagnosis/treatment report is downloaded into the local server, the nurses take a print-out and send the hard copy to the matron. The matron reviews the report and sends it to the resident doctor who reviews it and prescribes the suggested medications. The nurses are assigned the task of administering the medications. In Phase 1, the staff nurses played a managerial role and delegated

DPHIMS for Teledermatology

the task of administering treatment to the nursing aides. In Phase 2, the nursing aides took the responsibility of administering medications to the residents and also kept a tab on the progress of the skin conditions on these patients. In the event that the situation was not improving or worsening, the respective patient cases were uploaded into DPHIMS again to obtain a follow-up diagnosis/treatment. Figure 37 depicts this work flow for Phase 2.

Figure 37. Work flow after obtaining diagnosis/treatment plan from dermatologists via DPHIMS in Phase 2

5.3 Outcome Evaluation of the Clinical Trial

System satisfaction questions

1. How do you rate the overall improvement of the quality of healthcare offered to your patients after using PHIMS?

Excellent Good Fair Poor

2. Do you think that the medical care your patients received using this PHIMS service is equivalent to a regular clinic visit?

Yes, it is even better Yes, It is about the same

No, not as good I am not sure

3. Did you find it convenient to enter patient health information and upload the digital photographs of the patient's skin condition into PHIMS?

Yes, I found it convenient to use Yes, I found it somewhat convenient

No, I found it somewhat inconvenient No, I found it inconvenient to use

Figure 38(a). DPHIMS system satisfaction survey questions for nurses

DPHIMS for Teledermatology

User Experience

1. Were you comfortable providing diagnosis for patients over PHIMS?

Yes, I was very comfortable Yes, I was somewhat comfortable

No, I was somewhat uncomfortable No, I was very uncomfortable

2. Prior to this clinical trial, have you diagnosed a patient's skin conditions using the digital images of the diseased area of the skin?

Yes No

3. How confident were you in providing diagnosis for patients using only the information in the PHIMS system as compared to the traditional health care environment?

Yes, I was very confident Yes, I am somewhat confident

No, I am somewhat unconfident No, I am very unconfident

4. How do you rate the digital photographs of the patient's skin condition taken by the nurses? Did you receive pictures with good diagnostic quality for assessing the patient's skin condition?

Yes, I received very good pictures

Figure 38(b). DPHIMS user experience survey questions for dermatologists

An online survey form was given to both the nurses and the dermatologists to gauge the level of satisfaction and the user experience after using the DPHIMS system. The full online survey form is included in Appendix B of this document.

The survey was based on the Likert scale [55] and the questions were analyzed using a scale weighted from 0 to 100. As presented in Figures 38(a) and 38(b), the questionnaire consisted of multiple choice questions. A few questions based on system satisfaction had 4 equally weighted choices. A few other questions based on acceptance, experience and recommendation of the system had 2 equally weighted choices. The survey also contained open-ended questions requesting the user to provide their comments and experience in using the system. For a few questions that required a Yes/No answer, a text box was provided to explain the answer choice. Separate interviews were conducted for the nurses on issues regarding the acceptance of DPHIMS into their regular workflow. The system usage was also studied using the database and server logs. The difference in the usage and acceptance of the system between the staff nurses in Phase 1 and the nursing aides in Phase 2 was also evaluated. A comparison on the time

DPHIMS for Teledermatology

difference in sending a patient for FTF consultation with a specialist and in sending a patient for consultation via DPHIMS was also performed.

For the diagnostic report, the dermatologists provided the single most likely diagnosis and differential diagnosis if any. They were also asked to provide the treatment plan if available and any suggestions, comments or recommendations. The outcome of the DPHIMS diagnosis module was judged based on the effectiveness of the treatment plan (patient cured or not cured) provided over DPHIMS. An analysis on the types of diseases diagnosed, treated and cured over DPHIMS was also performed.

5.4 Results and Discussion

5.4.1 Telediagnosis Module

50 residents registered with DPHIMS as of 1st July 2007. 16% of the lesions started in less than a week before referral to DPHIMS, 16% of lesions started a few weeks before, 46% of the lesions started a few months before and 22% of the lesions started a few years before. A total of 83 diagnostic reports were prepared by the 2 dermatologists for the 50 patients, with 49 first-time reports via DPHIMS and 34 follow-ups. The average age of the participants was 81.8 years with 16% being male and 84% being female. During the period of the clinical trial, 11 patients registered with DPHIMS passed away due to natural causes that were not related to the skin diseases.

From Table II it can be seen that there were 5 residents who were neither pre-diagnosed nor given initial treatment for their skin conditions. These residents were diagnosed and treated by the dermatologists through DPHIMS, only based

on their medical records and the images. 3 out of these 5 were cured via DPHIMS without needing a single FTF consultation with the dermatologist. The status of 1 out of these 5 is unknown.

The types of diseases diagnosed after initial referral for these 5 residents are listed below,

- R1: differential diagnosis (Basal cell carcinoma, Merkel cell tumour, Adnexal tumour)
- R2: differential diagnosis (Arthropod bite reaction, Allergic versus irritant contact dermatitis, Erysipelas)
- R3: differential diagnosis (Tinea corporis, secondarily infected Herpes zoster (shingles), Contact dermatitis)
- R4: primary diagnosis (Seborrhoeic keratosis) and differential diagnosis (Basal cell carcinoma, Merkel cell carcinoma, Adnexal tumour)
- R5: differential diagnosis (Tinea corporis, Early herpes zoster, Erythema annulare centrifugum)

Table II. Diagnosis status before DPHIMS

Description	Number
Number of residents pre-diagnosed by resident doctor and given initial treatment	43
Number of residents pre-diagnosed by specialist and given treatment	2
Number of residents not pre-diagnosed	5

The post-diagnosis status is summarized in Table III.

