An Evaluation of Mobile Computing effect on Oncologists Workflow in Ambulatory Care Settings

by

Shadi Bani Melhem
BSN, University of Jordan, 2001

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

Master of Science

in the School of Health Information Science

Supervisory Committee

An Evaluation of Mobile Computing effects on Oncologists Workflow in Ambulatory Care Settings

by

Shadi Bani Melhem
BSN, University of Jordan, 2001

Supervisory Committee

Dr. Omid Shabestari, School of Health Information Science
Supervisor

Dr. Karen L. Courtney, School of Health Information Science
Departmental Member

Abstract

Supervisory Committee
Dr. Omid Shabestari, School of Health Information Science
Supervisor
Dr. Karen L. Courtney, School of Health Information Science
Departmental Member

Rationale:
The Cancer Agency Information System (CAIS) is the primary patient record for the British Columbia Cancer Agency (BCCA) but is only accessible on fixed computer workstations. The BCCA clinics have significant space limitations resulting in multiple healthcare providers sharing each workstation. Furthermore, workstations are not available in the patient examination rooms leading to multiple visit interruptions. Given that timely and efficient access to patient electronic records is fundamental in providing optimal patient care, the iPad Mobility Project was launched to introduce and evaluate the effect of mobile technologies and applications in improving access to CAIS and supporting clinicians' workflow.

Methods
The project evaluation framework was created in collaboration with the project stakeholders including BCCA clinicians. The framework included pre- and post-implementation questionnaires, pre- and post-implementation observational sessions, and post-implementation semi-structured interviews. Survey questionnaires mainly included standardized scales used to measure user expectations and perceptions before and after information systems implementation. Also, based on Canada Infoway System and Use Survey, the post-implementation questionnaire included questions that measure the mobile system success in terms of information quality, system quality, service quality, user satisfaction, and use measures. The response rate was 84% (n=44) for the baseline survey and 76% (n=52) for the post-implementation survey. Also, baseline and post-implementation observational sessions (n=5, n=6 respectively) were conducted to provide real-time data about the use of the available record keeping systems before and after the mobile system implementation. Post-implementation semi-structured interviews (n=11) were conducted to allow clinicians to reflect on their use of the iPad and VitalHub Chart application.

Results:
The results showed an overwhelmingly positive attitude to the use of the iPad and the VitalHub Chart application to support clinicians' mobile workflow through enhanced access to CAIS. Perceived benefits were related to three major categories: information accessibility and inter-professional communication; workflow efficiency and provider productivity, and patient care quality and safety. Conversely, perceived challenges were related to three major categories: software related challenges, hardware related challenges, and network infrastructure-related issues. Furthermore, the results showed that the success of mobile computing technology depends on its ability to support access to patients' electronic records and other central clinical information systems, on mobile devices and their applications' ergonomic features, and on end-user participation in mobile computing projects.

Implications
Mobile computing technologies have the potential to improve data accessibility, communication mechanisms, patient care quality, and workflow efficiency. However, realizing the full potential benefits of mobile computing technologies rely on several factors. Healthcare organizations need to have clear understanding of end users' needs, expectations, clinical tasks, and workflow. Engaging end-users in mobile computing technologies projects from the early stages of the project is essential to identify the various complex human, organizational, and contextual factors that affect the success of enterprise-wide mobile computing technology projects. Due to their inherent limitations, mobile computing technologies should be considered as complementary to and not as replacement to fixed computer workstations. Also, evaluating mobile technologies and applications usability is essential for both the success and safety of such innovative solutions.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BC	British Columbia
BCCA	British Columbia Cancer Agency
C&W	Children and Women's Hospital
CAIS	Cancer Agency Information System
CDSS	Clinical Decision Support Systems
CiVic	PHSA Center for Innovation, Validation, and Collaboration
CPOE	Computerized Provider Order Entry
DI	Diagnostic Images
EHR	Electronic Health Record
HIS	Health Information Systems
IT	Information Technology
PHSA	Provincial Health Services Authority
UVic	University of Victoria

Acknowledgments

I would like to acknowledge my supervisory committee for their enthusiasm and dedication to the field of health informatics. Particularly, I would like to express my deepest gratitude to my supervisor, Dr. Omid Shabestari, for his valuable guidance, patience, support, and encouragement. My sincere thanks also go to Dr. Karen Courtney and Dr. Jens Weber-Jahnke for their unique perspective, insightful comments, and feedback. I also wish to thank my managers, Dr. Jeff Barnett, Shaina Hood, my colleague Walid Youssef, and all the CIS team at PHSA for their support.

Dedication

I dedicate this thesis to my loving wife Safa Almaaitah, my daughter Reema Melhem, and my son Amer Melhem. Throughout this education journey, I have had the loving and unconditional support of my family. My wife and children have supported me with prayers, encouraging words that gave me strength to make this dream a reality. My wife and children have always stood by me and dealt with all of my absence from many family occasions with a smile.

Chapter 1: Introduction and Background

1.1 The Challenge of Cancer Care

The growing incidence of cancer in Canada and worldwide reflects the challenges that face healthcare systems in the prevention, diagnosis, and treatment of such a heterogeneous disease. In 2007, cancer was the leading cause of death in Canada, exceeding cardiovascular diseases (Canadian Cancer Society, 2012). In the same year, statistics showed that the number of Canadians who had been diagnosed with cancer was over seven hundred thousand. Based on previous statistics, it is estimated that one out of five Canadians are expected to have cancer during their lifetime and one out of four Canadians is expected to die from some sort of cancer (Canadian Cancer Society, 2012). Statistics from the United States show similar trends in terms of cancer incidence and expected cancer death (Siegel, Naishadham, & Jemal, 2012).

Cancer is a complex, heterogeneous disease. There are more than 100 types, associated with varied symptoms based on the cancer type and stage. In addition to the physical effects, cancer usually has profound negative effects on the psychological and social health status of patients and their family members. Cancer care usually involves complex decision-making, long-term complications, and multiple handoffs between primary and specialty healthcare professionals. In addition, it is usually difficult to predict the potential benefits and risks as patients vary in how they respond to the different treatment options. Therefore, cancer patients usually find it difficult to make decisions about care (Institute of Medicine (U. S.) Committee on Psychosocial Services to Cancer Patients / Families in a Community Setting, 2008).

1.2 Patient-centred Cancer Care and Information Technology

Cancer care organizations and healthcare authorities are increasingly shifting from fragmented healthcare models to a comprehensive interconnected patient-centred models to optimize cancer care and meet the multiple needs of cancer patients. Patient-centred care ensures that all clinical decisions are guided by patients' values, preferences, and needs (Institute of Medicine (U.S.). Committee on Quality of Health Care in America, 2001). Three foundational aspects characterize modern cancer care: state of the art clinical medicine that focuses on the patient's cancer and its biological features; the holistic care model that takes into consideration the physical as well as the psychological and social needs of cancer patients; and utilizing systems that support healthcare organizations in achieving clinical medicine and patient-centred care goals (Clauser, Wagner, Aiello Bowles, Tuzzio, & Greene, 2011).

Health information systems have the potential to support healthcare professionals in overcoming the challenges associated with cancer care and the complexity of medical information that healthcare providers usually need to consider in planning and providing cancer care (Executive Office of the President President's Council of Advisors on Science and Technology, 2010). Information technology can enhance cancer care services in many aspects:

- Information technology can help in the integration of patients' clinical and administrative information through the use of patients' electronic records and booking/registration systems. Such technologies and applications should support clinicians' access to the most updated patient clinical data, decision support systems, cancer management guidelines, and communication with their patients and other healthcare professionals (Patlak et al., 2011).
- Furthermore, information systems facilitate data collection for benchmarking and reporting of quality standards through the use of provincial and national cancer registries that are essential for both cancer care planning and policy making at the provincial and national level.
- Also, information technology facilitates data collection and tracking for research purposes through measurement of patient clinical outcomes and patient clinical trial matching.
- Patient portals and online resources enhance information availability for cancer patients to enable informed choice and better patient involvement in their care.
- Information systems improve cancer care safety by using bedside technology that

enhances clinicians' clinical decision making at the point of care and the application of evidence-based medicine.

1.3 Mobile Health: Global View

Mobile health (mHealth) is a relatively new emerging sub-discipline of the health informatics domain. Mobile health is concerned with utilizing mobile communications and network technologies for healthcare delivery purposes (Istepanian & Lacal, 2003). In addition to enhancing access to clinical information and improving communication among healthcare professionals, mobile information and communication technologies have been used to support hospital care, healthy behaviours, and educational awareness (Househ, 2012).

The rapid advancement in mobile and wireless technologies has created dramatic increase in the development, use, and adoption of such new innovations in almost every aspect of human life including healthcare. This global phenomenon is reflected in the number of mobile subscribers that reached almost 6 billion by 2011, representing a worldwide penetration of 86% (ITU World Telecommunication/ICT Indicators Database, 2012). In healthcare, the global penetration of mobile technologies created new opportunities to improve healthcare accessibility, quality, and efficiency, and cost effectiveness by supporting patients, healthcare professionals, and healthcare organizations.

The results of the World Health Organization (WHO) Global Observatory for eHealth (GOe) survey showed that more than 80% of WHO countries are offering at least one type of mobile health services (WHO Global Observatory for eHealth, 2011). These services varied from health call centres and emergency toll-free telephone services to mobile patient records and decision support systems (WHO Global Observatory for eHealth, 2011). Based on WHO organization regional distribution, the highest mobile health initiatives occurred in countries of the South-East Asia Region, while those in the African Region reported the fewest mobile health initiatives. When the survey results were analyzed based on World Bank income group, most mHealth initiatives occurred in high-income countries, while the lowest mHealth initiatives was associated with low-income countries. However, the difference in the number of member states in high income and low-income countries that reported at least one mHealth initiative was not significant (87%, 77% respectively), which indicate that mHealth is an appealing approach for most of the WHO countries (WHO Global Observatory for eHealth, 2011).

The WHO, the United Nations (UN), and the National Institute of Health (NIH) recognised the potential roles of mHealth technologies and applications in extending healthcare access to the most underserved and resource constrained communities in the world. Several mHealth projects were initiated to achieve the WHO millennium goals by 2015. These goals include reducing child mortality, improving maternal health, and halt the spread of HIV/ AIDS, malaria, and other major diseases. Therefore, a number of mhealth projects were initiated to increase healthcare education and disease awareness, communications with and training of healthcare professionals, remote monitoring, and diagnostic and treatment support (United Nations, 2008). For example, the "Text to Change" project focused on utilizing short-message service (SMS) to deliver mobile SMS educational awareness interventions to encourage testing and counselling for HIV/AIDS (Vital Wave Consulting, 2009). Other mHealth projects were initiated to evaluate the cost effectiveness of mHealth technologies. For example, the use of personal digital assistance (PDA) by healthcare workers in Uganda reduced the cost of collecting patients' health information by 25% (Vital Wave Consulting, 2009).

While having access to quality healthcare services is a privilege that most citizens of the developed countries enjoy, the potential application of mobile technology in healthcare delivery has been recognized in the developed world. The use of mobile technology for preventive health behaviour change (e.g. smoking cessation, physical activity, etc.) or clinical care behavior change (Diabetes self-management) have been explored in many studies (Franklin, Waller, Pagliari, & Greene, 2006; Hurling et al., 2007; Kwon et al., 2004; Obermayer, Riley, Asif, & Jean-Mary, 2004; Rodgers et al., 2005). A recent systematic review that investigated the effectiveness of using mobile phone test messages (SMS) to deliver behavioural change intervention found that SMS-delivered interventions have positive short-term behavioral outcomes, especially in population with low socioeconomic status (Fjeldsoe, Marshall, & Miller, 2009). However, the previous systematic review found that only 14 of the 33 studies met their inclusion criteria. The broad range of study designs and small sample size used in previous studies both limit the ability to draw strong evidence and highlight the importance of improving the quality and rigour of future studies (Fjeldsoe et al., 2009). Also, the review found that the majority of the included studies (n=10) focused on clinical care interventions, using mobile text messages as a reminder to increase adherence to treatment regimens among patients. Fewer studies (n=4) focused on preventive health behaviour change (e.g. smoking cessation) delivered through mobile SMS messages (Fjeldsoe et al., 2009). Despite the encouraging results of previous studies, the use of SMS messages as mHealth interventions mainly focused on certain patient groups (Liang, 2011).

1.4 Mobile Health: Paradigm Shift

Healthcare delivery systems around the globe continue to be pressured to contain cost while improving healthcare quality and safety. In Canada, a study by the Fraser Institute found the financial situation of the Canadian healthcare system unsustainable (Skinner, 2007). Health information systems (HIS) have been proposed as one of the solutions that will help improve healthcare quality, safety, and efficiency (Anderson & Aydin, 2005). Also, healthcare organizations have recognized the role of HIS in improving the quality and safety of cancer care. HIS has the potential to reduce medical errors by enhancing access to patients' clinical information as well as communication among healthcare professionals (Kubose, Cimino, & Patel, 2001; McKnight, Stetson, Bakken, Curran, & Cimino, 2001; Stetson, McKnight, Bakken, Curran, & et al, 2002). However, there are still some gaps in how HIS could be used effectively to meet the needs of healthcare professionals and their patients (Clauser et al., 2011).

In general, healthcare delivery involves a high level of mobility and time constraints. Physicians, nurses, physiotherapists, and other allied healthcare professionals are constantly moving between patients, wards, clinics, and different healthcare organizations. However, the deployment of health IT solutions has focused mainly on using fixed computer workstations to provide access to patient and administrative information. In other words, healthcare providers are tethered to a single location even though they might be needed somewhere else (Gurses & Xiao, 2006).

The availability of health-related mobile applications designed to help patients manage their conditions and promote healthy lifestyles have huge potential effects on the healthcare delivery system and the whole society. For example, mobile information technology is part of the Cancer Care Ontario (CCO) strategy to support health professionals and patient self-care. CCO offers three free mobile applications (apps) for the iPhone, Android, and windows phone 7. The first Mobile application is the Cervical Screening app (Cancer Care Ontario, 2013) that provides healthcare professionals easy access to a summary of cytology guidelines, algorithms for follow-up of abnormal cytology, patient resources, and information on the Ontario Cervical Screening Program. The second application is the Drug Formulary app ,which provides information for drugs used in systemic cancer treatment, symptom management, and patient information sheets (Cancer Care Ontario, 2013).. The third app is the Symptom Management Guides app that provides healthcare professionals both medication-related and non-medication-related recommendations based on symptom severity (Cancer Care Ontario, 2013). The development of such applications reflects the increasing recognition of mobile computing technologies role in improving cancer care through improving access to information and resources.

The e-Health Technology Program at MD Anderson Cancer Centre is another example of utilizing mobile applications for cancer care. The program focuses on the development and use of web, mobile and multimedia applications to enhance cancer prevention and care. These applications utilize video, audio and graphic design to support health behaviour change, symptoms management, and quality of life. The MD Anderson Cancer Centre website (http://www.mdanderson.org/) provides valuable information on trusted mobile applications that could be used by cancer patients as well as healthy people for cancer prevention and care. These applications include Cancer Treatment and Survivorship apps, Risk Assessment apps, and Quit Smoking apps (MD Anderson Cancer Centre, 2011). Furthermore, researchers at MD Andersons Cancer Centre utilize mobile technologies for research purposes to streamline information exchange between researchers and study participants. For example, the Ecological Momentary Assessment (EMA) features of mobile applications allow assessing behaviours, symptoms and emotional or cognitive statuses of people in real environments. The EMA features of mobile applications enhance the ecological validity of the collected data by overcoming the biases associated with retrospective recall and by capturing a more details than retrospective questionnaires (Burton, 2013).

The rapid technological advancements continue to drive the adoption of mobile computing technologies and their use in almost every aspect of our lives. The integration of mobile phone technology with portable computers, touch screens, browsers, cameras, multimedia players and thousands of mobile applications for medical, educational, fitness, and social networking uses created new opportunities for mobile health applications and technologies. However, most of the mHealth literature has focused on the development of stand-alone mobile health applications that were intended for the use of individuals, either patients or healthcare professionals. The use of enterprise-wide mobile technologies has been limited due to issues related to the human, ergonomic, and security features of mobile technology. The early attempts to integrate mobile computing technologies into complex healthcare settings faced many challenges and even failed. Similar to other health IT projects, mobile health technologies and applications failed not because of technical problems but more usually because of the human aspects of mHealth and how they fit in complex healthcare settings (Johnson, Meyer, Woodworth, Ethington, & Stengle, 1998; Rigby, 2006; J. Wu, Wang, & Lin, 2007).

1.5 Mobile health: Emerging Trends

As healthcare providers' adoption of mobile technology and applications continue to increase, new paradigms of mobile technology utilizations in healthcare settings have emerged. The Bring Your Own Device (BYOD) approach is based on allowing healthcare providers to use their personal smartphones and tablets to connect to a hospital's networks and to access healthcare and enterprise applications. Many healthcare organizations have readily accepted the BYOD approach because of the convenience and potential cost savings associated with allowing healthcare professionals to use their own devices (Healthcare Information and Management Systems Society, 2011; Shrestha, 2012).

However, Healthcare is a highly regulated industry, and failure to abide by laws related to the privacy and security of health information can prove costly and damaging to an organization's reputation and image. For example, In 2012, Alaska's Medicaid office agreed to pay the U.S. Department of Health and Human Services (HHS) $1.7 million to settle a case that began with a lost hard drive containing patient protected health information(U.S. Department of Health & Human Services, 2012). In 2011, More than 250,000 devices were infected by the DroidDream malware attack. This DroidDream malware manipulated Google Android mobile devices in order to access unique personal identifiable information and started downloading additional malicious programs without the user's knowledge (Kabachinski, 2013; Shrestha, 2012).

To address these privacy challenges, some healthcare organizations support only having personal mobile devices that are controlled and owned by the organization. This corporate owned, personally enabled approach allows healthcare professionals to have their own personal mobile device, which is owned and controlled by the organization policies. At the same time, it allows the organizations to control and monitor mobile technology use through the use of the organization Mobile Data management (MDM) software's. Another option is to supervise a set of mobile devices that remain under the organization direct control and can be configured on an ongoing basis. Supervised devices are typically organization-owned and dedicated to specific functions (e.g. EHR) and when added security is needed or desired, such as the case of healthcare where multiple healthcare professionals share a pool of devices (Clevenger & Books24x7, 2011).