Table III. Post-diagnosis status (1st July 2007)

Description	Number
Number of patients cured via DPHIMS	25
Number of patients not fully cured	12
Out of 12 patients listed above, the number of patient who were referred to NSC by the dermatologists over DPHIMS	6
Out of the 6 patients listed above, the number of patients adhered to the treatment suggestion and went to NSC for FTF consultation	0

It can be seen that 25 out of a total of 37 patients (11 passed away, 1 unknown status, 1 no diagnosis provided) were cured via DPHIMS, a 67.6% cure rate. The remaining 12 were not cured either due to partial/non-compliance to the suggested treatment plan or they may be suffering from a chronic relapse course. 17 residents (45.9%) were not recommended for an FTF consultation and out of them 11 residents were cured. Thus, for 11 out of 35 (29.7%), FTF consultations were correctly averted. This 29.7% is in line with the results in [56] with 27.7% and [11] recording a maximum of 31% FTF referrals averted. 20 residents out of 37 (54.1%) required an FTF consultation as suggested by the dermatologist. Due to financial reasons, these patients were not sent to NSC. But they continued to obtain specialist care through DPHIMS. 14 residents out of the 20 eventually recovered while following the suggested treatment plan. Their progress was also updated regularly by being referred for follow-ups via the DPHIMS system. Thus the total number of FTF referrals averted via DPHIMS with/without dermatologist's recommendation for an FTF consultation is the cure rate equaling

DPHIMS for Teledermatology

67.6% (25 residents). From the above, it can be seen that DPHIMS could help avoid unnecessary FTF consultations. These results show that DPHIMS enabled the elderly residents to obtain specialist care without having to leave the nursing home. This contributes to an increase in the perceived quality of care offered to them. Irrespective of the fact that DPHIMS averted live consults, similar to the results in Mallet [57], it can be said that only a few patients were purely diagnosed via DPHIMS. The rest of the patients still had to visit a dermatologist.

Heeding to a specialists advice is important but the residents were not able to go for a FTF visit due to the following reasons. Some of the residents have a family supporting them, while others are destitute with no family or were abandoned by their families. With virtually no income, they live under the government subsidies provided to the nursing home. These subsidies cater only to one hospital visit every 3 months for a full checkup and for emergency visits. This financial burden imposed on the nursing home and the resident’s family’s refusal to pay for the dermatologist visit were the two factors impeding the residents from visiting the dermatologist.

Table IV. Disease categories (first time diagnosis only, follow-ups not included)

Primary diagnosis	Occurrence
Psoriasis	3
Scabies	5
Eczema/dermatitis	10
Fungal infection	4
Seborrhoeic keratosis	1
Others	26

DPHIMS for Teledermatology

The categories of diseases diagnosed (primary diagnosis) over DPHIMS for 49 patients (1 patient not provided with diagnosis) are tabulated in Table IV. The category ‘Others’ showing 26 occurrences includes patients suffering from skin disease conditions like Erythematous papules, Purpura simplex and Tinea cruris. The category ‘Others’ also includes the 22 patient diagnoses with no primary diagnosis and only differential diagnoses. These diagnoses were confirmed during subsequent follow-ups.

5.4.2 Distinction in Nursing Staff Attitude in Phase 1 and Phase 2

The two distinct phases of the clinical trial led to some interesting observations on the attitude of the nursing staff and their effect on the process flow of the clinical trial. These issues are categorized into three areas, administrative, computer skills and involvement and responsibility. A summarized version of these issues is presented in Figure 39.

Figure 39. Summary of issues faced by nurses in Phase 1, solved in Phase 2

DPHIMS for Teledermatology

Administrative issues like the reluctance of the matron in allowing staff nurses to spend time for DPHIMS sessions and refusing overtime pay and not recognizing their work with DPHIMS were encountered in Phase 1. This issue was even brought up by one of the nurses during an interview. Comment by staff nurse as quoted from [51] is as follows.

“For the nurses, we have to give much of our time to enter the data of the patients to the D-PHIMS and taking photographs and explaining the overall information to the relatives to get consent from them while we have our routine duty to attend on the other hand. Anyway, this is a good system if we can allocate more time to familiarize with the system usage.”

These proved as one of the major factors which reduced the enthusiasm of the staff nurses to work with the system. These issues were addressed and solved in Phase 2. In Phase 2, the nurse aides were paid overtime based on an activity record book which recorded the work done by them during each DPHIMS session. From addressing this issue it was observed that the assent of the matron, the most senior staff at the nursing home, was of great importance. This enabled an increase in the acceptance level of the DPHIMS system by the nursing staff in Phase 2 as compared to Phase 1. Thus in a nursing home environment, it is more important for the matron to be convinced with the new technology introduced than the administration of the home.

Difference in the level of computer skills was the next issue faced. In Phase 1, a majority of the staff nurses had low computer skills and they could not use the system without assistance from the researcher, even after repeated training sessions. Due to this, they tended to get frustrated with the system, and became less enthusiastic about using the system without help. In Phase 2, however, most

DPHIMS for Teledermatology

of the nurse aides had undergone formal computer education or at least had general computer knowledge. They were able to learn to use DPHIMS quickly and could use the system independently without external assistance.

Involvement and responsibility was the third major issue. The normal job description of the staff nurses at the nursing home implied that they played a more managerial role, like supervising the nurse aides. Their work scope does not include administering medications to patients. Hence they did not perform the role of administering medications to the patients registered with DPHIMS. They often delegated this task to the nursing aides. Hence they were not in close contact with their patient to monitor their progress regularly. But during Phase 2, the nurse aides were already given the responsibility of administering the medications for the residents at the nursing home. Since their job required them to be in close contact with the patients, they were able to better observe the progress of the skin conditions. The nurse aides did not have to take up additional responsibilities due to the introduction of the DPHIMS system, which was not the case with the staff nurses in Phase 1.

Apart from the factors mentioned above, there were other subtle changes made by the nurse aides during Phase 2 to reduce the time of each DPHIMS session and to make these sessions more effective. They gathered all the important information from the patient's case note specific to the DPHIMS sessions and carefully referred to medical dictionaries in order to write explanations for the patient medications. The preparations not only helped them with easier and faster data entry but also acted as a mode for their education on topics like medications, diseases, patient sickness, symptoms of skin diseases, and treatment.

DPHIMS for Teledermatology

5.4.3 Nurse Survey

5 staff nurses from Phase 1 and 9 nursing aides from Phase 2 completed the online survey form. Figures 40 and 41 give their responses on system satisfaction.

Figure 40. Phase 1 survey results on system satisfaction.

Figure 41. Phase 2 survey results on system satisfaction.

DPHIMS for Teledermatology

From Figure 40 it can be seen that, all 5 nurses (100%) agreed that they found an improvement in the quality of healthcare after using DPHIMS compared to a regular clinic visit, but 3 (60%) mentioned that the medical care received after using DPHIMS was not as good as a regular clinical visit. 2 (40%) found the system (entering data / uploading digital images) very convenient to use whereas 3 (60%) found it somewhat convenient to use. 80% were satisfied with the overall concept and performance of DPHIMS [51].

From Figure 41, it can be seen that 7 nurses (78%) mentioned good and 2 nurses (22%) mentioned fair agreement that they found an overall improvement in the quality of healthcare after using DPHIMS compared to regular clinic visit. 3 (33%) mentioned that the medical care received after using DPHIMS was as good as a regular clinical visit where 1 (11%) said that it was even better, but 2 (22%) disagreed and 3 (33%) were not sure. 8 (89%) found the system convenient to use, and 100% were satisfied with the overall concept and performance of DPHIMS.

5.4.3.1 A Comparison on the Survey Results on System Satisfaction in Phase 1 and in Phase 2

A comparison of the survey results on nurse system satisfaction between Phase 1 and Phase 2 was performed. As the nurse sample size of the two groups is small, the Mann-Whitney Rank test was applied for the comparison. The null hypothesis for the test is defined as “similar levels of nurse system satisfaction in Phase 1 and Phase 2.” The Mann-Whitney U test is a non-parametric test for assessing whether two samples of observations come from the same distribution [58]. The statistical software SigmaStat was used for the above test using the raw data from Figures 34 and 35. In the questionnaire, Excellent was ranked as 1 and Poor as 4, hence a lower value would indicate a positive response. The

DPHIMS for Teledermatology

comparison result indicated a p value of 0.841. This implies that the null hypothesis cannot be rejected and that nurse response in Phase 1 and Phase 2 show similar levels of satisfaction with the DPHIMS system (84.1% probability of correctness of assumption). This seems contradictory to the observations and anecdotal evidence collected during the two phases, which indicated greater acceptance and satisfaction with DPHIMS in Phase 2 as compared to Phase 1. The possible reason is that the staff nurses gauged only the efficiency, ease of use of DPHIMS and the concept of teledermatology. But during Phase 2, the survey responses by the nurse aides encompassed their acceptance of the system into their workflow apart from their interest in DPHIMS and teledermatology.

5.4.3.2 Ability to use DPHIMS without External Assistance Vs Computer Literacy

It is observed from Figure 42 that for both groups, with formal computer education, the nurses had no difficulties in using DPHIMS without external assistance.

Figure 42. Computer skills vs. independent use of DPHIMS.

In Phase 2, it can be observed that one nurse aide with no computer education was comfortable in using DPHIMS without external assistance and one

DPHIMS for Teledermatology

nurse aide with computer education was not comfortable in using DPHIMS without external assistance. Checking the number of DPHIMS sessions attended by each of them, it is seen that the former had attended 80% more DPHIMS sessions than the latter. This shows that the DPHIMS interface can be learned relatively easily with multiple uses, irrespective of prior computer knowledge.

5.4.3.3 Responses on User Experience

The responses for the questions requiring Yes/No answers for both Phases are summarized below.

- Ease of use of DPHIMS interface: In Phase 1, majority of the nurses (4/5) agreed that they found the DPHIMS interface easy to use, but one respondent who had no formal education in computers said that the interface was difficult to use. In Phase 2, all of them (9/9) said that the interface was easy to use.
- Preference in using DPHIMS for storing and maintaining patient information: In Phase 1, majority of the nurses (4/5) said that they would prefer DPHIMS for electronically storing, maintaining and retrieving patient information. Similar results were obtained in Phase 2 with (8/9) nurses saying that they preferred DPHIMS. This result is consistent with the findings in [59], which concluded that a majority of the nurses have a favorable attitude towards computerization.

On interviewing the nurse aides in Phase 2, they said that while preparing for each DPHIMS session, they found it cumbersome to gather the necessary patient information from the heavy case notes. The nurses were impressed with the ease at which patient details could be retrieved and updated using the DPHIMS system.

DPHIMS for Teledermatology

- Recommending DPHIMS to other nurses: In both Phase 1 and Phase 2, all the nurses said they would be more than happy to recommend the DPHIMS to other nurses.

5.4.3.4 Comments on the System by Nurse Aides

A few comments made by the staff nurses and nurse aides' on the system are included below. These show that the system has a positive impact on the perceived quality of care offered to the residents at the nursing home.