According to a 2011 Survey by the Health Information Management Society (HIMSS), the majority of respondents (55%) noted that their organizations support only devices that are provided by and owned by the healthcare organization (Healthcare Information and Management Systems Society, 2011). However, the survey found that only 38% noted that their organization has a mobile technology policy in place that regulates the use of these devices and outlines the organization's mobile strategy which raised an important issue that need to be addressed to ensure the safety and compliance with health information privacy regulations and laws (Healthcare Information and Management Systems Society, 2011). Just one year later, the HIMSS mobile technology survey found two-thirds reported that their organization has a mobile technology plan in place which reflect the efforts and increasing awareness of the need to address clinicians information access needs while maintaining the security measures for using mobile computing technology (Moyer, 2013)**.**

1.6 BC Cancer Agency (BCCA) and Information Systems

The BC Cancer Agency is one of nine agencies operated by the Provincial Health Services Authority (PHSA). The BCCA is responsible for providing province-wide cancer care services to the residents of British Columbia. The services include cancer prevention, diagnosis, treatment, and rehabilitation. BCCA has adopted a comprehensive and integrated cancer care model to provide equitable, standardized, patient-centred care. This model is based on provincially distributed services, including six regional cancer centres, the Communities Oncology Network, the provincial cancer registry, and connecting systems, to provide high quality patient-centred care (BC Cancer Agency, 2011; Carlow, 2000).

BCCA recognized that an integrated information system is essential to fulfil its provincial cancer care responsibilities. Therefore, the Cancer Agency Information System (CAIS) was built on the principle of having only one patient record that can be accessed throughout the geographically distributed centres and clinics. CAIS is a collection of electronic applications that provide access to patients' registration information and laboratory results, medical documents and reports (consultation, radiology, notes, etc.), images, appointments, clinicians' schedules, and a "physician action list," which includes all documents that need to be acknowledged (Carlow, 2000; Henkelman, 2003).

Although the CAIS is the primary patient record repository, it is only accessible on fixed computer workstations and within the BC Cancer Agency facilities. The BCCA clinics have significant space limitations resulting in multiple healthcare professionals sharing each workstation. Furthermore, workstations are not available in the patient rooms during clinical conferences or grand rounds. During patient encounters, clinicians rely on paper charts (hybrid environment) that are either out of date or not available when needed.

Recognizing that prompt and efficient access to patient records is vital in providing optimal patient care, a novel and cost efficient solution is necessary to improve clinician access to CAIS. This prompted the BCCA and PHSA Information Management / Information Technology Services (IMITS) to embark on an innovative provincial collaboration to introduce and evaluate the effect of a mobile device to improve access to CAIS and support BCCA clinicians' workflow.

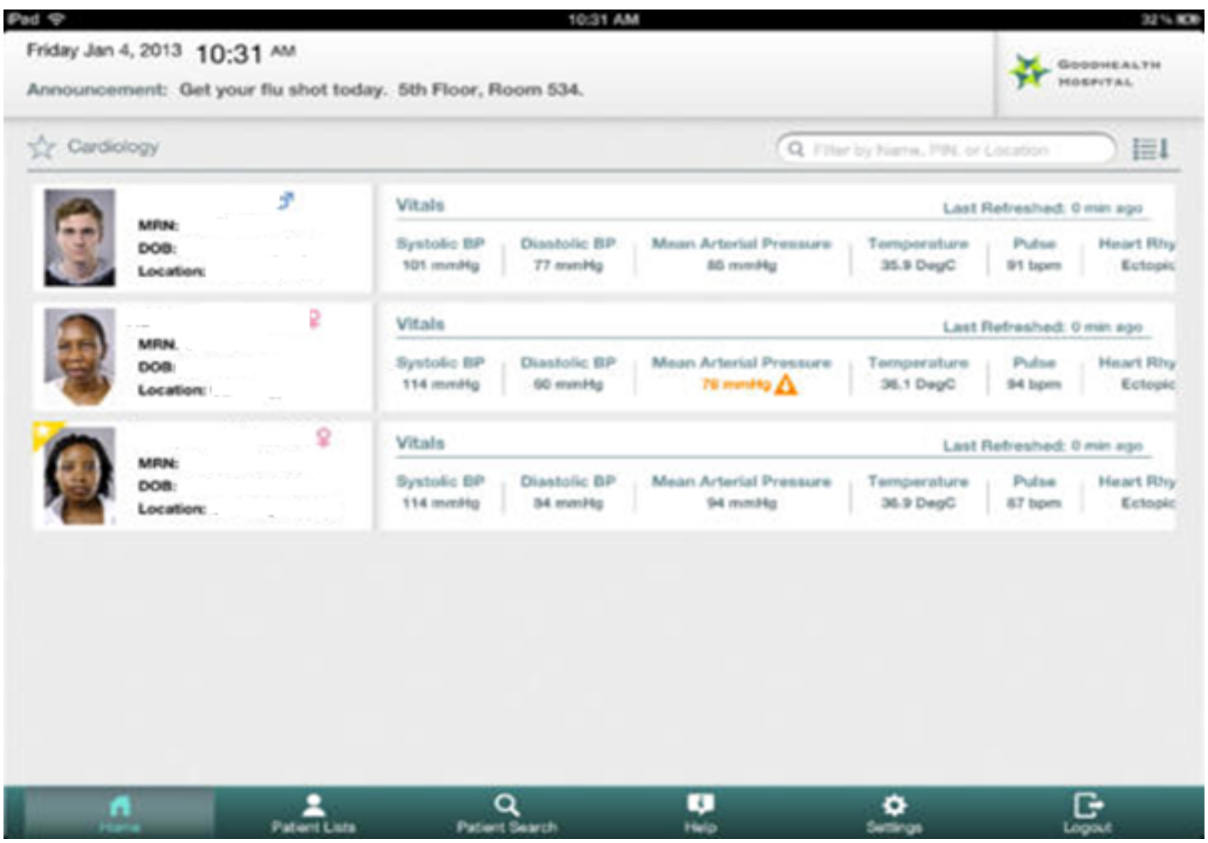
1.7 The IMITS iPad Mobility Project

The research presented in this thesis has been conducted as phase 1 of the IMITS Mobility Project at the Provincial Health Service Authority (PHSA). The IMITS Mobility Project was established in 2012 as an interdisciplinary pilot project with participants from PHSA IMITS Centre for Innovation, Validation, and Collaboration (CiViC), BCCA, Children and Women's Hospital, Health Shared Services of British Columbia (HSSBC), and the University of Victoria (UVic) to evaluate the use of the iPad to support clinical workflow. The project followed a phased implementation approach and started at the BCCA for 2 months (phase 1) followed by a Children and Women's Hospital (C&W) project (phase 2).

The IMITS Mobility Project involves interfacing a native iPad application, VitalHub Chart (http://www.vitalhub.com/) with the Cancer Agency Information System (CAIS). Participative and iterative design methodology was used to design and build the VitalHub Chart app with continuous collaboration and feedback from the Clinical Design Team, comprised of physicians. The VitalHub Chart app provides real-time access to patients' electronic records at BCCA (Figure -1). For the purposes of the pilot project, clinicians were provided access to a selected subset of the electronic health records including medications, laboratory results, documents, and notes, as well as oncologists' schedules and patients' appointments. Clinicians could also access a wide variety of Apple approved iPad apps at their own discretion. The mobility project involved clinicians from different professional disciplines (radiation oncologists, medical oncologists, residents, and oncology general practitioners).

The deployment strategy was based on using BCCA-owned mobile devices (iPad) that is assigned to a specific user for the period of the pilot project. At the end of the pilot project, all of the devices were collected from the project participants. This approach ensured that that the deployed devices are configured according the security measures established by the privacy department at Health Shared Services BC (HSSBC). Security measures were tested and evaluated. Initially the pilot project incorporated a mobile device management (MDM) system, Afaria (https://www.sapafaria.com/), which did not meet Health Shared Services BC (HSSBC) requirements and instead another proven MDM technology called “Active Sync”, was used to provide PHSA security measures.

At the time I joined PHSA, the project was in the early stages of analysis and design of the iPad application (VitalHub Chart). As a business analyst, I was assigned to lead the iPad Mobility Project evaluation. The project evaluation aligned with my interest in the opportunities and challenges associated with using mobile technology in healthcare settings. Therefore, the project evaluation was a great opportunity to do my thesis research.



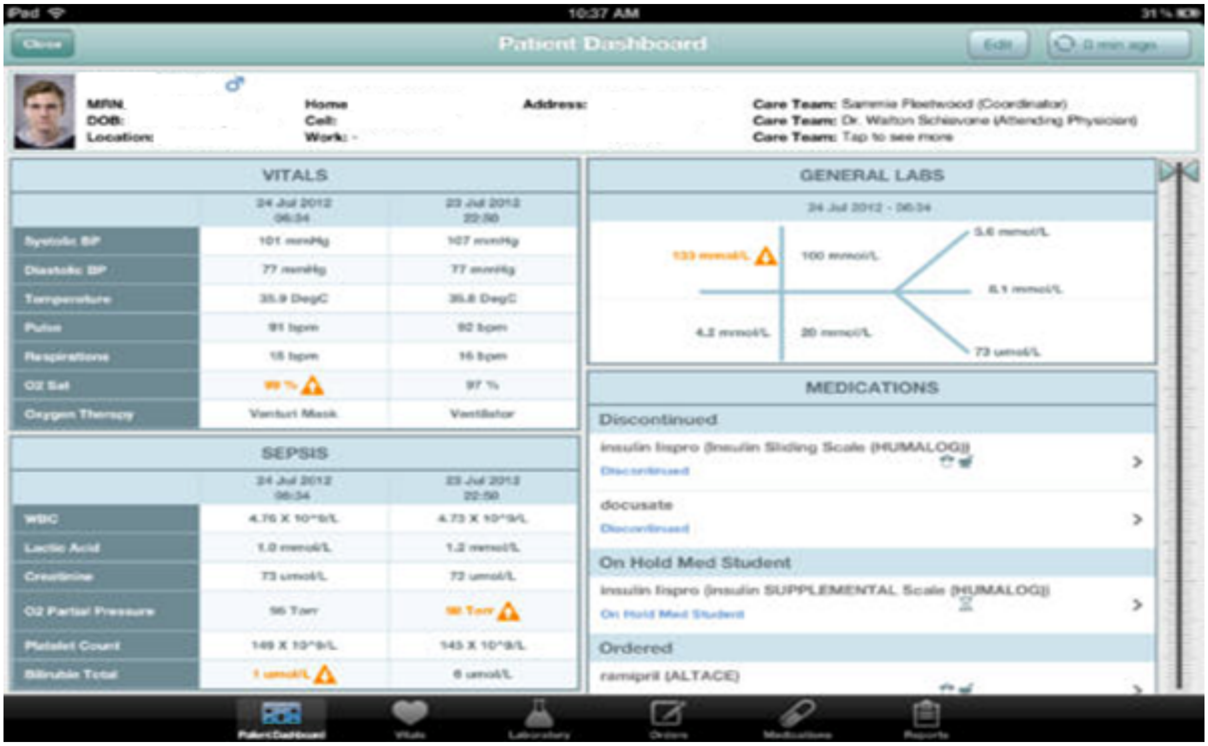


Figure 1 - Screenshots (VitalHub Chart App)

1.8 Statement of the Problem

As mentioned previously, most of the earlier studies have focused on the development of stand-alone applications that are intended for the individual patient or healthcare professional use. The results of many of the previous studies emphasize that realizing the full benefits of mobile technology depends on integrating these stand-alone applications with more complex health IT systems that exist in healthcare organizations, particularly the electronic health record (Ammenwerth, 2000; Househ, 2012). In addition to lack of integration with HIS, early mobile health projects faced many challenges due to ergonomic limitations (system speed, small screen size, short battery life, data entry mechanism), security and privacy concerns, and how they fit into the complex work environment of healthcare professionals (Chen et al., 2004; Kushniruk, Triola, Borycki, Stein, & Kannry, 2005; Wu, 2007).

In the last few years, there have been huge advancements in mobile technology and mobile computing technology capabilities have improved dramatically. For example, the new generations of mobile computing technologies have bigger screens, longer battery life, multiple functionalities, wireless connectivity, better security and authentication measures, and the availability of thousands of medical applications. Previous studies showed that close 50% of physicians in the United States and Canada were using mobile technology in 2004 (Martin, 2003; Miller, Hillman, & Given, 2004). On comparison, recent studies showed that mobile technology adoption rate has increased to almost 90% among healthcare providers (Wallace, Clark, & White, 2012). The high adoption rate among healthcare providers increased the demand for using mobile computing technologies to improve information access and communication with patients and other healthcare professionals. At the same time, healthcare organizations have recognized the potential benefits of using mobile technology to meet clinicians' information access and communication needs, and to improve healthcare quality, safety, and efficiency.

Anecdotes and informal results of the recent enterprise-wide mobile computing technology projects are encouraging. For example, the Ottawa Hospital has successfully developed and deployed a clinical mobile application that allows physicians and residents to access patients' electronic health records and other computerized resources (Geiger & Maisonneuve, 2012). However, there are a limited number of formal evaluation studies about mobile computing technology and how they are being used in healthcare settings. In specific, there is a lack of knowledge regarding the use of mobile computing technology to support clinicians' workflow and of its effect on healthcare professionals' work practices. Therefore, an understanding of clinicians' perspectives concerning mobile technology will provide insight into how it influences clinician practice and how to successfully introduce mobile technology in healthcare settings to support clinicians' information and access needs and ultimately to improve quality and safety in patient care.

1.9 Purpose and Significance of the Study

According to the sociotechnical approach, information systems include not only information technology but also the information processing and interaction between the information system and the end-user in a given environment. Therefore, evaluating the success of information systems requires evaluating not only the technology (hardware and software) but also the social and behavioural aspects that affect and are affected by the technology (Ammenwerth, Gräber, Herrmann, Bürkle, & König, 2003). That means the success of health IT projects depends heavily on many factors, including how the technology matches with clinical workflow, how the technology is being initiated in the organization, the quality of the output information, the available training and maintenance, system use, and users' motivations to use the system (Berg, 1999).

At the BCCA, timely access to patients' electronic records stored in the Cancer Agency Information Systems (CAIS) is vital for providing high quality and efficient care to cancer patients. However, the current situation of limited access to computerised resources and space constraints present a challenge to clinicians' workflow as well as patient care quality and safety. BCCA clinicians work in fast paced ambulatory care settings and depend largely on a hybrid environment of electronic and paper-based patient records and processes. The purpose of the project was to evaluate the effectiveness of using the most recent mobile computing technology (the Apple iPad and a native iPad application, VitalHub Chart) to support clinical workflow, provide a user-friendly mobile interface that will address the limited computerized resources and space limitations in the BCCA, and identify potential benefits and related challenges. In addition to being a complementary tool to enhance access to patient charts available through fixed desktop computers, the objective was to improve coordination and communication of healthcare workers in the BCCA clinical areas and enhance efficiency, thereby improving the quality of cancer patient care.

Health information technology literature indicates that most new IT/IS project failures have been attributed to non-technical aspects, human aspects such as user characteristics and current workflow, and healthcare professionals' resistance to use the systems as a consequence of limitations in their IT skills (Fitch, 2004; Wu, Wang, & Lin, 2005). While technological aspects are advancing at a fast pace, the human aspects of mobile computing technologies and applications and how they can be integrated into healthcare process and clinician workflow require further investigation. Understanding the end-user perspective on what constitutes usefulness of technology is both distinct from and complementary to that of system developers.

As a pilot project, the iPad Mobility Project required rigorous evaluation to help executive management/leadership at PHSA IMITS and BCCA make more informed decisions about adopting the iPad as a standard tool to access the BCCA information system. Recognizing that the success of information systems depends on their ability to meet end-user needs and compatibility with work practices, project stakeholders were highly interested in evaluating the project from clinicians' perspectives. Specifically, stakeholders were interested in understanding clinicians' perspectives on the benefits, opportunities, and challenges associated with the use of the Apple iPad and a native iPad application (VitalHub Chart) to support workflow, information access, and communication.

Health IT evaluation studies span the full spectrum of the system development life cycle (SDLC) from planning and analysis to design, implementation, and support phases. Given that mHealth is a new research area, especially at the enterprise level, more evaluation studies are needed. Recognizing that user acceptance is one of the most crucial factors in the success of health information technologies, evaluation studies that investigate end-user perspectives on what constitutes technology usefulness and how it could be utilized to support healthcare professionals are needed. Moreover, evaluation studies need to evaluate to what extent the recent advancements in wireless mobile computing technologies are able to support complex activities and processes of healthcare delivery.

1.10 Thesis Objectives

Given that mobile health is relatively new research area, the thesis objectives are:

1. To conduct a narrative literature review about mobile technology and applications that will inform the study design and allow the integration of the study results in the broader context of the literature. This type of review is useful in gathering together a volume of literature in a specific subject area and presenting a broad perspective on a topic and often describe the history or development of a problem or its management (Cronin, Ryan, & Coughlan, 2008; Green, Johnson, & Adams, 2006)
2. To conduct a multi-method evaluation study that will focus on the following:

- Exploring BCCA clinicians' perspectives on the effect of mobile technology on their practice and workflow.

- Exploring the opportunities and challenges of using mobile technology within BCCA ambulatory care settings. Specifically, evaluating the ability of the iPad and the VitalHub Chart application to meet BCCA clinicians' information and commination needs, and perceived effect on improving cancer care quality and safety.

1.11 Research Questions

The purpose of this research is to describe the impact of using the iPad and a native iPad application on BCCA clinicians' practice. The following research questions will be answered:

1. How do BCCA clinicians perceive the effect of the iPad and VitalHub Chart on their workflow and patient care?
2. What are the opportunities and challenges of using mobile technology in BC Cancer Agency ambulatory care settings?

This study utilized an exploratory, mixed method approach to investigate the research questions outlined above. In order to summarize the current state of knowledge in the area to serve as a background for the study, a narrative literature review regarding the use of various mobile technologies and applications in different healthcare settings was carried out. The literature is discussed in the following chapter.

Chapter 2: Literature Review

2.1 Methodology

The literature review explored the effectiveness of using mobile computing technologies and applications to support healthcare professionals in performing their clinical and other daily activities. Specifically, looked at how healthcare professionals perceive the effect of using mobile technologies in enhancing patient care quality and safety such as the ability to involve in their care, timeliness of patient care, clinical-decision making process, patient education, and error prevention. The literature review is conducted in May 2012, using the PubMed search engine. The medical subject-heading (MeSH) tool, which is used to index MEDLINE articles, did not contain “mobile computing”. Therefore, the electronic search used the following MeSH terms: " handheld computer " OR “bedside computing” OR “technology assessment” AND “healthcare provider” AND “computer systems evaluation”. Research studies that described the development, use, or evaluation of mobile computing technologies and application at health care settings (hospital, clinic) were considered for review. Studies not published in English were excluded. Also Studies were restricted to those published between 2000 and 2012 and have a full text and abstract available. The initial search returned 338 results. When restricting the results to publications in the last 10 years, published in English, and have full text and abstract available, the number of the search results was reduced to 168. After reviewing the abstracts, 40 articles were selected for reviewing based on their relevance to the current study. Details of the included studies are included in Appendix (E). It is important to note that the conclusions presented in this review was focused on medical literature and did not include other literature such as engineering literature, which may biased the findings and conclusions made in this chapter.