Comments by staff nurses during Phase 1

"For the patients, it is convenient having in-house dermatologist to consult because they need not to go to the clinic and save the traveling fees ..."

"(The D-PHIMS system is) "Available anytime, saves money and manpower; saves time."

"D-PHIMS is excellent in sending data and receiving diagnosis and treatment within 4-7 days."

Comments by nurse aides during Phase 2

"The system is very useful as it helps save time and money for the nursing home staff and the nursing home".

"The system has increased the comfort for the patients and the working staff."

"The system is very good for bed bound patients."

"When using the system, I have noticed that patients have less fear in showing all their skin problems when they are in their own rooms at the nursing home."

5.4.4 Time Difference between Diagnoses via DPHIMS and via FTF Consultation

The time needed to obtain diagnosis was estimated to get a picture of the usefulness of DPHIMS in the nursing home environment. The data were collected from the nursing home and from the DPHIMS database activity logs and tabulated in Figures 43 and 44. From the figures it can be seen that there is a significant reduction in the time taken while obtaining diagnosis over DPHIMS when compared to a clinic visit. Via DPHIMS, for a new referral, the resident is provided with the diagnosis/treatment plan within 8 days whereas it takes up to 61 days in a traditional healthcare environment. For a follow-up referral, the report is provided within 8 days using DPHIMS and 31~42 days via a regular clinic visit. The results of this study indicating a reduction in time taken for obtaining diagnosis/treatment via DPHIMS is consistent with the study results reviewed in [11]. Thus DPHIMS provided medical help to the residents sooner than regular clinic visits. This implies that the resident's skin conditions were diagnosed and treated at an earlier stage, thus improving the perceived quality of care offered to them.

Apart from reducing the total time to diagnosis, DPHIMS also helps reduce costs in addition to donated dermatologists' efforts. Without DPHIMS, to send a resident to the specialist clinic, a special ambulance is arranged by the nursing home. Then 2 of the nursing home helpers or nurse aides prepare the resident for the hospital visit and one travels with him/her to the hospital. With DPHIMS, diagnosis/treatment is provided to the resident without having to leave the nursing home and often (23 out of 35 cases) by averting FTF consultations altogether. Thus DPHIMS helps the nursing home reduce its manpower and

DPHIMS for Teledermatology

ambulance costs incurred when sending the residents for an FTF consultation without compromising the quality of care provided to the residents.

Traditional clinic visit: new referral			Traditional clinic visit: follow up referral		
CATEGORIES	TIME TAKEN		CATEGORIES	TIME TAKEN	
	Best Case	Worst Case		Best Case	Worst Case
Preparing patient to visit hospital	Half an Hour	One Hour	Preparing patient to visit hospital	Half an Hour	One Hour
Time to request and obtain an appointment for a new patient	Two Months	Two Months	Time of wait between obtaining a second appointment	Four weeks	Six weeks
Time taken by the ambulance to make a round trip	Half an Hour	One Hour	Time taken by the ambulance to make a round trip	Half an Hour	One Hour
Time spent in waiting in a hospital queue	One Hour	One and a Half Hours	Time spent in waiting in a queue in the hospital	One Hour	One and a Half Hours
Time to settle the patient back into their wards	Half an Hour	Half an Hour	Time to settle the patient back into their wards	Half an Hour	Half an Hour

Figure 43. Time spent in obtaining a diagnosis during a regular clinic visit.

Photographs taken in computer room			Photographs taken in patient's room		
CATEGORIES	TIME TAKEN		CATEGORIES	TIME TAKEN	
	Best Case	Worst Case		Best Case	Worst Case
Preparing patient to come to server room	Half an Hour	One Hour	Time to prepare (type out the medical information of the patient) and send a referral request online	One Hour and nine minutes on an average (1.09 hours)	Two hours, 24 minutes and 24 seconds (2.24.24 hours)
Time to take digital photographs of the patient skin condition	Ten minutes	Half an Hour	Time to take digital photographs of the patient skin condition	Twenty minutes	Forty minutes
Time taken to obtain a diagnosis	One Day	One week	Time taken to obtain a diagnosis	One Day	One week
Time to settle the patient back into their wards	Half an Hour	Half an Hour			

Figure 44. Time spent in obtaining a diagnosis using DPHIMS.

5.4.5 Specialist Survey Results

The survey for the dermatologists was taken once at the beginning of the clinical trial in 2005 (Phase 1) and once in 2007 (Phase 2). The survey was taken on the same specialists but at two different points in time. The results of the survey are depicted in Figures 45 and 46.

Figure 45. Dermatologist survey taken in the year 2005.

Figure 46. Dermatologist survey taken in the year 2007.

It is well known that an FTF consultation is considered the gold standard in the current health care setting. Hence for the Phase 1 survey, the response of the dermatologist who felt that that the medical care received after DPHIMS was not as good as a regular clinic visit was expected. Surprisingly, the other dermatologist answered that the medical care via DPHIMS was even better than a normal clinic visit. The reason was that he felt the system aided in improving and smoothening the logistics involved in making patient appointments and providing

DPHIMS for Teledermatology

consultations. He also felt that in some cases, it saved the elderly from making a visit to the hospital to receive treatment for their skin conditions.

From the responses in Figures 45 and 46, it can be seen that the system satisfaction of the dermatologists in Phase 1 was greater than in Phase 2. The degree of satisfaction with the system was related to the patient's ability to go for an FTF consultation on the dermatologist's request. A few patient cases involved a request from the dermatologist for an FTF session. These FTF consultations were necessary as the dermatologists had to perform lab tests, like fungal scraping and KIV biopsy, to make a definitive diagnosis. FTF consultations were requested also based on the severity of illness of patients. But these patients were not able to make an FTF visit due to financial constraints. Hence the decrease in system satisfaction of the dermatologist is mainly attributed to the inability to perform lab tests and difficulty in building a rapport with the patients.

There were also a few comments and issues that were brought up during the survey. The dermatologists mentioned that most of the times, the image quality were very good. Sometimes, although a slight decrease in image quality was detected; overall it was good for diagnosis. This response is similar to the results mentioned in [60] in that though there was a decrease in the image quality, there was little decrease in the diagnostic accuracy. The dermatologists said that images involving scalp disease was difficult to view and diagnose. The difficulties with scalp imaging and diagnosing conditions involving scalp using digital images were also mentioned in [56]. The dermatologist also added that real-time camera with video feed could be used along with still images to improve diagnosis.

The dermatologists expressed frustration over the fact that they were unable to touch and feel the patient. This, they mentioned, sometimes decreased

DPHIMS for Teledermatology

their confidence in providing diagnosis over DPHIMS, and they referred these patients for an FTF consultation as also found in [60]. On the interface of the DPHIMS system, the two dermatologists agreed that it was easy to use and that they were able to use it without external assistance. They also mentioned that the medical history was comprehensive enough for making diagnosis.

The dermatologist who shifted to UK during Phase 2 was able to continue providing consultation, diagnosis and treatment for his existing patients and could even accept new patients. The ability to overcome the long distance barrier impressed the dermatologists. They were very excited about retaining their patients without having to transfer them to other dermatologists, irrespective of their physical location.

Overall the dermatologists felt that DPHIMS could be used as a potential screening tool to help the residents at the nursing home get a specialist's care. According to them, DPHIMS can save unnecessary visits to a dermatologist and prevent skin diseases by early treatment and regular follow-ups. They noted that "FTF consultation is the golden standard but teledermatology is the next best thing for circumstances of constraint." The circumstances of constraints could be events like the earthquake/cyclone ravaged areas or a period like the SARS outbreak in 2003 where people were quarantined. A similar conclusion was also derived in the study by [61].

5.4.6 System Usage Results

The results for system usage were obtained from the database activity records. At the nursing home, there were 19 first time referral requests registered with this system during Phase 1. The average time taken to complete a referral

DPHIMS for Teledermatology

request, i.e., registering the patient, performing data entry, attaching digital images and finally uploading the referral request to the main server, took 1 hour and 41 minutes. The maximum time taken to complete a referral request was 4 hours and 41 minutes, and the minimum time was 31 minutes. Photographing a patient's skin diseases took an extra 20-40 minutes after completing the referral request. At the dermatologist's side, the average frequency of log-ins by the dermatologist was 8 per month with most of the log-ins clustered around certain days. The average time taken by the dermatologist to prepare and submit a diagnosis/treatment report was 9 minutes. The maximum time was 1 hour and 17 minutes whereas the minimum time taken was about two minutes.

There were 26 first-time referral requests registered with this system during Phase 2. The average time taken to complete a referral request was 1 hour and 23 minutes. The maximum time was 2 hours and 22 minutes, and the minimum time was 21 minutes. At the dermatologist's side, the average frequency of log-ins by the dermatologist was 9 per month. Again most of the log-ins were clustered around certain days. The average time taken by the dermatologist to prepare and submit a diagnosis/treatment report was 11 minutes. The maximum time was 1 hour and 17 minutes whereas the minimum time was 4 minutes.

In Phase 2 there were more patients as compared to Phase 1. Also, the average time taken for the nursing staff to complete a referral request in Phase 2 was 20 minutes less than that in Phase 1. The average time taken for the dermatologists to complete a diagnosis report was almost the same in both phases.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

DPHIMS with the S&F teledermatology module has proved to be clinically effective in managing skin conditions at the nursing home in Singapore. A cure rate of 67.6% was achieved using DPHIMS. The system was used on a regular basis to perform diagnosis and follow-ups for the residents. DPHIMS successfully averted 30% of FTF referrals and enabled residents to obtain complete dermatologist care from the comfort of the nursing home. DPHIMS has also significantly decreased the time for receiving medical help for skin conditions from the dermatologists. Thus there has been an improvement in the perceived quality of healthcare offered to these patients during the period of the clinical trial as diagnosis/treatment was provided to them regularly and faster without them having to leave the nursing home. It has helped in reducing the costs in terms of time and money incurred by the nursing home in sending the residents for a FTF consultation.

Based on the study experiences it is observed that for a system like DPHIMS to be successful and useful in a particular healthcare environment, the workflow of that setting must be thoroughly understood. This would introduce minimum changes to the existing workflow resulting in minimum inconvenience. Also, gaining acceptance from every level in the organization (management, matron, nurses) by understanding and resolving non-technical issues was instrumental in deciding the success of DPHIMS.

DPHIMS for Teledermatology

In the current nursing home setting in Singapore, based on the observations made from the two phases of the clinic trial, it is seen that the nurse aides at the nursing home would be more appropriate for working with and managing DPHIMS. Tangible benefits like overtime pay and intangible benefits like improving medical knowledge, recognition and recommendation from the matron or the senior staff nurse for career advancements would motivate and retain the interest of these nurse aides to use the system on a regular basis. This clinical trial has also reinforced the need to computerize patient records at the nursing home. Most of the hospitals in the US and in Singapore are becoming computerized with patient records being stored as electronic medical records. If facilities like nursing homes and primary care clinics follow a similar platform, it would facilitate the transfer of updated patient records between hospitals and other facilities.