2.2 Background.

Mobile health falls under the overarching definition of health informatics. According to the Canadian Health Informatics Association (COACH), health informatics refers to “the application of information technology to facilitate the creation and use of health related data, information, and knowledge" (Canadian Health Informatics Association, n.d). Mobile health (mHealth) is further defined by Instepanian and Lacal (2003) as the "emerging mobile communications and network technologies for healthcare systems". .

In the literature, health care providers are shown as early adopters of mobile technology. Since the introduction of the Personal Digital Assistants (PDA) in the early 1990s, healthcare providers recognized the potential benefits of mobile computing technology. By 2004, handheld computers were used by 40% to 50% of physicians in the United States and Canada (Martin, 2003; Miller, Hillman, & Given, 2004). In 2005, there were 559,800 nurses who were using PDAs compared to 408,020 physicians in the United States and Canada (Lu, Xiao, Sears, & Jacko, 2005a). Balen and Jewesson (2004) found that 28% of pharmacists in one Canadian hospital were using PDAs on a daily basis (Balen & Jewesson, 2004). Healthcare professions use these technologies for clinical education, to communicate with their colleagues, to support their clinical decision making, and to access enterprise Health Information systems (HIS). Adoption at the enterprise level is relatively new and most mobile applications are still standalone. Also, most attempts of integrating mobile computing with the enterprise health information systems faced many challenges. However, with further developments, there are more advanced mobile technologies that are available for clinical use.

2.3 Mobile Technologies and Healthcare Providers Education

Students from various health disciplines have been using mobile technologies and applications to support their educational needs and enhance their confidence in clinical decision-making (Fisher & Koren, 2007; Koeniger-Donohue, 2008; Leung et al., 2003). Medical students, residents, and attending physicians are required to acquire and remain updated with vast amounts of medical information related to their medical education and patient care. Medical student and resident interest in using mobile technology started with the release of the Apple Newton PDA in 1993 and the Palm Pilot in 1996. In 2006, Kho et al. estimated that around two thirds of medical students and residents use PDAs for educational purposes (Kho, 2006). Medical textbooks, drug reference tools (e.g., ePocrates Rx), and medical calculators were rated as the most useful PDA applications.

Mobile technology has been used to track and evaluate medical students' educational progress. Traditional methods for assessing healthcare students educational and learning experience has been replaced by the use of computerised resources including mobile computing technology. Several studies reported the use of a handheld-based records and procedure logs to track and analyze the students' workload and identify gaps in their educational experience (Kurth, Silenzio, & Irigoyen, 2002; Lee, Sineff, & Sumner, 2002; Seago, Schlesinger, & Hampton, 2002; Wallace, Clark, & White, 2012). Using a handheld device, students can enter patients' encounter information into a spreadsheet that can be easily sent to central database for analysis, evaluation, and feedback. The benefits of using handheld procedure logs include high data reliability, low data entry workload, the ability to provide quick feedback, and improved overall computer literacy (Davies et al., 2012; Denton, Williams, & Pangaro, 2003; Engum, 2003; Hammond & Sweeney, 2000).

The practice of evidence-based medicine is an essential component for enhancing student's clinical decision-making and patient safety. Leung et al (2003) assessed the educational effectiveness of PDA-based decision support (InfoRetriever) on learning evidence-based medicine among fourth year medical students at the University of Hong Kong (Leung et al., 2003). The clinical decision support system (CDSS), InfoRetriever, provided access to seven evidence databases. This included abstracts from the Cochrane Systematic Reviews, practice guidelines, clinical decision rules, risk calculators, and basic information on drugs. The results showed that the use of handheld-based was associated with significant improvements in participants' educational experience with evidence-based medicine compared to modest improvement associated with the use of the traditional pocket cards guidelines. However, the success of using handheld-based CDDS to support learning evidence-based medicine was associated with several factors including supportive faculty attitudes, good knowledge of evidence-based medicine, and enhanced computer literacy skills (Johnston et al., 2004).

In nursing education, research has shown that PDA use in a clinical practicum is associated with positive effects on enhancing information retrieval, critical thinking, professional image, communication skills, and healthcare safety and efficiency (Fisher & Koren, 2007; Koeniger-Donohue, 2008). Wittmann-Price, Kennedy, and Godwin (2012) evaluated nursing students and staff nurses perceptions about the use of smartphones to access clinical reference information during a 10-week clinical rotation at a medical-surgical unit (Wittmann-Price, Kennedy, & Godwin, 2012). In this mixed method study, nursing students used their personal smartphones to download a software package. This package included access to nursing diagnosis, pharmacology, and laboratory information; an encyclopaedia; and the MEDLINE database (Wittmann-Price et al., 2012). The results showed that smartphones are powerful resources for nursing students' information needs and clinical decision-making. Students felt that using smartphone in clinical setting increased their confidence in providing patient care. The medical-surgical unit staff believed that students should be allowed to use their smartphones for clinical purposes. They saw that its usage made students more prepared and confident when providing patient care. However, the study highlighted the importance of considering other factors like students' financial situation and technical skills when considering incorporating smartphones into nursing educational programs. Also, the study identified the need for future studies to evaluate patient satisfaction with the use of mobile technology to support their care delivery. The future studies need to consider demographic variables (e.g. age, and comfort with technology) and the socioeconomic status, and their effect on the level of technology use and user satisfaction (Wittmann-Price et al., 2012).

Limitations

The proponents of using mobile computing technologies in clinical settings emphasize that handheld computers provide rapid, point-of-care access to needed information. However, medical students might become overly dependent on their peripheral brains and handhelds could negatively impact their learning experience (Crelinsten, 2004). While most medical students and residents found handheld PDAs to be useful for medical education purposes, concerns about the impact of using mobile technology on patient-providers relationship has been raised by both medical residents and junior doctors in the United Kingdome (Payne et al., 2012). This highlight the importance of evaluating how mobile technology is being used by medical, nursing, and other allied health students in healthcare setting (Payne et al., 2012).

The multiple educational applications currently available for students require active role from both educational program leaders and healthcare organizations to evaluate and identify the best educational applications for students learning purposes (Davies et al., 2012; Wallace et al., 2012). Furthermore, usability issues related to small screen size and data entry mechanisms have led to growing concerns about potential medical errors when using such technologies in clinical settings for patient care activities (Kushniruk et al., 2005).

2.4 Mobile Technology Use in Clinical Practice

Healthcare practice is an information intensive environment where healthcare professionals constantly correlate the latest diagnostic and therapeutic information with patients' clinical data. It requires coordination among the different healthcare providers. Mobile personal applications help coordinate care and manage clinical work. Also, timely access to medical knowledge and clinical reference applications is helpful, especially with the continuous growth of available medical knowledge, the expectation to follow clinical guidelines, formulary restrictions, and the time limitations placed on healthcare providers. Similarly, access to patient information is critical for sound clinical decision-making and ultimately patient care quality and safety. Mobile computing technologies and applications has the potential to enhance healthcare professional access to medical knowledge resources, clinical reference applications, and patient clinical information systems. This section discusses the various mobile applications that have been reported in the literature.

Personal management applications

Mobile technology offers variety of personal management applications that have been used by healthcare professionals to organize their daily activities (calendars), for note taking (notepads), and for care coordination with other healthcare professionals. Early generations of mobile technology have been used to facilitate patients' handoff process between healthcare providers (Luo, Hales, Hilty, & Brennan, 2001). In an early study, Luo, Hales, Hilty, and Brennan (2001) described how the basic PDA features (To-Do list, schedule, address book, and notepad functions) could be used to enhanced care coordination, workflow efficiency, and time saving. However, a number of limitations have been reported. It was found that data entry was difficult when using a stylus or a virtual keyboard. Also, the fragility of the device and the associated security risks if the device is lost or stolen are limitations when using a PDA (Luo, Hales, Hilty, & Brennan, 2001). Even with these limitations, mobile devices are still appealing for healthcare providers. Especially with the newer smartphones and tablet computers that offer more advanced features and capabilities that can support their work. This includes wireless communication properties such as web browsing, instant messaging, emails, and video conferencing.

Clinical reference applications

Mobile technologies and applications have been used to help healthcare professionals to cope with the constantly increasing pharmacology knowledge. The amount of information needed to identify the risks of all possible drugs–drug combinations are beyond the capabilities of human memory. In comparison to paper-based pharmacology references, mobile drug applications have many advantages including quick and easy access at the point of care, the ability to check drug interaction, and access to updates related to new drug information and recalls from regulatory agencies (Baumgart, 2005). Lack of access to updated information regarding medications indications, dosing guidelines, side effects, and contraindications was found to be associated with increased adverse drug events (Marano, Murianni, & Sticchi, 2005; Cullen et al., 1997; Lazarou, Pomeranz, & Corey, 1998; Leape et al., 1995).

Pharmacopeias, drug reference applications, are considered among the early-adopted mobile applications. Positive effects of using drug reference applications have been reported in many studies (Rothschild et al., 2006). A 2002 survey study found the use of *ePocrates Rx* application to be associated with positive effects on professional satisfaction; efficiency with faster access and retrieval information retrieval; clinical decision-making; and patient safety (Rothschild, Lee, Bae, & Bates, 2002). Among the 946 survey respondents, 80% reported improved drug knowledge as a result of using *ePocrates Rx*, 54% reported higher level of satisfaction with their clinical practice, and 50% reported avoiding one or more serious adverse event per week through the use of *ePocrates Rx* (Rothschild et al., 2002). Despite the positive results, the authors called for more rigorous evaluation using randomized controlled trials to confirm these perceived benefits.

In 2006, Rothschild et al, evaluated the level of use of a software package that included a *pharmacopeia*, a medical diagnostic and therapeutic reference, and an infectious disease reference (Rothschild, 2006). The results showed that the most used application was the drug reference application (mean=6.3 times/day) and the majority of the survey respondents (61%) believed that the use of the clinical reference package prevented adverse drug events or medication errors three or more times during the four weeks study period (Rothschild, 2006). Based on the study results, it was concluded that realizing the full benefits of mobile clinical reference applications depended on healthcare organizations' support to provide mobile access to patients' electronic healthcare record (EHR). Also, integrating clinical reference applications with health information systems (e.g. EHR, CPOE), and providing financial and training support (Rothschild, 2006).

In a systematic review of the literature, Garritty and EI Emmam (2006) found that the majority of peer-reviewed studies related to the use of PDA focused on physicians and/or medical residents (Garritty & EI Emmam, 2006). Responding to this gap in the literature, Stroud, Erkel, and Smith (2008) studied PDA use among nurse practitioners (NPs) in the United States (Stroud, Smith, & Erkel, 2009). Among the 126 randomly selected participants, 64% were using PDA. The drug reference applications (mainly ePocrates Rx) were highly appreciated followed by medical textbooks (e.g. Griffith's 5-minute clinical consult) and medial calculator applications (e.g. MedCalc) (Stroud et al., 2009). The majority of the study respondents believed that PDA use improved their productivity (75%), supported their clinical decision-making (91 %), and promoted patient safety (89%) (Stroud et al., 2009).

Medical knowledge applications and online resources

Immediately after the introduction of the Apple Newton PDA in 1996, further exploration was done to use mobile technology in accessing clinical textbooks. The Constellation project was launched to develop and evaluate the effectiveness of providing residents with a PDA loaded with digital medical textbooks, medical calculators, and built-in personal organizer functionality (address book, notepad, etc.). Residents from two US-based hospital participated in the project. The project was evaluated using pre- and post- surveys and an audit trail to track system use. The results showed that most participants had positive experience with use of the PDA in their clinical practice due to ease of access and device portability. On the other hand, residents experienced some challenges related to the ergonomic aspects of the PDA. Some of the limitations listed were the devices' heavy weight, and some difficulty with the data entry mechanisms. Also, the PDA limited memory did not allow downloading the full textbooks, which negatively impacted residents' perception of the PDA usefulness. Nowadays, technological advances have made it possible for healthcare professionals to access a variety of electronic medical references through many platforms including mobile technology. According to a recent survey study, medical residents prefer to use electronic medical resources for their reading activities (Edson et al., 2010). The majority of the respondents (94%) cited UpToDate (http://www.uptodate.com/home) as the most effective resources for knowledge acquisition and to find answers for clinical questions at the point of care (Edson et al., 2010).

From a nursing perspective, information management constitute a large part of the nurses' roles. For that reason mobile technology can be a great "fit" for nursing education and practice (Cassey, 2007; Koeniger-Donohue, 2008). Krauskopf and Farrell evaluated the accuracy and efficiency of clinical decisions made by novice nurse practitioner (NPs), using either PDA-based Griffith's Five-Minute Clinical Consult application or the traditional textbook, to answer specific clinical scenarios (Krauskopf & Farrell, 2011). Participants were randomized either to the PDA group or the textbook group and both completed the same two simulation clinical scenarios in a randomly assigned order. While the study did not evaluate the accuracy of PDA resource, the results showed that accuracy of the PDA-group was equal to the textbook group when making decisions regarding laboratory values, diagnosis, and treatment. In terms of efficiency, PDA users required significantly less time to determine an answer in three of six clinical decision-making areas with equivalent accuracy to the textbook group. However, the authors emphasized the need for developing and employing scientific methods to evaluate the quality of mobile health applications.

The recent advances in mobile computing technologies and wireless networks have made it possible to access online medical sources at the point of care to answer questions that might arise during medical rounds and bedside patient care. Hauser et al. designed a prospective cohort study to evaluate the effectiveness of using wireless handheld computers in meeting clinicians' informational needs during clinical rounds at the point of care (Hauser, 2007). The PDA application MD on Tap (http://mdot.nlm.nih.gov/proj/ mdot/mdot.php) allowed clinicians to find answers from the MEDLINE database to support evidence-based medical practice. Clinicians were able to answer 68% of the clinical questions during clinical rounds (Hauser, 2007). Therefore, clinical questions that arise at the bedside can be addressed by well-designed handheld applications such as MD on Tap that allow clinicians to quickly access relevant citations. Nowadays, there are several mobile applications (e.g. PubSearch, PubMed on Tap, askMEDLINE) that allow healthcare providers to access many of the available biomedical literature databases such as PubMed/MEDLINE and Essie (Dala-Ali, Lloyd, & Al-Abed, 2011; Hunter, Hardwicke, & Rayatt, 2010; Mosa, Yoo, & Sheets, 2012).

Clinical decision support application

Many studies have demonstrated that computerized decision support systems have a positive impact on a clinician's decision making especially during prescribing medications. Despite these positive results the use of decision support systems is still very limited in healthcare settings (Sintchenko, Iredell, Gilbert, & Coiera, 2005). Mobile devices may overcome some of the barriers faced with the use of decision support systems and the limitations of a desktop computer. Sintchenko and colleagues designed a handheld decision support system for intensive care unit (ICU) clinicians. The six-month study showed that the use of the handheld decision support system reduced the use of antibiotics and length of stay in the ICU (Sintchenko et al., 2005). In another study by Berner and colleagues, the use of a handheld decision support tool demonstrated safer treatment decisions at the point of care. However, the authors recognized the need to integrate the handheld decision support system with an electronic medical record to support efficient and safer healthcare in ambulatory care settings (Berner et al., 2006). Also, further evaluation needs to compare the benefits of using a mobile platform over a computer workstation (Sintchenko et al., 2005)

2.5 Access to Enterprise Health Information Systems (HIS)

Health information systems (HIS) have been proposed as one of the solutions that will help improve healthcare quality, safety, and efficiency (Anderson & Aydin, 2005). However, Previous study showed that clinicians are concerned about the potential negative impacts of health information systems (HIS) on their workflow and patient care processes (Ash, Sittig, Campbell, Guappone, & Dykstra, 2007; Ash et al., 2007). One of the identified reasons for these negative effects is that health information technology (IT) deployment has focused mainly on using fixed computer. This does not support the mobility needs of many healthcare professionals. Fixed computers forces healthcare providers to be tethered to a single location even though they might be needed somewhere else for clinical work (Gurses & Xiao, 2006). Several mobile solutions have been proposed to address these challenges including the use of computer on wheels (COWs), PDAs, and tablet computers. While mobile COWs offer a large screen, research has shown that they could impair healthcare providers' mobility because it is difficult to move from one location to another or into a patient's room (Koppel, Wetterneck, Telles, & Karsh, 2008).

The feasibility of using PDAs to improve healthcare providers' access to patients' electronic records started shortly after their introduction. At the end of 1997, a simulation study was used to evaluate a multifunctional digital assistance prototype at the university hospitals of Heidelberg (Ammenwerth, Buchauer, Bludau, & Haux, 2000). Based on the study results it was concluded that mobile computing technology success depends on many factors including the ability to provide end users with multiple functionalities (data entry, information access, knowledge access, communication, and personal organization features), the device ergonomic features (ease of use), and the availability of reliable wireless network infrastructures. Since these results were based on a simulation study, the research team called for further field study to confirm their results. Also, the authors identified the need for further studies to investigate mobile device data security, integration with the hospital HIS, user interface, communication among healthcare professionals, impact on workflow, and patient-provider relationship (Ammenwerth et al., 2000).

Early attempts to integrate mobile computing technologies with complex HIS faced many challenges related to the human aspects of these technologies and how they fit in the complex environment of healthcare settings (Johnson et al., 1998; Rigby, 2006; J. Wu et al., 2007). Using PDAs to access HIS has been limited by several factors including the small screen size for complex data representation, cumbersome data entry mechanism, limited memory, and few security features for protecting sensitive data. One of the early PDA projects that aimed to improve access of healthcare providers was conducted at New York Presbyterian Hospital (NYPH). The mobile clinical information system PalmCIS allowed NYPH clinicians to access a subset of patient information found in the electronic record. The results of the system log analysis and user survey demonstrated that users reacted positively to PalmCIS information and features. However, clinicians identified the system speed as one of the major limitations to PalmCIS use, a connection/retrieval time of 15 seconds on average was perceived as too slow, which discouraged use of the application. Other issues were related to the slow and cumbersome sign on function, limited functionalities, and user interface problems (Chen, 2003).

With the emergence of Tablet PCs, healthcare organizations started exploring their potential to improve healthcare providers' access to HIS. For example, clinicians at Saint Clare's Hospital in north central Wisconsin used tablet PCs to access patients' electronic health records. As described by the director of information technology services, the portable tablet allowed clinicians to access records across all of the hospital facilities (Waton, 2006). However, despite the high acceptance level reported, there was no formal evaluation of how the system was integrated with clinicians' workflow, or the effect on patient care. Other healthcare organizations, like Orlando Regional Healthcare in Florida, used both tablet computers and COWs to address clinicians' access and communication needs. The Panasonic Toughbook was selected as the tablet computer of choice. It is reported to be durable, easy to use, and has a longer battery life. However, information regarding the impact of the tablet use on workflow and patient outcomes is lacking (Waton, 2006).