The dermatologists were satisfied with DPHIMS and were able to see the advantages of the system in helping them provide help to the disadvantaged of the society. They felt that DPHIMS had a good potential as a screening tool, but it had its drawbacks wherein they were not able to make a definitive diagnosis in some cases and had to meet the patient personally. In these few instances, they were frustrated about not being able to meet the patient for an FTF visit to make a definitive diagnosis due to the financial constraints of the patients.

Thus in future for DPHIMS to be used as a regular tool at nursing homes in Singapore, the residents must alternate between the traditional mode of healthcare delivery and DPHIMS. The patients would have to adhere to the dermatologist's suggestion for an FTF visit when deemed essential. For skin conditions that the dermatologists feel does not necessitate an FTF visit, diagnosis

DPHIMS for Teledermatology

could be performed via DPHIMS for a reduced consultation fee. The nurse aides being computer savvy and adaptable to changes could manage DPHIMS and patient referrals. Benefits like overtime pay, recommendation from matron for career advancement etc. would motivate the nurse aides to use the system on a regular basis. Thus DPHIMS could help avert FTF visits when considered not needed by the dermatologists by providing them with an alternative channel to diagnose/treat patients without seeing them. This may prove to be expense-saving for the patients and the healthcare organizations as the skin diseases have a high chance of being treated at an early stage with frequent follow-ups by using DPHIMS.

6.2 Recommendations for Further Research

The distributed architecture of DPHIMS enables easy expansion of the network. Further research can focus on including other disease conditions which are prevalent among senior citizens. For example tele-diagnosis modules for managing conditions like dementia and post-stroke rehabilitation could be implemented with DPHIMS apart from dermatology.

The telerehabilitation module in DPHIMS would have to cater to the uploading and storage of videos capturing exercise routines of patients. It would also have to include online surveys for each post-stroke condition in order to assess the progress of the patients. The module should allow physiatrists, physiotherapists or occupational therapists to upload sample exercise videos to serve as guidance for the patients. The teledementia module would have to mainly concentrate on assessing the progress of the patient's condition through online questionnaires. These questionnaires would judge the dependency levels of the

DPHIMS for Teledermatology

patients suffering from dementia. These help in calculating fall risks, the need for increased care, etc. of the patient.

The concept of DPHIMS at nursing homes has already motivated other research groups like the University of Oulu [62] to expand the operational capabilities to include mobile services for emergency responses etc. World Bank delegates funding the ministry of Bangladesh to build telemedicine services expressed interest in adapting the distributed model of DPHIMS for the telemedicine project in Bangladesh. Hence DPHIMS is suitable not only in urban areas like Singapore but also in developing countries like Bangladesh.

Finally, future works can also concentrate on providing DPHIMS services to community centers, general physician office and residential homes.

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DPHIMS for Teledermatology

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APPENDIX A

R05-12.

Adding years of healthy life

DSRB Ref: DSRB-A/05/229

6 Commonwealth Lane
Level 6 GMT Building
Singapore 149547
Tel: 6471 8900 Fax: 6471 2129
www.nhg.com.sg
RCB No. 200502150H

24 August 2005

Dr Leow Yung Hian
Senior Consultant
National Skin Centre

Dear Dr Leow,

Distributed personal health information management system for dermatology at Homes for Senior Citizens

This is to inform you that the NHG Domain Specific Review Board has approved the above research project to be conducted.

Documents reviewed are:

- a) IRB / DSRB Application Form: Distributed personal health information management system for dermatology at Homes for Senior Citizens, Version 1 dated 18 July 2005
- b) Study Protocol: Version 1.0 dated 18 July 2005
- c) Patient Information Sheet and Consent Form: Version 1.0 dated 18 July 2005
- d) Investigator Brochure: Edition 1 released 1 September 2005, Version 1.0 dated 18 July 2005
- e) Data Collection Form: Patient Questionnaire Version 1.0 dated 18 July 2005
- f) Data Collection Form: Nurse Questionnaire Version 1.0 dated 18 July 2005
- g) Data Collection Form: Consultant Questionnaire Version 1.0 dated 18 July 2005
- h) Web Security Form: Version 1.0 dated 18 July 2005
- i) Non-Disclosure Agreement: Version 1.0 dated 18 July 2005

DSRB also acknowledges receipt of the following:

- a) Chinese Patient Information Sheet and Consent Form: Undated Version

Please note that it is the responsibility of the Principal Investigator to ensure that the translated copies are an accurate reflection of the original approved document.

Page 1 of 2

DPHIMS for Teledermatology

DSRB Ref: DSRB-A/05/229

The approval period is from 24 August 2005 to 23 August 2006. Your study number is DSRB-A/05/229. Please use this code for all future correspondence.

Continued approval is conditional upon your compliance with the following requirements:

1. Only the approved Information Sheet and Consent Form should be used. It must be signed by each subject prior to initiation of any protocol procedures. In addition, each subject should be given a copy of the signed consent form.
2. No deviation from, or changes of the protocol should be implemented without documented approval from the NHG DSRB, except where necessary to eliminate apparent immediate hazard(s) to the study subjects, or when the change(s) involves only logistical or administrative aspects of the trial (e.g. change of monitor or telephone number).
3. Any deviation from, or a change of, the protocol to eliminate an immediate hazard should be promptly reported to the NHG DSRB within 7 calendar days.
4. Please submit the following to the NHG DSRB:
 - a. All serious adverse event (SAE) reports accompanied by NHG DSRB SAE cover note. In order to assist the DSRB, the NHG DSRB SAE Cover Note should accompany all SAE reports. Please find all forms and guidelines on reporting on the Internet at www.research.nhg.com.sg.
 - b. Report on any new information that may adversely affect the safety of the subject or the conduct of the study.
 - c. NHG DSRB Project Status Report Form – this is to be submitted 4 to 6 weeks prior to expiry of the approval period. The study cannot continue beyond the expiry date until re-approved by the NHG DSRB.
 - d. Study completion or termination report

With best regards,

A handwritten signature in black ink, appearing to read 'Giam Yoke Chin', is written below the text 'With best regards,'.