Integrating mobile computing technology with healthcare providers' workflow is an important factor in the success of mobile HIS**.** Reddy et al. (2005) examined the effect of introducing wireless pagers on information flow and work practices. The results showed that the wireless alert pager created new routes of information flow that disturbed existing work practices. These results highlights the importance of understanding healthcare professionals established work practices, the existing information flow, and the limitations of these technologies (Reddy, McDonald, Pratt, & Shabot, 2005). In order to understand mobile computing technologies' influence on healthcare provider practices and patient outcomes, future research studies need to answer the question of the extent to which the device mobility contributes to the results of the study. In doing so, researchers need to analyze what is being done, when it is occurring, how it is being done, and where it is happening. In a recent systemic review, Prgomet et al. examined the available evidence regarding the impact of mobile technology on physician work practices and patient care (Prgomet, Georgiou, & Westbrook, 2009). The results showed that handheld technologies were found to positively impact information accessibility, data management, rapid response, and error prevention in healthcare settings. Despite the reported potential benefits, the researchers found limited evidence to confirm that mobile computing technologies will be used in certain locations and in the expected manner. For example, while tablet computers allow clinicians to access and document patient data at the bedside, an observational study found that physicians preferred to use the tablet outside the patient room during daily rounds (Andersen, Lindgaard, Prgomet, Creswick, & Westbrook, 2009b). It was concluded that the choice of the mobile device relies on the clinical role, the nature of the clinical task, the required degree of mobility, and the device design and characteristics.

In 2007, a survey questionnaire was used to evaluate the usefulness and ease of use of a tablet computer (Toshiba 200M Portégé) in supporting oncologists clinical and non-clinical needs (Murphy, 2007). The survey compared the tablet to regular computer workstations and paper chart. All participants agreed that the tablet computers supported some tasks better than fixed computer workstations. These tasks included reviewing images and lab results with the patient, providing more up-to-date information than the paper chart, accessing Intranet portals to review management guidelines, printing prescriptions, test requisitions, and patient educational material. However, even though the tablet brought the computer to the exam room and allowed the clinician to access up-to-date information, users faced some challenges in using the tablet in their daily routines. According to the author, "although the clinic staffs have integrated tablet computers into their workflow, it is not an easy fit" (Murphy, 2007, p. 8). For example, some users found it cumbersome to carry the tablet around in the clinic. Also, the lack of reliable wireless network and technical problems increased the cognitive overhead and workload. In subsequent study at the BC Cancer Agency (BCCA), a centre-wide tablets implementation (iMPROVE pilot project) resulted in 1.14-minutes/chart reduction in printing and filing information already available through the Cancer Agency information system. (Murphy, Wong, Martin, & Edmiston, 2009). It was concluded that the cost saving in staff time could be used to support the implementation of wireless systems in other cancer centres. Also, the pilot project results confirmed that tablets should be complementing but not replacing the regular workstation (Murphy, Wong, Martin, & Edmiston, 2009).

With the emergence of more powerful mobile tablets like the iPad, there has been an increasing interest in utilizing such innovations to improve healthcare providers' access to central HIS. In 2010, the Ottawa Hospital launched a pilot project to configure a clinical application that would make patient information available on an iPad mobile platform (Geiger & Maisonneuve, 2012). The first version of the clinical mobile application (CMA) allowed physicians and residents to access patient lab results, diagnostic imaging reports and transcribed documents at the patient bedside. In addition, the application provided access to other resources such as the hospital's drug formulary, and the hospital's collection of online journals. The overwhelmingly positive results of the pilot project and high satisfaction with the application encouraged the development team to enhance the application with a Picture Archiving & Communication System (PACS) viewer. Since the pilot project was successful, the Ottawa Hospital Governance Committee approved the purchase of over 1800 additional iPads. The confidentiality of patient data was insured through different measures including iOS hardware device encryption, ensuring that the CMA does not store any patient data on the application, and the ability to wipe the device remotely. At the beginning of 2012 the Ottawa Hospital became the first hospital in the world to be live with Computerized Provider Order Entry (CPOE) on an iPad (Geiger & Maisonneuve, 2012).

A recent qualitative study at Fairview Health Services investigated the factors behind physicians' strong demand for using a mobile tablet (iPad) for an implementation of electronic health record (Epic ASAP™) in two emergency departments (Rao, Adam, Gensinger, & Westra, 2012). The qualitative analysis of the participants' interviews revealed three major themes that explained clinicians' perceptions about the usefulness of implementing the electronic health record on the iPad (Rao et al., 2012). These themes included improved patient-physician interaction, improved workflow with the iPad, and structural benefits of the iPad. Patient-physician relationship is vital to providing excellent care and improving health outcomes (Ball & Lillis, 2001; Hsu et al., 2005; Rao et al., 2012). Physicians believe that using an iPad support face-to-face communication, enhance patient education, and improve patient satisfaction. Furthermore, physicians expected that the iPad would improve their workflow because it will allow them to access patients' information faster and easier, reduce redundancy, and support their mobility needs. Based on previous personal experience, physicians believed that the iPad has a structural design benefits over desktops and laptops. The iPad touch screen was perceived as easy to use and support instinctive learning. From an infection control perspective, the iPad was perceived as easier to disinfect than desktop computers and laptops. Also, since the iPad does not have a cooling fan, physicians believed it would reduce the risk of air-born infection that might be related to desktop or laptops.

2.6 Evolution of Mobile Technology

Personal Device Assistant (PDA)

The first generation of handheld computers (PDA) was based on two main operating systems (OS): the Palm OS and Windows CE OS (Pocket PC) (Embi, 2001; S. Fischer, Stewart, Mehta, Wax, & Lapinsky, 2003). Windows-based PDA offered wider functionality, larger memory, and better screen resolution than Palm-based PDAs, while the Palm-based PDA provided more clinical applications with better usability.

Healthcare professionals had to consider these factors when selecting a PDA. Also, take into consideration that these two platforms did not interface easily. According to Schneider and colleagues, healthcare professions considered platform compatibility with their colleagues' PDA as advantageous since this facilitates data sharing (Schneider, Kostecke, & Tokazewski, 2001). Also, a greater memory size for reading reference textbooks and the availability of needed clinical applications is beneficial. Generally, Palm-based PDA was more popular among health care providers due to its usability and the availability of clinical applications.

Smartphones

The first smartphone was a combination of PDA and mobile phone functionalities. Currently, smartphones are viewed as multi-purpose devices with advanced features. Smartphones today include more features such as portable media players, digital cameras, GPS navigation system, high-resolution touch screens, web browsers, Wi-Fi, and mobile broadband connectivity (Marceglia, Bonacina, Zaccaria, Pagliari, & Pinciroli, 2012). Modern smartphones are based on one of the major operating systems like Google's Android, Apple's iOS, Nokia's Symbian, RIM's Blackberry OS, Samsung's Bada, and Microsoft's Windows.

Tablet computers

The concept of tablet computers originated in the 19th and 20th centuries; however, it is only recently that tablet computers achieved worldwide success. The Apple iPad release in 2010 is considered the first tablet computer to achieve worldwide commercial purposes. It had 18 million in sales by the end of 2010 (Marceglia et al., 2012). The success of the iPad opened a new competitive market that encouraged many manufacturers to develop many new tablet computers. Similar to smartphones, major operating systems for tablet computers include: Apple iOS, Google's Android, and Microsoft's Windows (Nosrati, Karimi, & Hasanvand, 2012).

With the further advancements in technology, healthcare professionals' adoption of mobile technology is increasing. In 2006, PDA adoption among US-based healthcare professionals was estimated to be between 45% and 85% (Garritty & El Emam, 2006). Dasari, White, and Pateman (2011) found that 59% of British anaesthetists owned an iPhone. Of those who owned an iPhone, 60% actively used medical apps for clinical activities, and 47% for educational purposes (Dasari, White, & Pateman, 2011). In another survey study from the United Kingdom, 79% of medical students and 74% of junior doctors owned a smartphone. The Apple iPhone was the most adopted device among students and junior doctors (56%, 68% respectively), and the majority of both students and doctors owned one to five medical related applications (Payne, Wharrad, & Watts, 2012). This could also be attributed to the new generation of healthcare providers entering the profession.

Limitations

While there are plenty of mobile applications (apps) for healthcare providers, most have not been evaluated for either content or efficacy.. A 2011 survey among orthopedic surgeons and residents, found that despite the prevalence of smartphones and apps there were few high quality apps that are designed to meet their needs (Franko, 2011). While application reviews might be helpful, there are usually few apps that have been reviewed extensively to make an informed choice. Similarly, medical app ranking websites ran by physicians and medical students, such as iMedicalApps (http://www.imedicalapps.com/), reflect the need for rigorous evaluation of newly introduced apps. The US Food and Drug Administration (FDA) just recently released guidelines for regulating medical apps. This is considered another step toward helping healthcare professionals as well as patients in selecting the appropriate and safe medical apps (U.S. Department of Health and Human Services Food and Drug Administration, 2013). However, these regulations cover only apps that will be used as an accessory to a regulated medical device or to transform a mobile platform into a regulated medical device. The FDA guidelines clearly state, “FDA’s mobile medical app policy does not apply to mobile apps that function as an electronic health record (EHR) system or personal health record system” (U.S. Department of Health and Human Services Food and Drug Administration, 2013).

2.7 Synthesis of the Literature

Healthcare professionals are considered among the early adopters of mobile computing technologies and applications. This has created many opportunities to support healthcare professionals' educational and practice needs. The technological advancement and enhanced features of mobile computing technologies in the last few years have evoked a new revolution in mobile technology adoption and use. Mobile technologies and applications have been used in many areas including medical education, communication between healthcare providers, clinical decision-making, and access to clinical information systems. The integration of mobile phone technology with other mobile devices, such as portable mobile computers, and thousands of mobile applications created new opportunities that could benefit healthcare providers, patients, and the whole healthcare system. However, even with the abundant availability of downloadable medical applications (apps) for both healthcare providers and patients, the majority are still stand-alone applications that have not been evaluated for efficacy and content.

At the enterprise level, mobile computing technology adoption is relatively new and most of the available literature is focused on the development of stand-alone mobile health (mHealth) applications, their feasibility, and the opportunities and challenges within the field of mHealth. Early attempts to integrate mobile computing technologies with complex health information systems (HIS) faced many challenges. While mobile health technologies have been challenged by technical problems, technical aspects of mobile technologies have been progressing at a fast pace. On the other hand, further research is needed to understand the human aspects of mHealth and how the technologies fit in complex healthcare settings (Johnson, Meyer, Woodworth, Ethington, & Stengle, 1998; Rigby, 2006; J. Wu et al., 2007). . Recently, Healthcare organizations are starting to realize the potential benefits of mobile computing technologies and applications. Mobile technologies can help meet healthcare providers' information and communication needs, enhance provider productivity, and improve the quality and safety of healthcare delivery. For example, the Hospital of Central Connecticut developed an application that allows patients to look up emergency department wait times using their iPhone (Rhea, 2010). In another example, the University of Pittsburgh Medical Center (UPMC), an integrated global health enterprise, has developed a Blackberry mobile application that allows clinicians to access electronic health record information. The application, developed at UPMC, allows clinicians to view important patient information such as lab results, medications, allergies, problems, and physician notes (UPMC, 2010).

The growing interest in developing and integrating mobile applications with more complex health IT applications have been driven by many factors. These factors include the fast-paced advancement in the technical aspects of mobile computing technologies, their wide adoption by healthcare providers and patients, and the potentially enabling role of mobile computing to accelerate and facilitate healthcare providers' acceptance and use of more complex health IT applications. The latter is particularly important considering the fact that despite the potential benefits of different health IT solutions like electronic health record (EHR), computerized provider order entry (CPOE), and clinical decision support systems (CDSS); the adoption of these technologies is still facing resistance from healthcare providers. One of the reasons is the lack of understanding of how these technologies will fit into the complex workflow of healthcare providers, who usually work in highly mobile environments, under time pressure, and within organizational work practices and hierarchies (Reddy, 2005) The increasing demand for using mobile computing technology to access HIS has the potential to overcome healthcare professionals resistance for using complex HIS (e.g. EHR). Also, the success of using mobile computing technologies and applications to support health care providers in healthcare setting has been reported in a number of pilot project such as the iPad pilot project at the University of Chicago Internal Medicine Program and the iPad project at the Ottawa Hospital (Geiger & Maisonneuve, 2012; Patel, Chapman, Luo, Woodruff, & Arora, 2012).

2.8 The Need for Mobile Health Evaluation Studies

Inadequate access to the patient's clinical data at the point of care and ineffective communication among healthcare professionals have been identified as potential proximal causes of medical errors (Kubose et al., 2001; McKnight et al., 2001; Stetson et al., 2002). Healthcare organizations are increasingly investigating the ability of wireless networks and mobile computing technologies to provide seamless ubiquitous access to their central clinical information systems.

The future of mobile computing technologies and the realization of their full benefits depend on integrating the current stand-alone mobile applications with more complex systems and technologies in complex healthcare settings (Househ, 2012). There is great value in integrating mobile health applications with the hospital wide electronic health records. Central to this integration is our ability to better understand the human aspects of mobile health technologies and the complex work activities and practices that exist in different healthcare settings. More research is needed to understand the effect of new mobile technologies and applications on healthcare providers' clinical workflow, their success factors and limitations, their effect on patient care, and their usability (Househ, 2012).

Healthcare professionals are increasingly demanding the use of new mobile computing technologies and applications to support their information and communication needs. However, healthcare organizations' limited resources and competing priorities require them to justify and demonstrate the benefits of health IT solutions including mobile health applications. Evaluation studies that investigate the different aspects of using mobile technology and the effects of its use in different healthcare settings will be essential to fill this gap. More rigorous evaluation studies will help organizations that are considering mobile computing technologies to make more informed decisions. The lessons learned and the evidence that can be reached through evaluating mobile computing technologies contribute to healthcare organizations' ability to meet the growing demand while maintaining patient safety, confidentiality, and quality of care. Also, understanding what mobile computing technologies can and cannot do in complex healthcare settings will be essential in order to maximize their benefits and avoid any negative impact.

Mobile health (mHealth) is a new research area and most of the available literature focuses on the development and use of stand-alone mobile technologies and applications intended for patient or healthcare professional use. More evaluation studies are needed to establish the field of mobile health as a mature sub-discipline of health informatics, especially with the emerging paradigm of using personal mobile devices (BYOD) to access organizational HIS.

Chapter 3: Methodology

3.1 Introduction

Health informatics has been focused on technological aspects and has developed solutions that have to search for problems (Smith, 1996). The technology-driven approach has led to a lot of unsuccessful projects in the healthcare sector and information systems that do not address the real needs of the users (Berg, 2001). Previous studies confirmed that user resistance to HIS is one of the primary reasons for health IT projects' failure (Lo, n.d; Lyytinen, 1988; Reuss, Menozzi, Büchi, Koller, & Krueger, 2004). However, user resistance was not always attributed to technical problems. Other factors, including HIS data format and content, user characteristics, motivations, and skills, and organizational problems were also contributors to resistance. In contrast, a problem-driven approach explores how to solve a particular problem using information system, which seems more appropriate for designing healthcare information systems (Coiera, 2003). The following section provides background information on the various HIS evaluation frameworks and approaches that informed the design of the iPad Mobility Project evaluation framework.

3.2 Background: HIS evaluation

HIS evaluation studies contribute to our understanding of information technology roles in healthcare. Evaluation also enhances our ability to build systems that are capable of delivering a broad range of economic and clinical benefits. For example, evaluation can be done to gain end-user commitment to the new system being implemented, understanding the system impact on end-user decision making, established work practices, and the benefits and challenges of HIS. Heathfield suggested that HIS evaluation is carried out to demonstrate accountability, to develop or bolster individuals' performance, systems, and organizations, and to create new knowledge (Heathfield, Pitty, & Hanka, 1998). Hence, stakeholders need to be involved throughout the evaluation process to identify the different evaluation rationales of different stakeholders (Gremy, Fessler, & Bonnin, 1999).

There are many evaluation frameworks that have been proposed to evaluate the different aspects of information systems. However, there is no single framework that is seen as a perfect fit for HIS evaluation. This reflects the diversity of evaluation needs and the complexity and difficulty of measuring the most important tangible and intangible aspects of information systems (Serafeimidis, 2002; Yusof, Papazafeiropoulou, Paul, & Stergioulas, 2008). Ammenwerth et al. (2003) described some of the problems that researchers encounter during HIS evaluation in terms of complex evaluation projects, complex evaluation objects, and limited motivation for evaluation. Hence, many researchers emphasized the importance of maintaining the rigour of the research study while recognizing the interest of organizational stakeholders (Aydin, 2005a; Rossi, Freeman, & Lipsey, 2003). The availability of many evaluation frameworks can be leveraged to develop HIS evaluations frameworks that address the different needs of multiple stakeholders. In other words, evaluation frameworks can be modified to match the core evaluation objectives and to answer valuable evaluation research questions and not just those that are easy to measure (Yusof et al., 2008).

Researchers identified different important components to be included in an evaluation framework. Yusof et al (2008) identified five areas that are essential in HIS evaluation: who, what, when, why, and how (Yusof et al., 2008). Serafeimidis added "which," an element including technical measures, system or information quality measures, and user satisfaction measures (Serafeimidis, 2002). Kaplan (1997) proposed general and yet ambitious methodological guidelines for evaluation. These guidelines include focusing on a variety of interests, using various methods, being changeable, choosing a longitudinal study design, and being both formative and summative. Kaplan focuses on evaluating different technical, economic, and organizational aspects of HIS using multiple research methods including both quantitative (surveys, cost-benefit analysis) and qualitative methods (interviews, observations). Using multiple data collection methods helps deal with the complexity of HIS by allowing stronger data analysis through triangulation, and ultimately increases the reliability of the evaluation results. Also, Kaplan advocated that the researcher should be able to change or modify the evaluation methods, research questions, and phases throughout the evaluation process as needed. While evaluation research designs that are longitudinal allow the researcher to collect data over time, being formative and summative allows use of the results to improve HIS during and after system implementation (Kaplan, 1997).

3.2.1 Subjectivist vs. objectivist evaluation approach

Moehr acknowledged that there are two contrary methodologies to HIS evaluation: the objectivist and subjectivist approaches (Moehr, 2002). The primary goal of the objectivist approach is eliminating subjectivity based on the assumption that there is a valid model for the world and that measurable attributes exist for all elements of the model (Moehr, 2002). These objectivist truths are then "used deductively to understand the truth of complex systems made up of these components" (Moehr, 2002). The advantage of using the objectivist approach is that it is based on strong theoretical base that is widely accepted among the research community. The results of the objectivist approach usually can be generalized to similar population as evidence is generated through precise measurement, testing of hypothesis based on representative sample of observations, and statistical analysis of the data (Bürkle, Ammenwerth, Prokosch, & Dudeck, 2001; Jackson & Verberg, 2007). However, given the complexity of information systems and their constantly changing environments, the objectivist approach seems to lack flexibility and the ability to address the full spectrum of HIS evaluation goals and needs (Bürkle et al., 2001).

On the other hand, rather than trying to eliminate subjectivity, the subjectivist approach tries to take full, considerate advantage of it. The subjectivist approach focuses on describing the system in its natural environment and the perceptions of people interacting with each other and with the system in that environment. In general, the subjective approach involves identifying questions and themes to be pursued, data collection using various qualitative methods, data refinement and cross checking with participants, and using inductive reasoning to understand the phenomenon. The flexibility of the subjectivist approach allows modifying and/or adding research questions, as more information is made available. Because of this adaptability, Moehr (Moehr, 2002) suggests that it should have a leading role in HIS because it could not only complement the objectivist approach but also help focus the objectivist approach evaluation. The benefits of using the subjectivist approach are related to its flexibility and ability to adjust to changes such as changes to questions raised by stakeholders or other influences on the system under study. Another benefit is the ability to generate a thorough detailed analysis from limited number of cases in timely manner which provide a more cost effective rigorous evaluation than other methods that require a lot of artificial constraining conditions (Bürkle et al., 2001). However, the ability to generalize the results is limited as it relates to specific population and context (Bürkle et al., 2001).

3.2.2 Formative vs. summative approach

Other perspectives discussed in the literature classify information systems evaluation as formative or summative. While formative evaluation occurs during HIS development phases so that it can be modified based on the results, summative evaluation occurs after system implementation to determine the results that have been achieved, such as outcomes and impacts, goals achievement, unintended effects, or comparison with other systems (Neville et al., 2004). According to Van Der Meijden et al., evaluation of HIS should start as early as possible and should continue throughout the whole system life cycle (Van Der Meijden, Tange, Troost, & Hasman, 2003). The authors emphasize the benefits of utilizing both quantitative and qualitative data collection methods to enhance the results' credibility through triangulation. Also, the authors call for more formative evaluation that aims to improve the information system during development and implementation. This research study represents only part of the formative and summative evaluation that was conducted during the project period. Other evaluation methods included several technical and clinical testing sessions that involved BCCA clinicians, the project team, and HSSBC security experts.

In conclusion, there has been a growing trend to evaluate health information systems and that evaluation must be an essential component of HIS implementation. Understanding the problems and challenges that the health IT system is supposed to address is a vital component in HIS evaluation. Furthermore, evaluating HIS effects requires understanding both the technology and the social and behavioural processes that impact and are impacted by the introduction of new HIS (Aydin, 2005a; Rossi et al., 2003).

3.3 iPad Mobility Project Evaluation Framework

In this study, the IMITS Mobility Project refers to the evaluation of a native iPad application

(VitalHub) interfaced with the Cancer Agency Information System (CAIS) and the overall processing and exchange of healthcare information and services via mobile devices. The IMITS Mobility Project was initiated to support clinical workflow by providing an easy mobile access to the BCCA computerized resources. The evaluation framework was developed in collaboration with the project stakeholders at BCCA and PHSA IMITS (Table.1). Several BCCA staff and managers reviewed the evaluation framework and the research methods including the Director of Clinical Informatics (BCCA), Program Director - Oncology Solutions (BCCA), Department Head (Radiation), and the Project Manager. Even though the study was based on exploratory-grounded theory methodology to answer the research questions, stakeholders were interested in complementing the study with baseline and post-pilot surveys. Health informatics literature recognized the value of using both qualitative and quantitative methods in providing a more comprehensive view of the phenomenon under study (Borycki, 2010; Van Der Meijden et al., 2003).

This mixed-method evaluation study involved using both quantitative (questionnaires) and qualitative methods (direct observations) before and after the implementation of the iPad project. Also, the study involved post-implementation semi-structured qualitative interviews. While the results of both quantitative and qualitative data were analyzed individually, they were used in the synthesis of the results. Typical mixed triangulation study has separate section for both quantitative and qualitative data collection and analysis (Creswell, Fetters, & Ivankova, 2004). Then, in the discussion section, the investigator discusses the results of both analysis and presents the two forms as supporting or conflicting evidence (Creswell et al., 2004). The following figure (2) explains the sequence of the mixed methods used in the evaluation of the iPad Mobility Project.

Figure 2. Sequence of Data collection methods

Data collection method	Goal	Indicators/Measures
Pre-pilot survey questionnaire	To capture baseline data related to expectation and experience	1-Prior experience with using mobile device 2-Level of comfort in using mobile devices 3-Users' expectations for the mobile system use 4-Users' expectations for the mobile system functionalities 5-Users' expectations for the system usefulness 6-Users' expectations of the effect on their relationship with clinicians/patients 7-Users' background information
Pre-pilot (observation)	To capture baseline data related to clinicians' productivity/data access	1-Data accessibility, availability during patient visits. 2-Problems/issues encountered in accessing patient data.
Post-implementation (observation)	To capture actual real-time data related to the iPad VH Chart effect on clinicians' productivity/information accessibility	1- Data accessibility, availability during patient visits. 2-Problems/issues encountered in accessing patient data.
Post-implementation interviews	To gather more detailed and thorough feedback through qualitative data	1-The quality of the system in terms of functionality and performance 2-The quality of data contained within the system in terms of content and availability 3-The quality of the system in terms of serving clinicians' everyday needs in the practice 4-The effect the iPad application has in managing patient conditions. 5-Major changes in clinicians' day-to-day work 6-The biggest challenges with respect to the iPad deployment 7-Opportunities in relation to using the iPad app as compared to how things were done previously 8- Other comments and feedback
Post-implementation survey	To gather post-pilot data to compare against baseline survey and interview results and evaluate the success of the pilot.	1-Baseline survey measures 2-System quality: usability, reliability, security 3-Information quality: *Content*: completeness, accuracy, and relevance. *Availability*: speed, format, and layout of information. 3- Service quality: *Responsiveness*: Overall quality of the service provided to the system, implementation process, training, ongoing support. 4- System use: *Self-reported use*: use per day, use per week, use for patients (%) *Intention to use:* recommendation to others to use the system 5- User Satisfaction: overall satisfaction, productivity, etc.

Table 1. iPad Mobility Project Evaluation Framework

3.3.1 Qualitative methods

Grounded Theory

Grounded theory methodology allows the discovery of theory from the data that explains underlying social processes (Glaser & Strauss, 1967). Grounded theory principles are based on symbolic interactionism and pragmatism literature (Corbin & Strauss, 1998). In research that aims to generate theory, grounded theory is among the most widely used and influential methods of qualitative research (Jackson & Verberg, 2007). Grounded theory data can come from anything that would describe the topic including observations, interviews, government documents, multimedia (videos and tapes), books, and newspapers (Corbin, 1990).

A descriptive, exploratory, grounded theory study was used to analyze BCCA clinicians' perspectives on the utilization and benefits of using the iPad and a native iPad application (VitalHub) to access the CAIS in the BCCA ambulatory care setting. Baseline data was collected using direct observations. Post-implementation data was collected using semi-structured interviews and observations.

The grounded theory approach was selected for this study for many reasons. Grounded theory, as a qualitative approach, has been increasingly used in health informatics research to distinguish and describe the effect of HIS on healthcare processes, especially when there is little research about the effect of new innovations. Furthermore, grounded theory is emerging as a powerful methodology that can be used throughout the system life cycle from design and development to the implementation and evaluation of HIS (Ash, Lyman, Carpenter, & Fournier, 2001; Cummings, 2011; Peute, 2010). Moreover, grounded theory provided thorough comprehension of oncologists' perspectives on the reality of caring for cancer patients and the effect of the iPad and VitalHub app, on oncologists' workflow, decision-making process, interaction with cancer patients, and challenges related to the use of mobile HIS.

Ideally, researchers who use grounded theory approach begin the study with no preconceived theory and, as a result, the theory originating from the data is likely to reflect reality (Corbin & Strauss, 2008). However, setting aside previous theoretical ideas does not mean that the researcher has to isolate himself from previous theoretical knowledge but rather that he should not be restricted by previous knowledge or impose preconceived ideas on the data (Cummings & Borycki, 2011). Putting aside personal views and biases on the research topic (bracketing) is usually done by keeping a record of personal views and feelings about the topic so that the interpretations of the data do not reflect personal beliefs but those of the participants. As a healthcare professional, the investigator has been exposed to various information systems. Therefore, he kept detailed record of his views, experience, and feelings about the use of mobile technology in healthcare settings. This involved constant comparison of the participants' transcribed interviews to the investigator own records. For the observations, the investigator confirmed his observations and interpretations during the interview part as all observation participants, except for one, participated in a subsequent interview shortly after the observation session.

Baseline observations were used to capture real-time information about the current available resources for BCCA clinicians. A paper-based observation sheet was used to collect data related the availability of the current information resources (desktop computers, paper charts), the level of use, tasks, the context of use, users interactions, workflow challenges, and workarounds. The same procedure was followed in the post-implementation observation to understand how BCCA clinicians used the iPad and VitalHub Chart application to access patient clinical data, and any challenges related to the use of the iPad. This involved how and when the iPad was being used, for what task, context, and any reported challenges (Appendix B). Since clinicians were observed in their natural setting, the observer was able to identify the opportunities and challenges in accessing patient clinical data while using both the current resources and the iPad application. The observer was aware of the potential Hawthorne impact and explained the purpose of the observation to every participant in the observation study. The researcher is a registered nurse and was fully aware of the need to be sensitive and unobtrusive during the observational sessions in BCCA clinical settings. Based on each clinician's preference and availability, most of the post-implementation interviews were conducted immediately after the observation to allow the clinician to reflect on their experience.

The post-implementation interview questions were adopted from the University of Victory e-health observatory toolkit -User Assessment Interview Script available at (http://ehealth.uvic.ca/resources/tools/ImpactAssessment/2012.03.12-User_Assessment_Interview_Script-v3.0.pdf). The questions were semi-structured in nature and collected information regarding participants experience with the use of the iPad and VitalHub Chart app, The quality of the system in terms of functionality and performance, the quality of data contained within the system in terms of content and availability, The quality of the system in terms of serving clinicians' everyday needs in the practice, The effect the iPad application had in managing patient conditions, major changes in clinicians' day-to-day work , the biggest challenges with respect to the iPad deployment, opportunities in relation to using the iPad app as compared to how things were done previously, and other comments and feedback (Appendix B).

3.3.2 Quantitative methods

Survey research is one of the common approaches used in evaluating HIS effects. It usually involves collecting information from a representative sample using standardized measures. Even if the sample is limited to certain user groups within the organization, evaluation researchers must take necessary measures to obtain adequate representative response from the study participants. Moreover, the use of appropriate standard measures with established reliability and validity is essential in evaluation research studies as it allows comparison of the results of different studies and saves the researcher the time-consuming process of creating new valid and reliable measures (Aydin, 2005b).

Attitudes of healthcare providers have significant impact on the successful implementation of new clinical information systems. In this study, the baseline survey targeted BCCA clinicians' attitude toward and expectations regarding the use of the iPad (Appendix B). Specifically, the research team and the project stakeholders were interested in assessing clinicians' expectations as to what effect the new mobile clinical information systems would have on patient care and on clinicians' workflow within BCCA's unique environment. The baseline questionnaire included Likert-type as well as multiple-choice questions. It provided background information about participants' demographics, prior experience with mobile technology, level of comfort with using mobile technology, types of hardware, perceived ease of use, perceived usefulness. Also, the questionnaire collected information about participants' expectations for the effects of using the iPad on their workflow, productivity, job satisfaction, information accessibility, the ability to involve patients in care planning and decision making process, patients acceptance of mobile technology use, staff retention at the BCCA, and the overall quality and safety of patient care. Furthermore, questions were asked about the expected level of use, when the iPad app (VitalHub Chart) will be used (before, during, after patient visits), how it will be used (access to patient data, patient education and communication, inter-professional communication), and the effect on the level of use of other information resources (desktop computers, paper-based charts).

Baseline survey questions were repeated in the post-implementation questionnaire to allow comparing participants experience with their baseline expectations (Table. 2). The post-implementation survey questions included Likert-type questions, multiple choice questions, and open-ended questions that allowed users to reflect on their experience and provided further feedback (Appendix B). Also, the post-implementation collected information about the overall success of the IMITS iPad Mobility Project in terms of the iPad and VitalHub Chart app system quality measures (ease of use, learnability, response time, security, performance reliability), VitalHub Chart application information quality measures (completeness, accuracy, relevance, format acceptability, current information), service quality measures (technical support, training resources, level of support needed). Also, the post-implementation questionnaire included separate questions for both the iPad and the VitalHub Chart app in terms of system usage measures (Number of times the iPad/VH chart was used per day, days per week, percentage of use for patient care, and when it was used (before, after, during patient encounter), and how it was used (patient information access, communication, clinical-decision making).

Baseline Survey questions were adopted from the Employee/Staff Pre-Go-Live Expectations/Perceptions Clinical Information Systems Survey and the End-user Computing Satisfaction Survey (Agency for Healthcare Research and Quality (AHRQ), 2012b; Doll &

Torkzadeh, 1988). The post-implementation survey questions were adopted from the Canada Infoway System and Use Survey and the End-user Computing Satisfaction Survey (Agency for Healthcare Research and Quality (AHRQ), 2012a; Doll & Torkzadeh, 1988). The psychometric characteristics of the End-user Computing Satisfaction Survey were found to have adequate reliability and validity across a variety of applications (Doll & Torkzadeh, 1988). Using a survey of 618 end users, Doll and Torkzadeh conducted a factor analysis and modified their instruments to 12-item scale with Cronbach's Alpha of 0.92. Specifically, the Coefficient Alpha for the various components were found to be 0.89 for content, 0.91 for accuracy, 0.78 for format, 0.85 for ease of use, and 0.82 for timeliness (Aydin, 2005b; Doll & Torkzadeh, 1988). In a subsequent study, the reliability of End-User Computing Satisfaction scale was assessed again using the test-retest method to establish instrument stability (Torkzadeh & Doll, 1991). Using 41 respondents, the reliability was tested at three points in time. The results suggested high reliability with coefficient alpha of 0.88, 0.89, and 0.90 for the first, the second, and the third administrations of the instrument respectively (Torkzadeh & Doll, 1991). Canada Health Infoway System and Use Survey is based on the DeLone and McLean information System success Model that has been tested extensively in the literature in terms of validity and robustness (Lau, Hagens, & Muttitt, 2006; Lau, 2009; William H. Delone & Ephraim R. McLean, 2003). Evaluation Subject Matter Experts and Infoway's Benefit Evaluation team developed the System and Use survey measures to assess the quality, usage and net benefits of health information system in a given organization and to identify potential barriers. The survey has been used in a variety of Canadian evaluation projects including Diagnostic Imaging Systems (DIS), Electronic Medical Records (EMR), and other HIS projects (Canada Health Infoway (Organization), 2012; Lau, Price, & Keshavjee, 2011). Table (2) and table (3) shows the variables identified during the project design phase and updated after go-live.

Table 2. Quantitative Variables (Pre Versus Post-implementation)

Variables X	Variable Y
iPad use	Fitness to clinician workflow
Information accessibility	

Variables X	**Variable Y**
Use of the iPad Before patient visit (Baseline)	*Use of the iPad Before patient visit (Post-implementation)*
Use of the iPad During patient visit (Baseline)	*Use of the iPad During patient visit (Post-implementation)*
Use of the iPad After patient visit (Baseline)	*Use of the iPad After patient visit (Post-implementation)*
Use of the iPad Between patient visits (Baseline)	*Use of the iPad Between patient visits (Post-implementation)*
Information accessibility	
Information accessibility	Use of VH Chart before patient visit
Information accessibility	Use of VH Chart during patient visit
Information accessibility	Use of VH Chart after patient visit
Information accessibility	Use of VH Chart between patient visits
Productivity	
Productivity	iPad use (baseline)
Productivity	Versus i*Pad app VitalHub chart* (Post-implementation)
Productivity	*Reduced need for paper chart* (Post-implementation)
Productivity	*Timeliness of patient care.* (Post-implementation)
Productivity	*Time required for office preparation and planning*. (Post-implementation)
Productivity	*Timely access to patients' data*. (Post-implementation)
Productivity	*Fitness to clinician workflow* (Post-implementation)
Professional satisfaction	
Professional satisfaction	*Improved productivity*

Variables X	**Variable Y**
Professional satisfaction	*Staff recruitment and retention at the BCCA*
Professional satisfaction	*Timely access to patient information*
Communication	
Inter-professional communication (Baseline)	*Inter-professional communication* (Post-implementation)
Inter-professional communications	T*imeliness of patient care*
Patient education and communication	
iPad use for Patient education and communication	Enhanced *overall quality of patient care*
iPad use for Patient education and communication	*Overall safety of patient care*
VH Chart use for patient education and communication	*Patients' engagement in the care planning process*.
VH Chart use for Patient education and communication	*Overall quality of patient care*
VH Chart use for *Patient education and communication*	Timely access to patient data.
VH Chart use for Patient education and communication	*Accuracy of clinical information.*
Clinical Decision-making (use of VH Chart)	
Clinical decision-making	*Safety of patient care.*
Clinical decision-making	*Fitness to clinicians' workflow.*
Clinical decision-making	*Timely access to patient data*
Clinical decision-making	*Accuracy of clinical information.*
Clinical decision-making	*Relevant clinical information*
Clinical decision-making	*Most updated clinical information*

Table 3 Quality & use measures (Post-implementation survey)

Quality & use measures (Post-implementation survey)	
System quality	*Ease of use,* *Learnability* *Response time* *Security, performance reliability*
Information quality measures	*Completeness* *Accuracy,* *Relevance* *Format acceptability* *Current information*
Service quality measures	*Technical support,* *Training resources* *Level of support needed.*
System usage measures	*# Of times used/ day* *# Of days/ week* *% Of patient* *Stage of use (before, after, during patient encounter)*
Purpose of use	*To access patient information* *Communication* *Clinical-decision making.*

3.3.3 Participants and settings

Observation and Interviews

According to Strauss and Corbin (1998), there is no exact number a researcher should consider as a requirement for grounded theory. They further clarified that the most significant aspect of sampling in grounded theory is to have participants that represent diverse perspectives about the phenomenon. In this study, the phenomenon in question is the use of native iPad application (VitalHub) that allows BCCA oncologists to access CAIS. Sampling in grounded theory was not pre-determined prior to data collection and it was continual until saturation was reached (A. Strauss & Corbin, 1998). Saturation determined sample size and referred to a state in data analysis where participants' narratives became repetitive and verified previously collected data (Jackson & Verberg, 2007). Purposeful and referral sampling were used to recruit participants for the interviews and observational sessions as explained in the recruitment methods section. The inclusion criteria were as follows:

- Currently working at the BCCA as Medical Oncologist or Radiation Oncologist or Oncology Resident or Oncology General Practitioner (OGP).
- Can read, write, and speak English.
- Able to give informed consent.
- Participating in the iPad pilot project.
- Currently working in one of the BCCA centres.