A/Prof Giam Yoke Chin
Deputy Chairman
NHG (Domain Specific Review Board A)

Cc: Medical Director, NSC c/o Research Department, NSC (via fax only)
Deputy Medical Director, NSC c/o Research Department, NSC (via fax only)
A/Prof Soh Cheong Boon, Associate Professor, School of Electrical and Electronic Engineering, National Technological University (via fax: +65 6896 7448)

Page 2 of 2

DPHIMS for Teledermatology

6 Commonwealth Lane
Level 6 GMT Building
Singapore 149547
Tel: 6471 8900 Fax: 6471 2129
www.nhg.com.sg
RCB No. 200002150H

DSRB Ref: DSRB A/05/229

19 July 2006

Dr Leow Yung Hian
Senior Consultant
National Skin Centre

Dear Dr Leow,

RENEWAL OF NHG DOMAIN-SPECIFIC REVIEW BOARD (DSRB) APPROVAL

Project Title: Distributed personal health information management system for dermatology at Homes for Senior Citizens

We are pleased to inform you that the NHG DSRB has renewed the approval for the above study to be conducted. The approval period is from 19 July 2006 to 18 July 2007.

The documents reviewed are:

- a) IRB / DSRB Application Form: Distributed personal health information management system for dermatology at Homes for Senior Citizens, Version 1 dated 18 July 2005
- b) Study Protocol: Version 1.0 dated 18 July 2005
- c) Patient Information Sheet and Consent Form: Version 1.0 dated 18 July 2005
- d) Investigator Brochure: Edition 1 released 1 September 2005, Version 1.0 dated 18 July 2005
- e) Data Collection Form: Patient Questionnaire Version 1.0 dated 18 July 2005
- f) Data Collection Form: Nurse Questionnaire Version 1.0 dated 18 July 2005
- g) Data Collection Form: Consultant Questionnaire Version 1.0 dated 18 July 2005
- h) Web Security Form: Version 1.0 dated 18 July 2005
- i) Non-Disclosure Agreement: Version 1.0 dated 18 July 2005

We acknowledge the receipt of the following:

- Appendix A: New findings and Relevant Information that Affect the Risk/Benefit of the Study
- Appendix B: Subject Information

DPHIMS for Teledermatology

DSRB Ref: DSRB A/05/229

Continued approval is conditional upon your compliance with the following requirements:

1. Only the approved Participant Information Sheet and Consent Form should be used. It must be signed by each subject prior to initiation of any protocol procedures. In addition, each subject should be given a copy of the signed consent form.
2. No deviation from, or changes of the protocol should be implemented without documented approval from the NHG DSRB, except where necessary to eliminate apparent immediate hazard(s) to the study subjects, or when the change(s) involves only logistical or administrative aspects of the trial (e.g. change of monitor or telephone number).
3. Any deviation from, or a change of, the protocol to eliminate an immediate hazard should be promptly reported to the NHG DSRB within seven calendar days.
4. Please submit the following to the NHG DSRB:
 - a. All unanticipated problems involving human subjects including serious adverse events (SAE) should be reported. In order to assist the DSRB, all SAE reports should be accompanied by the NHG DSRB SAE Cover Note. Please find all forms and guidelines on reporting on the internet at www.b2bresearch.nhg.com.sg.
 - b. Report(s) on any new information that may adversely affect the safety of the subject or the conduct of the study.
 - c. NHG DSRB Project Status Report Form – this is to be submitted 4 to 6 weeks prior to expiry of the approval period. The study cannot continue beyond the expiry date, until re-approved by the NHG DSRB.
 - d. Study completion or termination – this is to be submitted using the NHG DSRB Project Status Report Form within 4 weeks of study completion or termination.
5. We are happy to inform you that the NHG Research QA Program has been launched in May 2008. The program aims to promote responsible conduct of research in a research culture with high ethical standards, and to identify potential systemic weaknesses and make recommendations for continual improvement. This research project may be randomly selected for completion of self assessment worksheet or for a study review by the QA team. For more information please visit www.b2bresearch.com.sg.

Yours sincerely,

A handwritten signature in black ink, appearing to read "Ang Ah Ling", is placed above the printed name.

Dr Ang Ah Ling
Chairman

NHG Domain Specific Review Board A

Cc: Medical Director, NSC c/o Research Department, NSC (via fax only)
Deputy Medical Director, NSC c/o Research Department, NSC (via fax only)
A/Prof Soh Cheong Boon, Associate Professor, School of Electrical and Electronic Engineering, National Technological University (via fax: +65 6896 7448)

APPENDIX B

Consultant Survey

(Data Collection Form Consultant Questionnaire Version 1.0 Dated 15-07-2005)

Please complete this survey. Please ask for help if you have any questions. Thank you.

1. How do you rate the overall improvement of the quality of healthcare offered to patients after using PHIMS?

Excellent - 1 Good - 2 Fair - 3 Poor - 4

2. Do you think that the medical care you provided to patients using this PHIMS service is equivalent to a regular clinic visit?

Yes, it is even better -1 Yes, It is about the same - 2

No, not as good - 3 I am not sure - 4

3. Were you comfortable providing diagnosis for patients over PHIMS?

Yes, I was very comfortable - 1 Yes, I was somewhat comfortable - 2

No, I was somewhat uncomfortable - 3 No, I was very uncomfortable - 4

4. Did you encounter any problem diagnosing the patient's medical condition with only the patient's electronic medical records and digital photographs of their skin conditions?