Observations participants were medical or radiation oncologists who worked in different BCCA centres. Two Medical Oncologists (MO) and one Radiation Oncologist (RO) participated in five pre-pilot observational sessions. Three RO and three MO participated in six post-implementation observational sessions. The observations were conducted by taking field notes in relation to how the current record keeping systems are being used, challenges, resources availability, interaction among healthcare team members, the level of collaboration required, and workarounds. Eleven user interviews were conducted, nine in-person interviews, and two phone interviews. Three medical oncologists, two residents, and six radiation oncologists participated in the post-implementation interview. The next chapter (Results) provides more detailed descriptions of the participants' background and demographic information.

Surveys

Both surveys (baseline and post-implementation) were sent to all of the IMITS Mobility Project participants (52 participants). All of the project participants were oncologist and residents working at different BCCA centres. Of those, 44 participants completed the baseline survey (response rate 84%) and 40 completed the post-implementation survey (response rate 76%). the next chapter (Results) presents the demographic distribution of the participants according to location, gender, and professional role.

3.3.4 Ethics Approval

Since the study was conducted in the BCCA, it required an ethical approval from the University of British Columbia (UBC) BCCA Research Ethics Board. The application was submitted on July 16, 2012. A notice of ethical approval was obtained on July 30, 2012 (Appendix D). After that, an application for ethical review was submitted to the University of Victoria's Human Research Ethics Board (HREB) on August 3rd, 2012. The University of Victoria HREB notice of ethical approval was obtained on August 27, 2012 (Appendix D)

A detailed consent form was sent to all the study participants explaining the purpose of the study, the research team involved in the study, the right to refuse participation (voluntary participation), inclusions/exclusion criteria, what does the study involve, participants responsibilities, the level of risk involved (Appendix C). The consent clearly explained that participants have the right to withdraw from the study or reschedule at any time if they felt embarrassed, uncomfortable, anxious, or upset during the observation or interview period. Also, participants were informed that they will be identified using alphanumerical codes to protect their privacy and confidentiality and that only the research team will have access to the alphanumerical codes, which was kept in a locked filing cabinet, separate from the study data. Furthermore, the consent explained the minimum level of confidentiality risk related to the study. Participants were able to withdraw from this study at any time without providing any explanation. Also, participants were informed that the study results would be reported in an aggregated format without any identifying information.

Participants were informed that signing the consent form in no way limits their legal rights against the investigators, or anyone else. Furthermore, the study team or participating institutions were not released from their legal and professional responsibilities. Contact information for the University of British Columbia (UBC) BCCA Research Ethics Board as well as the University of Victoria's Human Research Ethics Board (HREB) were provided to the participant in case he/she had any concerns or complaints about his/her rights as a research subject and/or experiences while participating in this study.

3.3.5 Recruitment methods

The following recruitment methods were used:

- Before the start of the pilot project, the project manager initiated the first contact with the iPad pilot project users using a BCCA email list that was available to the project manager. The initial letter of contact stated that potential participants would be able to participate in all or any part of the evaluation study. Also, the research team contact information was made available to the potential participants in the initial contact letter (Appendix A).
- TeamSite (SharePoint), a web-based collaboration tool used within the PHSA/BCCA environment, was used to announce the study. The project TeamSite included the study purpose and objectives, and links to the baseline and post-implementation surveys. Each of the survey links explained clearly the purpose of the survey and the research team contact information. Also, the instructions clearly stated that participation in the study was totally voluntary, and that only aggregated results would be reported.
- The observation and the interview study details were posted on the project TeamSite as the study proceeded. Participants who were interested in either the interview or the observation part of the study contacted the principal investigator to arrange the most suitable date and time for the study.
- Participants who agreed to participate in the study were asked to refer other potential participants for the study. To minimize potential bias (e.g. oncologists who have supervision authority over residents), the study consent form stated clearly that participation in the study is voluntary. Also, the investigator confirmed that that no

individual responses will be reported and that participation is totally voluntary before each observation or interview. The researcher did not obtain the potential participants' contact information. The project manager provided the research team contact information to the potential users who contacted the principal investigator if they were interested in the study.

3.3.6 Data collection methods

Surveys

A Canadian web-based tool, Fluidsurveys (http://fluidsurveys.com/), was used to administer both anonymous surveys to all participants of the IMITS Mobility Project. Using an online survey tool for quantitative data collection was chosen for several reasons. There was a short turnaround time for dissemination and response. Internet access in the modern healthcare context is ubiquitous, and all of the survey participants had access to an Internet-enabled computer at BCCA. Also, participants were distributed in five cancer centres across British Columbia and the online tool was the most cost-effective approach for the research. Furthermore, online tools support standardization with respect to survey questions and consistency with respect to responses. However, online survey tools have some limitations including end-users' perception that the survey is junk mail and inaccurate email lists (Lefever, Dal, & Matthíasdóttir, 2007). This has been addressed through initial communication between the project manager and the project participants. As mentioned previously, the project TeamSite included links to the baseline and post-implementation surveys. Each of the survey links explained clearly the purpose of the survey and the research team contact information. Also, the instructions clearly stated that participation in the study was totally voluntary, and that only aggregated results would be reported.

The baseline survey was administered two weeks before the project go-live date. The post-implementation survey was administered after two months of the project go-live, near the end of the pilot project. The baseline and post-implementation survey questionnaires were administered anonymously and all responses were kept strictly confidential. No identifying data were collected and only aggregated data were reported. For example, participants were asked about their age group instead of the exact age to eliminate the possibility of identifying participant by his/her age.

Observations

Direct observations were conducted two week before the project go-live date to understand how BCCA clinicians accessed patients' data using the available resources (desktop computer, paper charts, etc.) and the common challenges they faced when using these resources. A paper-based observation sheet was used to collect data related to the number of available computers for clinicians, tasks, and challenges. Two weeks after the project go-live date, further direct observations were conducted to understand how BCCA clinicians used the iPad and VitalHub Chart application to access patient clinical data, and any challenges related to the use of the iPad. This involved how and when the iPad was being used, for what task, and any reported challenges.

The consent form was sent to each of the observation participants in advance so that they would have adequate time to review the consent (Appendix C). On the day of the observation, the researcher explained the consent form and the activities that would be observed before signing the consent. Clinicians were asked to report any challenges or requests to the observer at the end of the observational sessions. However, some of the clinicians provided feedback immediately as they were performing their daily clinical tasks.

Interviews

The post-implementation interviews were conducted from two weeks after the project go-live date and continued throughout the pilot project period. Participant consent was obtained in the same way described previously (Appendix C). The researcher and each interviewee agreed on a specific date, time, and place to conduct a semi-structured interview. Most of the post-implementation observation participants were able to participate in the interview part shortly after the observation. This was to gain in-depth understanding about each participant's experience with the iPad and VitalHub application and the way it affected their workflow, information access needs, and patient care quality and safety. In this research study, the interviews were audio recorded and transcribed verbatim. The researcher started with a few open questions that defined the area to be explored (the effect of iPad native application on clinician's workflow), for example "What are your thoughts about using mobile technology for patient care in BCCA?" The interview started with the easy-to-answer questions and proceeded to more difficult questions throughout the interview. The interviewer used the "probing" technique to gain more detailed understanding of the interviewee's meanings and to discover areas or ideas that were not expected at the beginning of the research.

There are several issues that needed careful attention when conducting interviews. For example, the researcher used neutral questions and tone to avoid asking leading questions and ultimately biasing the interview (Britten, 1995). Also, the researcher reassured participants that there was no right or wrong answer to the questions and that the answers were totally anonymous. The researcher tried to keep the interview focused on the research topic while giving the interviewees enough time to explain their meaning. Moreover, the researcher ensured that the interviews were conducted in a setting with the least distraction possible.

According to Patton (1987), a good qualitative interview question is one that is neutral, sensitive, and clear. Also, Patton listed six categories of questions that could be asked during the interview (Patton, 1987). These questions are based on opinion or value, on behaviour or experience, on knowledge, on sensory experience, on feeling, and those asking about demographic or background details (Patton, 1987). Examples of probing questions included: How often do you use the iPad and VitalHub Chart application? Have you had any problems while using the applications? And so on.

3.3.7 Data analysis

Surveys

The researcher used one of the most common statistical analysis software packages, the statistical package for the social science (SPSS, V.19), to analyze the baseline and post-implementation survey questionnaires, which will be presented in the next chapter. The baseline questions were included in the post-implementation survey in addition to the questions from Infoway System and Use survey. The researcher used Cronbach's Alpha to test the reliability of the baseline and post-implementation survey questionnaire items. Cronbach's alpha determines the internal consistency or average correlation of items in a survey instrument to gauge its reliability. It is an indicator of reliability associated with the variation accounted for the true score of the underlying hypothetical variable (construct) that is being measured. Cronbach's alpha value ranges from 0 to 1 and the higher the score the more reliable the generated scale. In most social science research studies, a reliability coefficient of 0.70 or higher is considered acceptable (Gliem & Gliem, 2003).

The researcher used the Kendall's tau test for correlational statistics. A correlation coefficient is intended to measure "strength of relationship". However, different correlation coefficients measure strength of relationship in different ways. The Kendall coefficient has an intuitively simple interpretation and has much simpler algebraic structure than other coefficients (e.g. Spearman coefficient). When dealing with two ordinal measures that are related in a crosstabs (or at least an ordinal independent variable and a dependent variable that can be interpreted as dichotomous), the most appropriate measures of association are the gamma Kendall tau, or the less preferred Somer's D. Kendall's Tau looks at the difference between the probabilities that any 2 points will agree on the relative ranks of the variables compared to the probability that they will disagree. Kendall's is used when you have 2 measurements of a single sample and you want to know whether they are related, but you don't meet the criteria for Pearson's Correlation. In particular if the data is non-normal or ordinal, there are outliers, or the relationship is monotonic but not linear (variation of X is not associated with a change of Y and vice versa), the confidence intervals are more reliable and it works better on ordinal data that is close to being categorical.

The researcher assessed the correlation between the subjects' responses to survey questionnaires in terms of the iPad and VitalHub Chart application ability to meet clinicians' baseline expectations. The Kendall's tau results range from -1 to +1, with the sign indicating the direction of the relationship. The negative results (opposite direction) mean that as one increases the other decreases, while the positive results (same direction) mean that as one goes up so does the other. The closer the test values to -1 or +1 the stronger the relationship, as explained in Table (4) below.

Table 4 - Kendall's Tau Value Interpretation

+ Or - 0.30 or above	Strong
+ Or - 0.20 to 0.29	Moderate
+ Or -0.10 to 0.19	Weak
Less than + or - 0.10	Very weak

Interviews and Observations

For the qualitative part of the study (observations and interviews) grounded theory was used to analyze the results. In grounded theory, data analysis starts after the collection of the first set of data in a cyclical process (constant comparative method). For the sake of consistency, this study employed the Straussian data analysis approach, which includes open, axial, and selective coding.

Open coding involves breaking down, exploring, linking, conceptualizing, and classifying data to pinpoint discrete concepts, which are the primary units of data analysis. At this initial stage, data collected through interviews and observations were analyzed to initially identify the current data access mechanisms and practices of BCCA clinicians in ambulatory clinical areas. This included data on how clinicians access the Cancer Agency Information System (CAIS) and identifying and categorizing the challenges associated with the current practices, processes, and tools. The second component was the use of the mobile information system at BCCA and how these tools are used to support clinicians in providing cancer care. The third component dealt with identifying discrete issues around clinicians' attitudes toward and perceptions about the usefulness of the iPad and VitalHub Chart application in their practice. Once concepts were identified they were assembled together to establish initial categories. Open coding was continuous as new information was collected and emerging concepts and categories were compared to existing concepts and categories. For example, the first level of coding (open coding) yielded several labels such as limited access, interruption, space constraints, computer availability, delays, and ease of use.

Axial coding is the process of linking categories by comparing each category to every other category (Jackson & Verberg, 2007). During this phase, fragmented data was rebuilt by establishing new links between categories and sub-categories (Corbin, 1990; A. Strauss & Corbin, 1998). For example, previous labels were grouped together into higher-level concepts like resource availability, clinician productivity, and usability. The final coding level was accomplished when these categories were linked to each other and to the literature findings to develop the themes that explained the interview results and contributed to the final recommendations. For example, previous concepts were further grouped into categories and sub-themes such as care coordination, challenges of the hybrid environment, benefits of mobile computing, and success factors for mobile computing.

3.3.8 Summary of the Study timing

The study was conducted over two months period as described in Table (5) below.

Table 5 - Timing Summary

Date	**Research stage**
July–August 2012	Ethics approval: – BCCA Ethics Board approval – UVic Ethics Board approval
August 2012	Data collection: – Baseline Survey administered – Baseline observation – Baseline data analysis
September 2012	Data collection: – Post-implementation observations – Post-implementation interviews – Post-implementation survey

Chapter 4: Results

In this chapter, the results of the questionnaires, observations, and interviews are presented. First, the baseline and post-implementation results are presented including participants' demographics and background information as well the various statistical analysis results related to the use of the iPad and VitalHub Chart application in the BCCA. The observation and interview results are then presented to complement the survey results and provide in-depth insight into clinicians' perceptions and experience with the use of mobile computing technologies and applications in terms of perceived benefits, challenges, and success factors.

4.1 Participants Demographics

4.1.1 Participant demographics (baseline & post-implementation)

The baseline and post-implementation surveys were sent to all project pilot users (52 clinicians) with relatively high response rate (84% (n = 44) for the baseline and 76% (n = 40) for the post-implementation). Survey respondents represented the five Cancer Agency Centres. However, the majority of the respondents were from Vancouver Centre (62% baseline, 64% post). The survey respondents represented the various professional disciplines; however, the majority were either Medical Oncologist (48% baseline, 51% post) or Radiation Oncologist (36% baseline and post). In terms of gender, survey respondents were almost equally distributed in the baseline while in the post-implementation survey the majority were male (64% compared with 36% female). In terms of age, respondents, for both baseline and post-implementation surveys, were relatively well distributed between the different age groups that fall between 30 and 60 years old. The following table (Table 6) summarizes participant demographics and background information identified in the baseline and post-implementation survey questionnaires.

Table 6. Summary of Participants Demographics and Background Information (Baseline & Post-implementation Survey Questionnaires

	Baseline	**Post-implementation**
Response Rate	84% *(44 out of 52 users)*	76% *(40 out of 52 users)*
Gender		
• Male	52% (n=21)	64% (n=25)
• Female	48% (n=20)	36% (n=14)
Age (years)		
• < 30	9.5% (n=4)	8% (n=3)
• 30–40	33% (n=14)	26% (n=10)
• 40–50	24% (n=10)	38% (n=15)
• 50 – 60	24% (n=10)	23% (n=9)
• > 60	9.5% (n=4)	5% (n=2)
Clinical Role		
• Radiation Oncologist	36% (n=15)	36% (n=14)
• Medical oncologist	48% (n=20)	51% (n=20)
• Resident	12% (n=5)	8% (n=3)
• Oncology General Practitioner (OGP)	5% (n=2)	5% (n=2)
Cancer Centre		
• Vancouver BCCA Centre	62% (n=26)	64% (n=25)
• Fraser Valley BCCA Centre	12% (n=5)	10% (n=4)
• Kelowna BCCA Centre	14% (n=6)	13% (n=5)
• Abbotsford BCCA Centre	2% (n=1)	5% (n=2)

	Baseline	Post-implementation
• Vancouver Island Centre	10% (n=4)	8% (n=3)

4.1.2 Participants' background information (baseline and post-observation)

Observations were conducted in three BCCA centres: the Vancouver Cancer Centre (VCC), the Fraser Valley Cancer Centre (FVC), and Fairmont Outpatient Clinics. Two Medical Oncologists (MO) and one Radiation Oncologist (RO) participated in five pre-pilot observational sessions. Three RO and three MO participated in six post-implementation observational sessions. Participants were observed for two hours in different outpatient clinical settings at the BCCA. The following table (Table 7) summarizes participants' background information identified in the baseline and post-implementation observations.

Table 7 Baseline and Post-implementation Observations–Participants' Background Information

	Baseline	Post-implementation
No. of observational sessions	5	6
Gender		
• Male	80% (n=4)	67% (n=4)
• Female	20% (n=1)	33% (n=2)
Clinical Role		
• Radiation Oncologist	40% (n=2)	50% (n=3)
• Medical oncologist	60% (n=3)	50% (n=3)
Cancer Centre		
• Vancouver BCCA Centre	60% (n=3 observations)	33% (n=2 observations)
• Fraser Valley BCCA Centre	20% (n= 1 observation)	33% (n=2 observations)
• Fairmont Outpatient Clinic	20% (n=1 observation)	33% (n=2 observations)

4.1.3 Participant demographics and background information (Interviews)

Semi-structured interviews were conducted in the post-implementation phase of the project to allow clinicians to reflect on their use of the iPad and VitalHub Chart application. Eleven user interviews were conducted, nine in-person interviews, and two phone interviews. Three medical oncologists, two residents, and six radiation oncologists participated in the post-implementation interview. The interview ranged from half an hour to one hour depending on each participant's availability. Table (8) summarizes participants' background information identified in the post-implementation interview.

Table 8 Post-implementation Interviews–Participants' Background Information

Post-implementation interviews	
No of interviews	11
Gender	
• Male	73% (n=8)
• Female	27% (n=3)
Clinical Role	
• Radiation oncologist	54% (n=6)
• Medical oncologist	27% (n=3)
• Resident	18% (n=2)
Cancer Centre	
• Vancouver BCCA Centre	45% (n=5 interviews)
• Fraser Valley BCCA Centre	18% (n= 2 interviews)
• Fairmont Outpatient Clinic	18% (n=2 interviews)
• Abbotsford BCCA Center	9% (n=1 interview)
• Vancouver Island Centre	9% (n=1interview)

Statistical analysis of the pre- and post-implementation survey questionnaires was conducted using the Statistical Package for the Social Sciences (SPSS, V.19). Cronbach's Alpha was used to test reliability of the subjects' responses to survey questionnaires concerning the expectations and effect of mobile system implementation. Reliability statistics showed that the alpha coefficient for the baseline survey is 0.899 and for the post-implementation survey is 0.970 (Table 9). These results indicate that the survey items have relatively high internal consistency since in most social science research a reliability coefficient of 0.70 or higher is considered acceptable (Gliem & Gliem, 2003).