No, I did not have problems - 1 Yes, I had problems - 2

5. If your answer to Question 4 is 'yes', could you list the problems you encountered.

6. Prior to this clinical trial, have you diagnosed a patient's skin conditions using the digital images of the diseased area of the skin?

Yes - 1 No - 2

DPHIMS for Teledermatology

7. How confident were you in providing diagnosis for patients using only the information in the PHIMS system as compared to the traditional health care environment?

Yes, I was very confident – 1

Yes, I am somewhat confident - 2

No, I am somewhat unconfident - 3

No, I am very unconfident – 4

8. How do you rate the digital photographs of the patient's skin condition taken by the nurses? Did you receive pictures with good diagnostic quality for assessing the patient's skin condition?

Yes, I received very good pictures - 1

Yes, although the pictures were sometimes unclear, it was good for diagnosis - 2

No, the image quality must improve as it makes diagnosis difficult - 3

No, the photographs are unsuitable for diagnosis - 4

9. Did you find the user interface of the PHIMS system easy to use?

Yes, I found it easy to use - 1

No, the interface was difficult to use - 2

10. If you have answered (in question 9) "No the interface was difficult to use", could you suggest some changes for further improvement?

11. Were you able to use the PHIMS system without any external assistance after the initial demonstration of the system by the researchers?

Yes -1

No -2

12. Did you encounter any technical difficulty obtaining the necessary patient and medical information from the PHIMS system for consultation?

No, I did not have problems - 1

Yes, I had problems - 2

13. If your answer to Question 12 is 'yes', could you list the problems you encountered.

14. Did you find it more convenient to attend to patient's consultation requests using PHIMS as compared to regular clinic visits which has a fixed appointment system?

Very convenient - 1

Somewhat convenient - 2

Somewhat inconvenient - 3

Very inconvenient - 4

15. Are you satisfied with the overall concept and performance of the PHIMS?

Yes, I am very satisfied - 1

Yes, I am somewhat satisfied - 2

No, I am somewhat not satisfied - 3

No, I am not satisfied at all - 4

16. Would you recommend our PHIMS service to other consultants?

Yes - 1

No - 2

Please use the remaining space to write any comments regarding your experiences during this clinical trial (e.g. what are the 3 features you like most/least in PHIMS? what features need to be added or deleted to improve it further?...)

DPHIMS for Teledermatology

Nurse Survey

(Data Collection Form Nurse Questionnaire Version 1.0 Dated 18-07-2005)

Please complete this survey. Please ask for help if you have any questions. Thank you.

1. How do you rate the overall improvement of the quality of healthcare offered to your patients after using PHIMS?

Excellent - 1 Good -2 Fair - 3 Poor - 4

2. Do you think that the medical care your patients received using this PHIMS service is equivalent to a regular clinic visit?

Yes, it is even better - 1 Yes, It is about the same - 2

No, not as good - 3 I am not sure - 4

3. Were your patients comfortable while receiving diagnosis for their skin conditions using PHIMS?

Yes, they were very comfortable - 1 Yes, they were somewhat comfortable - 2

No, they were somewhat uncomfortable - 3 No, they were very uncomfortable - 4

4. Were your patients comfortable when you took digital photographs of their skin conditions and uploaded into PHIMS for assessment by the dermatologist?

Yes, they were very comfortable - 1 Yes, they were somewhat comfortable - 2

No, they were somewhat uncomfortable - 3 No, they were very uncomfortable - 4

5. Prior to this clinical trial, have you had any experiences in dermatologic photography?

Yes - 1 No - 2

6. Were you comfortable with handling the digital camera and taking photographs of your patient's skin condition?

Yes, I was very comfortable - 1 Yes, I was somewhat comfortable - 2

No, I was somewhat uncomfortable - 3 No, I was very uncomfortable - 4

7. Did you find the user interface of the PHIMS system easy to use?

Yes, I found it easy to use - 1

No, the interface was difficult to use - 2

8. If you have answered (in question 7) “No the interface was difficult to use”, could you suggest some changes for further improvement?

9. Were you able to use the PHIMS system without any external assistance after the initial demonstration of the system by the researchers?

Yes - 1

No - 2

10. Did you find it convenient to enter patient health information and upload the digital photographs of the patient’s skin condition into PHIMS?

Yes, I found it convenient to use - 1

Yes, I found it somewhat convenient- 2

No, I found it somewhat inconvenient- 3

No, I found it inconvenient to use - 4

11. Does the use of PHIMS reduce the need for your patients to visit a dermatologist for checkup?

Yes - 1

No - 2

12. Do you prefer to use the PHIMS system for storing and maintaining your patient’s health records as compared to the traditional health care environment?

Yes - 1

No - 2

13. Do you prefer using the PHIMS system to seek consultation with the dermatologist for your patient’s skin problems instead of your patients personally visiting the dermatologist?

Yes, I prefer using the PHIMS system - 1

No, I prefer the patients to personally visit the dermatologist - 2

DPHIMS for Teledermatology

14. What is the average time taken by the dermatologist to provide you with the diagnostic report after you have submitted the request for consultation?

1 day - 1 1-4 days - 2 4-7 days - 3 More than 1 week - 4

15. Are you satisfied with the overall concept and performance of the PHIMS?

Yes, I am very satisfied - 1 Yes, I am somewhat satisfied - 2
No, I am somewhat not satisfied - 3 No, I am not satisfied at all - 4

16. Would you recommend the PHIMS service to other nurses?

Yes - 1 No -2

Please use the remaining space to write any comments regarding your experiences during this clinical trial (e.g. what are the 3 features you like most/least in PHIMS? what features need to be added or deleted to improve it further?...)