Table 9 Cronbach's *Result*

Survey type	**Cronbach's Alpha**
Baseline	0.899
Post-implementation	0.970

When dealing with two ordinal measures that are related in a crosstabs (or at least an ordinal independent variable and a dependent variable that can be interpreted as dichotomous), the most appropriate measures of association are the gamma Kendall tau, or the less preferred Somer's D. Kendall's Tau looks at the difference between the probabilities that any 2 points will agree on the relative ranks of the variables compared to the probability that they will disagree.

Kendall's is used when you have 2 measurements of a single sample and you want to know whether they are related, but you don't meet the criteria for Pearson's Correlation. In particular if the data is non-normal or ordinal, there are outliers, or the relationship is monotonic but not linear (variation of X is not associated with a change of Y and vice versa). The confidence intervals are more reliable and it works better on ordinal data that is close to being categorical.

4.2 Questionnaire results

The baseline and post-implementation surveys were conducted to measure BCCA clinicians' expectations before and after the use of the iPad and VitalHub Chart application. Survey questions evaluated clinicians' perceptions and experience in relation to data accessibility, inter-professional communication, workflow efficiency and provider productivity, job satisfaction, and patient care quality and safety measures (communication, involvement, patient education, clinical decision making, and overall patient experience). In addition, the post-implementation questionnaire included several questions related to the overall success of the IMITS iPad Mobility Project focusing on iPad quality measures (responsiveness, security, reliability, features), VitalHub Chart application information quality measures (completeness, relevance, accuracy, format, comprehensiveness), service quality (implementation process, technical support, training), user satisfaction measures (enjoyableness, easiness to use, user friendliness), and self-reported use measures (iPad/VitalHub Chart use/day, iPad/VitalHub Chart use/week, iPad/VitalHub Chart use/before patient visit, iPad/VitalHub Chart use/during visit, iPad/VitalHub Chart use after patient visit, iPad/VitalHub Chart use/ patient (%)), which are presented in the system evaluation section of this chapter.

Prior Experience and Adoption of Mobile Technology

The baseline survey results show that clinicians have already embraced mobile computing technology at their personal life and clinical practice, even before the start of the IMITS Mobility project. In general, the survey results show that clinicians at BCCA are among the early adopters of mobile computing technology (with more than 90% (n=38) of the respondents are using mobile computing technology in their clinical practice). The majority of the respondents (> 80%) are either very comfortable or comfortable with using mobile computing technology. The apple iPad and iPhone are the dominant mobile devices that have been adopted by the majority of the respondents (69%, 60% respectively) (Figure, 3).

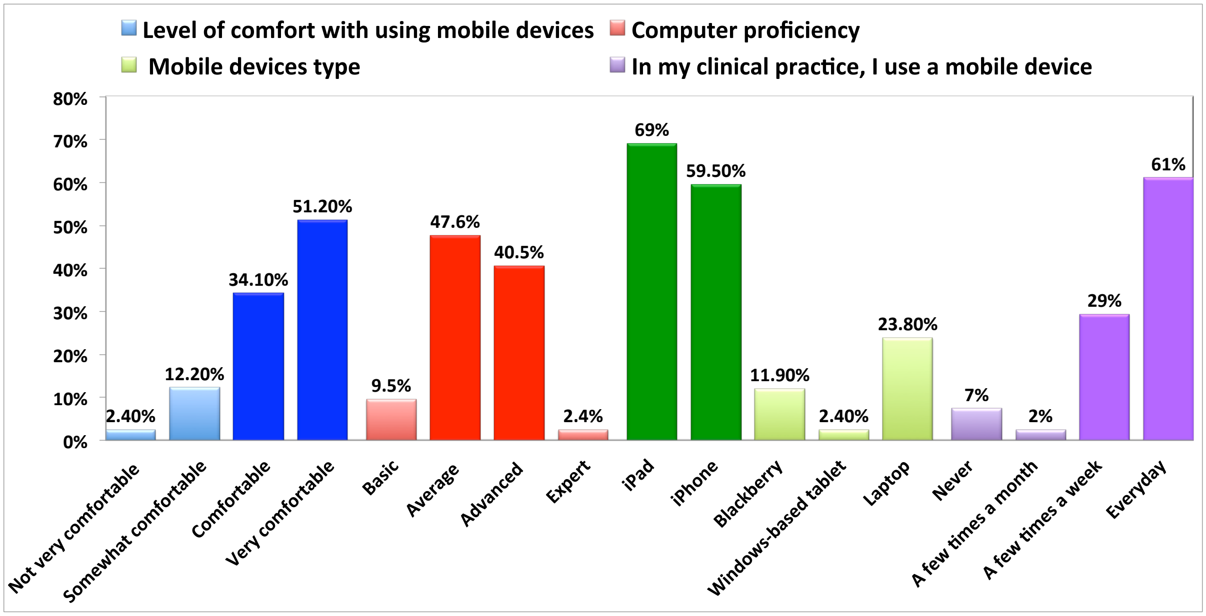


Figure 3. Prior Experience and Adoption of Mobile Technology (Baseline)

Information Accessibility

Given the limited computerized resources at the BCCA, one of the most relevant questions was related to the iPad and VitalHub Chart app ability to address clinician information access needs. The percentage of clinicians who expected that the iPad would improve their access to patients' charts slightly decreased from 97% (n=41) in the baseline to 95% (n=37) in the post-implementation survey (Figure. 4). However, the results remained high and showed that the iPad has improved information accessibility by enhancing clinicians' access to CAIS through the use of the VitalHub Chart app. The majority of the post-implementation respondents reported decreased need for paper charts and desktop computers (85% (n=33) and 69% (n=27) respectively) (Figure. 5). Therefore, clinicians reported an increase in the time they could spend directly with their patients 62% (n=24).

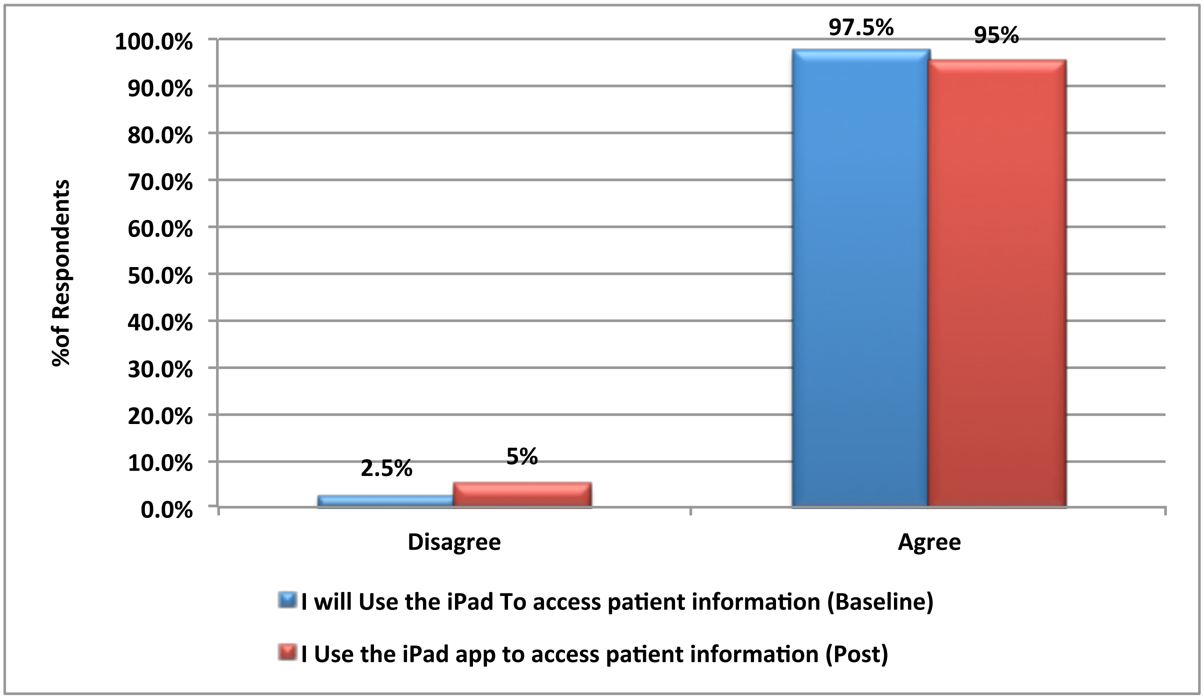


Figure 4. Enhanced access to patients' charts (Baseline expectations Vs. Post-implementation)

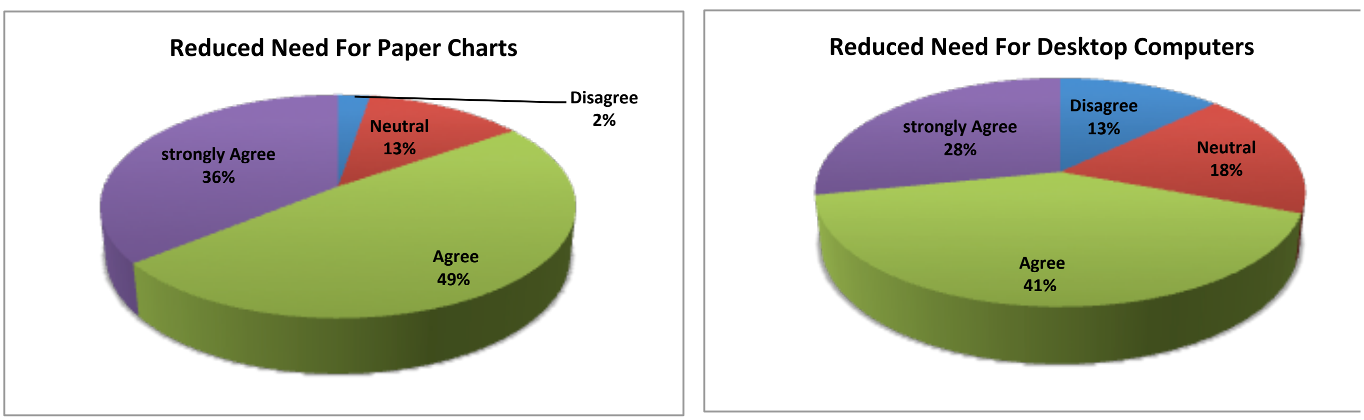


Figure 5. Reduced Need for Paper Charts/Desktop (Post-implementation)

When correlating the use of the iPad with clinicians' workflow fitness, positive and strong correlation was obtained (Kendall's tau 0.404) and the results were statistically significant (Table 10). However, when correlating the results for the iPad use with information access throughout the patient visits, results showed that implementation of the iPad project was associated with a moderate negative effect (Table 10). In contrast, when correlating the information accessibility with the use of the VitalHub Chart app throughout patient visit, positive results were found (Table 10). These unexpected findings are further explained in the discussion chapter.

Table 10 Cross *Tab: Use of the iPad / VitalHub Chart Versus Clinicians workflow/ time of use (stage).*

Correlation type	Kendall's tau-b value	Significance
iPad use versus fitness to clinician workflow	0.404	0.004
Use of the iPad (to access patient information)		
Before patient visit (Baseline Vs. post-implementation)	-0.09	0.445
During patient visit (Baseline Vs. post-implementation)	-0.225	0.04
After patient visit (Baseline Vs. post-implementation)	-0.309	0.004
Between patient visits (Baseline Vs. post-implementation)	-.219	0.045
Information accessibility		
Information accessibility Vs. Use of VH Chart before patient visit	0.377	0.006
Information accessibility Vs. Use of VH Chart during patient visit	0.40	0.004
Information accessibility Vs. Use of VH Chart after patient visit	0.329	0.018
Information accessibility Vs. Use of VH Chart between patient visits	0.337	0.020

Inter-professional Communication

The effect of the iPad on clinicians' communication was another area that was captured through the questionnaire. The percentage of clinicians who expected that the iPad would improve inter-professional communication slightly increased from 45% in the baseline to 51% in the post-implementation survey (figure. 6).

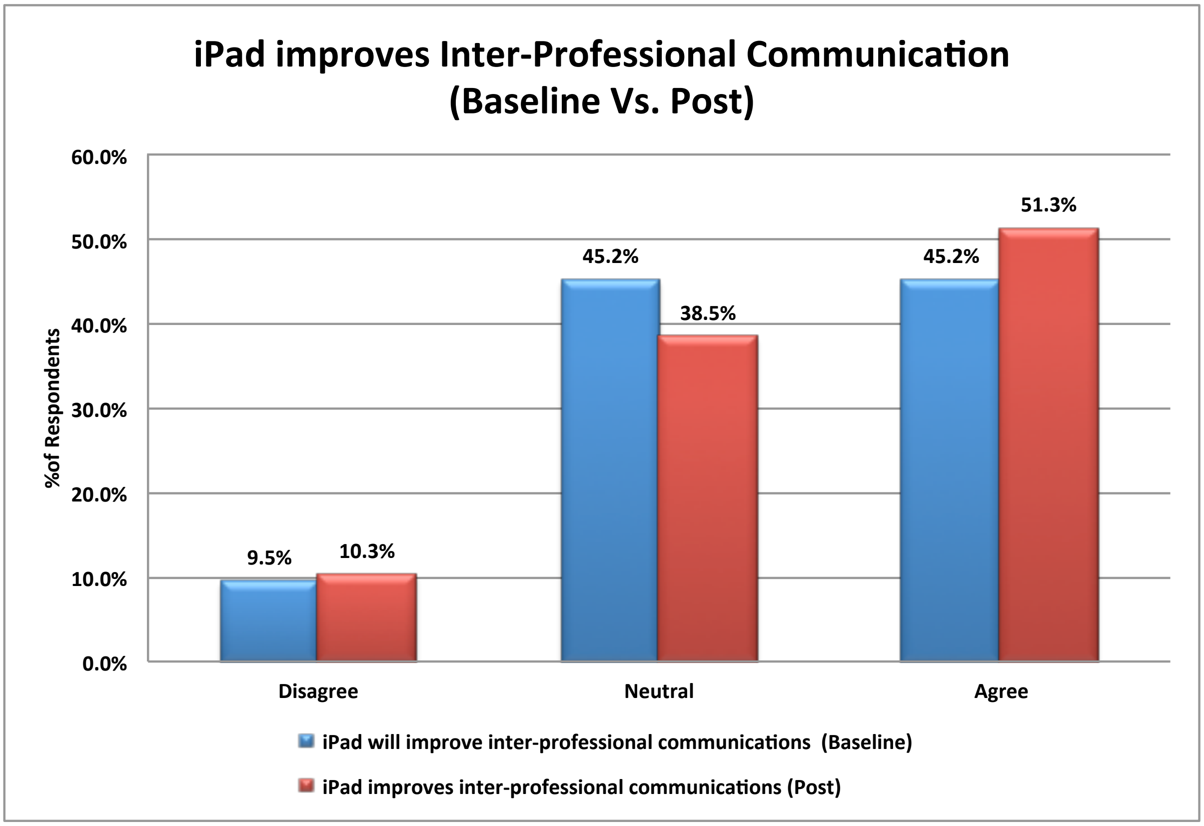


Figure 6. Inter-professional communication (Baseline vs. Post)

However, when correlating BCCA clinicians' expectations for using the iPad for communication with other clinicians and their actual use after the implementation, the results revealed positive correlation (Kendall's tau .393, P value 0.004) that is statistically significant (Table 11). Also, strong association was found between inter-professional communication improvements and the timeliness of patient care services (Table 11).

Table 11 *Cross Tab: Use of the iPad for Inter-professional Communication Pre- Versus Post-implementation*

Correlation type	Kendall's tau-b value	Significance
Communication		
Inter-professional communication (Baseline Vs. post-implementation)	0.393	0.004
Inter-professional communications versus *timeliness of patient care*	0.345	0.003

Productivity

The effect of the iPad on clinicians' Productivity was captured in the baseline and post-implementation questionnaires. The percentage of clinicians who expected that the iPad would improve clinicians' productivity slightly decreased from 81% (n=33) in the baseline to 80% (n=31) in the post-implementation survey (figure. 7).

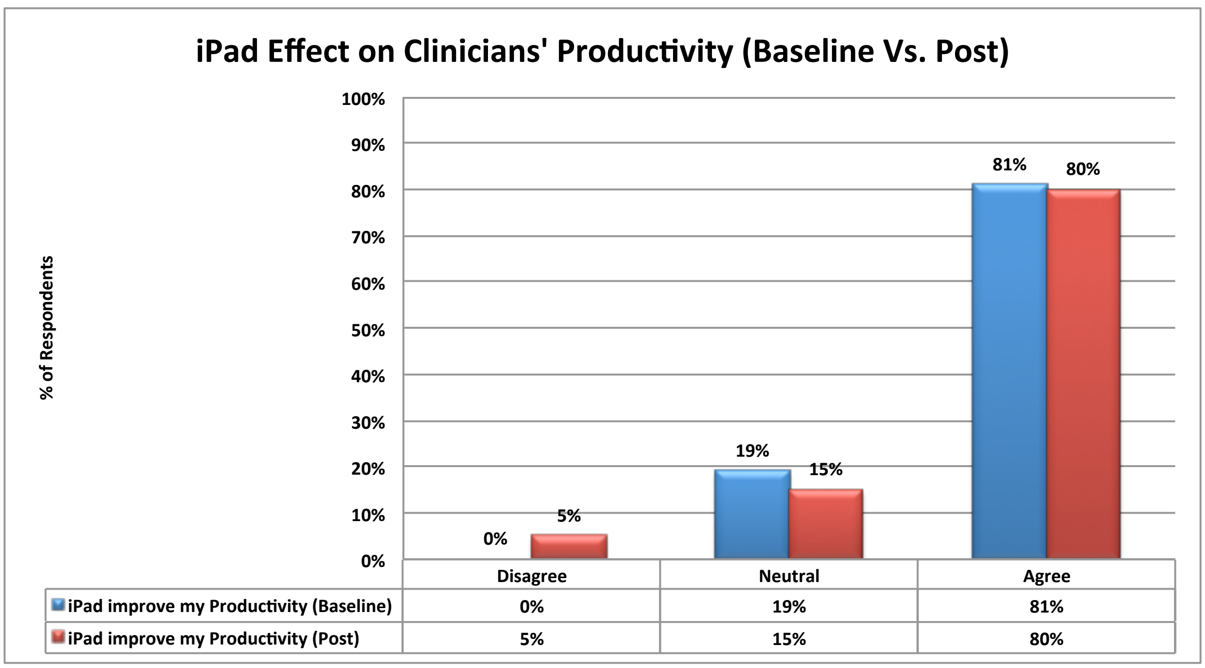


Figure 7. iPad Effect on Clinicians' Productivity (Baseline Vs. Post)

Also, in the baseline survey, correlation statistics showed that there was a weak positive association between the iPad use and clinicians' productivity (Kendall's value 0.15) and results were not statistically significant (Table 12). In contrast, when productivity was correlated to use of the mobile application (VitalHub) during patient visits, the results (Table 12) showed a strong correlation (Kendall's value .399) and results were highly significant (P value .002). This confirms that clinicians have highly appreciated the enhanced access to CAIS through the mobile application. Increased productivity was further analyzed through survey questionnaires. Increased productivity was related to the iPad application (VitalHub) effects including limited disruption through reducing the need for paper charts and desktop computers, improved timeliness of care delivery, enhanced accessibility to resources, and reduced time spent in offices and administrative activities and on desktop computers (Table 12).

Table 12 *Cross Tab: Productivity Versus iPad Use (Baseline)/Productivity Versus VitalHub App Use (Follow Up)*

Correlation type	**Kendall's tau-b value**	**Significance**
Productivity		
Productivity improvement versus iPad use (baseline)	0.15	0.889
Productivity versus i*Pad app VitalHub chart* (Post-implementation)	0.399	0.002
Productivity Versus *Reduced need for paper chart* (Post-implementation)	0.523	0.000
Productivity versus *timeliness of patient care.* (Post-implementation)	0.732	.000
Productivity versus *time required for office preparation and planning*. (Post-implementation)	0.16	0.271
Productivity versus *timely access to patients' data*. (Post-implementation)	0.527	.000
Productivity versus *fitness to clinician workflow* (Post-implementation)	0.787	.000

Job Satisfaction

Regarding job satisfaction, 67% (n=26) of the users reported increased sense of proficiency and job satisfaction after the implementation of the iPad Mobility project. Furthermore, the majority of clinicians (85%, n=34) believed that the use of the iPad application made their job easier (Figure. 8).

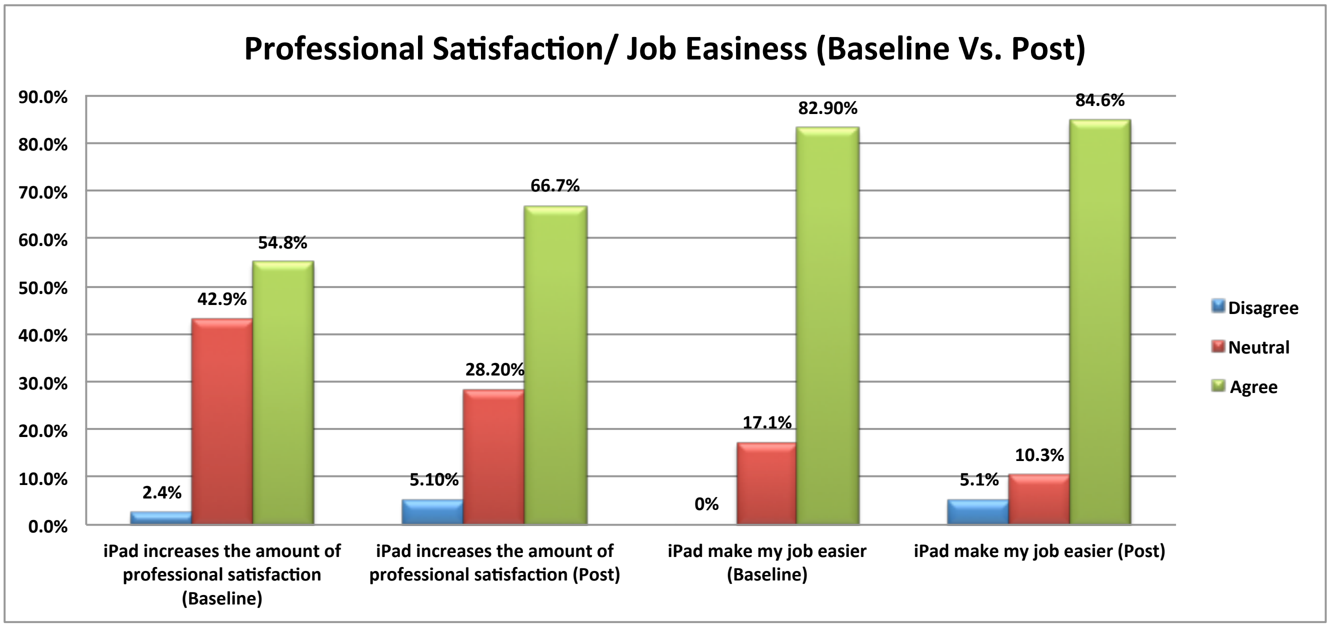


Figure 8. Professional Satisfaction, Job Easiness (Baseline Vs. Post-implementation)

Correlational statistical analysis revealed strong positive associations between professional satisfaction and improved productivity (Kendall's value 0.435, P value 0.002), professional satisfaction and timely access to patient information (Kendall's value 0.305, P value 0.067), and professional satisfaction and the ability of the BCCA to retain high quality staff Kendall's value (0.39, P value 0,006) (Table. 13).

Table 13 *Cross Tab: Professional Satisfaction with Different Ordinals*

Correlation type	Kendall's tau-b value	Significance
Professional satisfaction		
Professional satisfaction versus *improved productivity*	.435	0.002

Correlation type	Kendall's tau-b value	Significance
Professional satisfaction versus *Staff recruitment and retention at the BCCA*	0.385	0.006
Professional satisfaction versus *timely access to patient information*	.305	0.067

Patient Engagement and Communication

The effect of the iPad on patient education and communication was a vital area that was addressed in the questionnaires. The percentage of clinicians in the baseline who expected to use the iPad to facilitate communication with their patient (74%, n= 31) dropped to (46%, n=18) after the implementation, which will be discussed in the next chapter (figure.9). In Contrast, The results of the post-implementation questionnaire showed that the majority of clinicians (64% n=28) believe that the iPad app (VitalHub Chart) improved their ability to involve patients in the care planning process (figure.9).

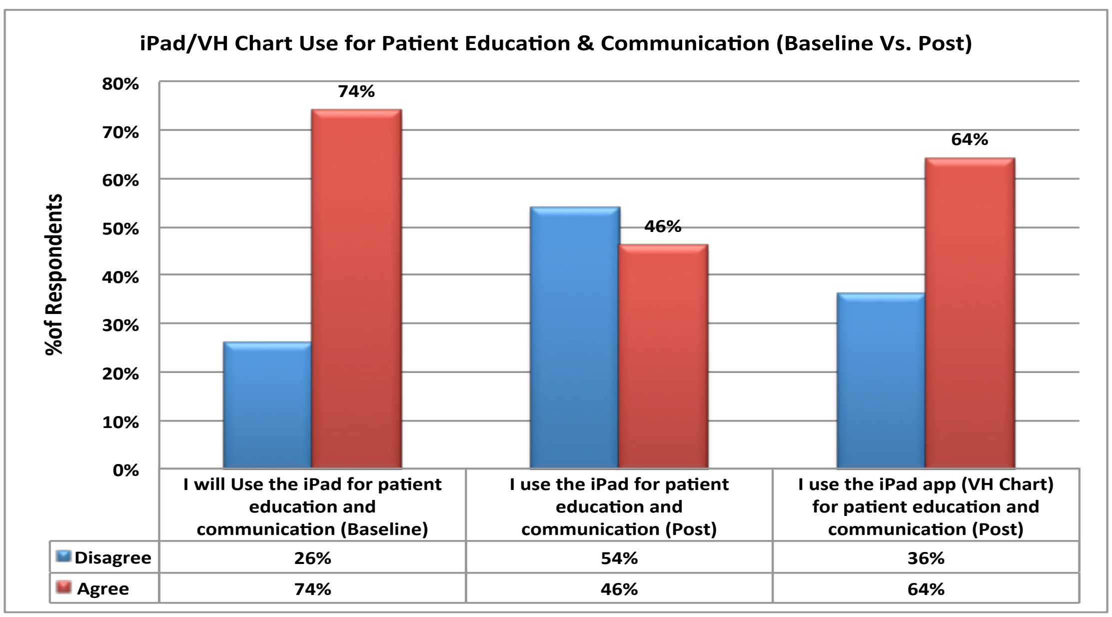


Figure 9. iPad Use for Patient Education & Communication (Baseline Vs. Post)

Also, when correlating clinicians' ability to involve patients in their care with the use of the iPad app (VitalHub app) for patient education and communication, the results showed strong relationship that is statistically significant (Kendall's tau-b .479, P value .000) (Table 14). Further analysis revealed that using the iPad and VitalHub Chart app for communication and patient education has strong relation with the overall patient care quality, the overall safety of patient care, system quality, and information quality (Table 14).

Table 14 *Cross Tab: Use of the iPad/VH Chart Versus patient engagement, patient care quality, patient care safety, system quality, information quality,*

Correlation type	**Kendall's tau-b value**	**Significance**
Patient education and communication *(as a result use of the iPad/ VH)*		
VH Chart use for patient education and communication **versus** *patients' engagement in the care planning process*.	0.479	0.000
iPad use for Patient education and communication **versus** enhanced *overall quality of patient care*	0.408	0.001
iPad use for Patient education and communication **versus** *overall safety of patient care*	0.350	0.010
VH Chart use for Patient education and communication **versus** *overall quality of patient care*	0.409	0.002
VH Chart use for *Patient education and communication* **versus** timely access to patient data.	0.480	0.000
VH Chart use for Patient education and communication **versus** *accuracy of clinical information.*	0.302	0.046

Clinical Decision Making and Patient Safety

In the baseline survey, more than half of clinicians (54%, n=23) expected that they would use the iPad for clinical decision-making. The results even increased slightly to 61% (n=34) in the post-implementation survey (Figure. 10). The results showed strong correlation between use of the iPad application for clinical decision-making and the patient safety (Kendall's tau-b .394, P value .003). Analogous results were seen between the use of the iPad application for decision-making and the application ability to deliver accurate, relevant clinical information in a timely manner (Table 15).

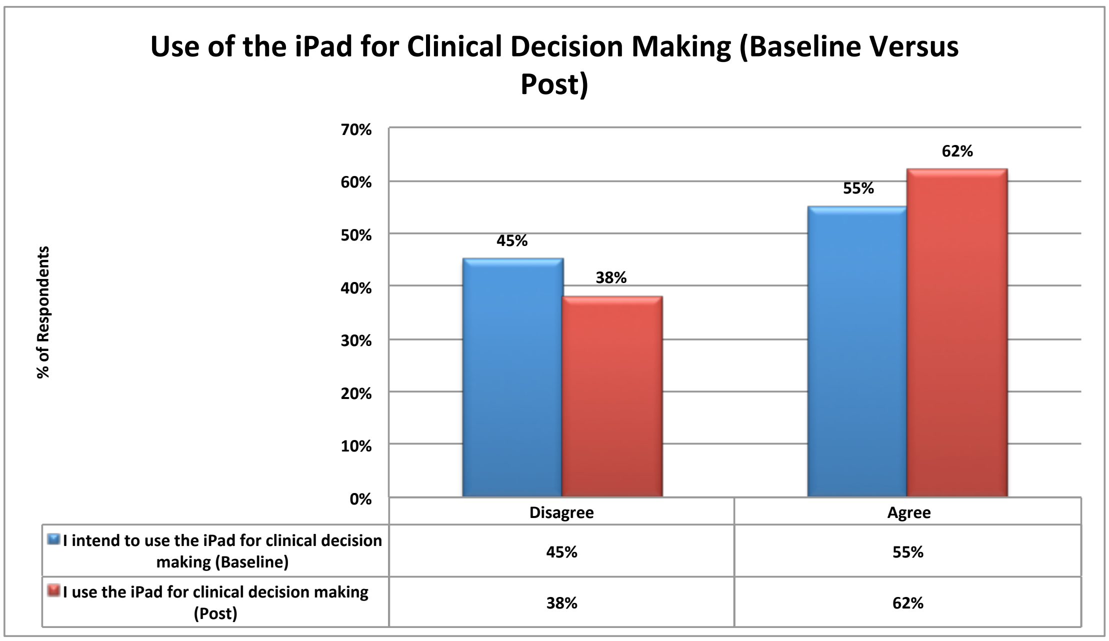


Figure 10. Use of the iPad for Clinical Decision-making (Baseline Vs. Post)

Table 15 *Cross Tab: Use of the iPad Application Versus Different Ordinals*

Correlation type	**Kendall's tau-b value**	**Significance**
Clinical Decision-making (use of VH Chart)		
Clinical decision-making **versus** *safety of patient care.*	0.394	0.003
Clinical decision making **versus** *fitness to clinicians' workflow.*	0.355	0.011
Clinical decision making **versus** *timely access to patient data*	0.346	0.025
Clinical decision making **versus** *accuracy of clinical information.*	0.340	0.028

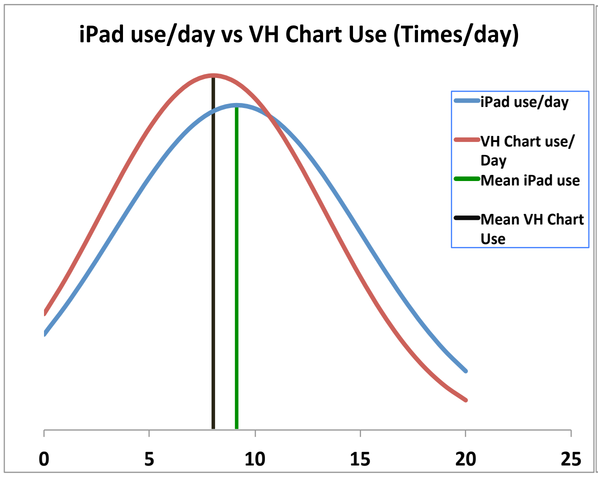
Correlation type	**Kendall's tau-b value**	**Significance**
Clinical decision making **versus** *relevant clinical information*	0.417	0.004
Clinical decision making **versus** *most updated clinical information*	0.378	0.010

System Evaluation

The following results are related to the iPad and VitalHub Chart application success measures obtained from the post-implementation survey. These measures include self-reported use measures, level of satisfaction with the iPad quality measures, VitalHub Chart application information quality measures, and service quality (implementation) measures.

System Usage

Most of the respondents (66%) reported that they used the iPad and VitalHub Chart daily with an average of 9.2 and 8 times/day respectively. Of the remaining respondents, 26% reported using the system always compared with only 8% who rarely used the system. Most of the respondents reported using the system for almost 50% of their patients. While the majority of the respondents (95%) used the VitalHub Chart application to access patient information, the iPad was used for other purposes including clinical decision making, patient education, and communicating with other clinicians (62%, 49%, and 46% respectively). Most of the clinicians used the system either before or during patient encounters (82%, 67% respectively) (Figure 11). Also, usage data was captured automatically using the system log, which revealed similar trends for usage patterns as it was published in previous publication (J. Wu et al., 2013) 4



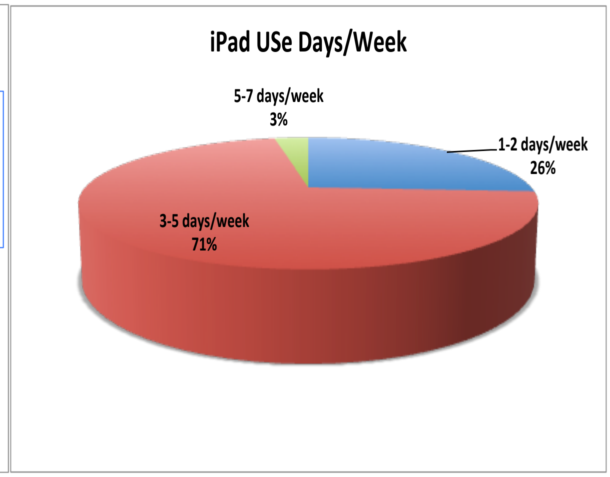
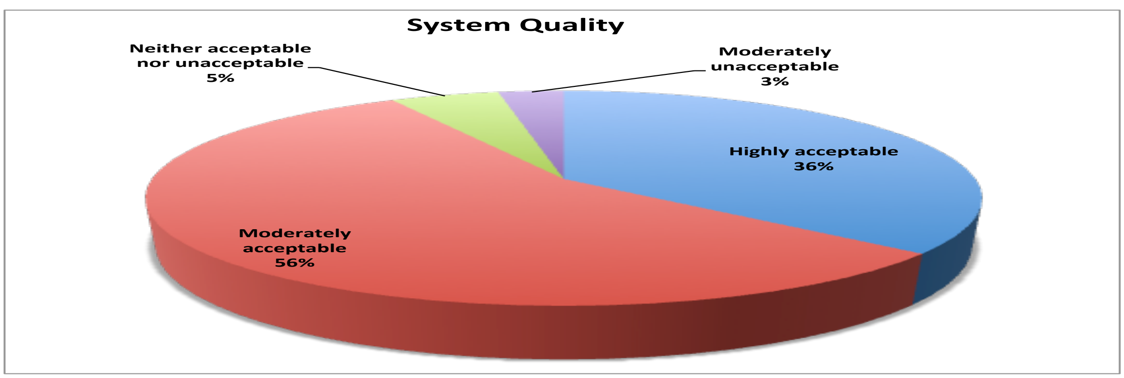


Figure 11. VH Chart Use (days/week)

System quality: responsiveness, security, reliability, features

Most of the clinicians (92%) found the response time, security, and reliability of the iPad and the VitalHub Chart application to be either moderately or highly acceptable (Figure. 12).



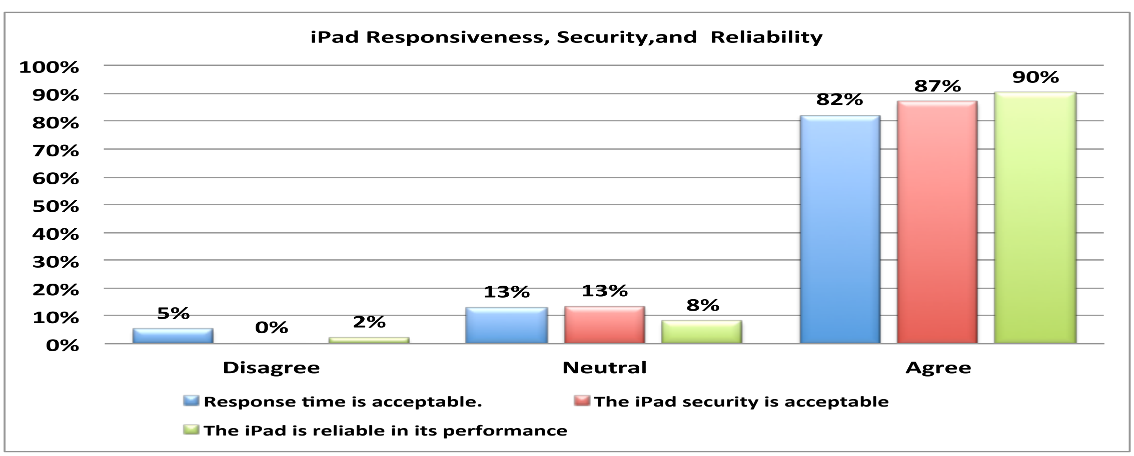
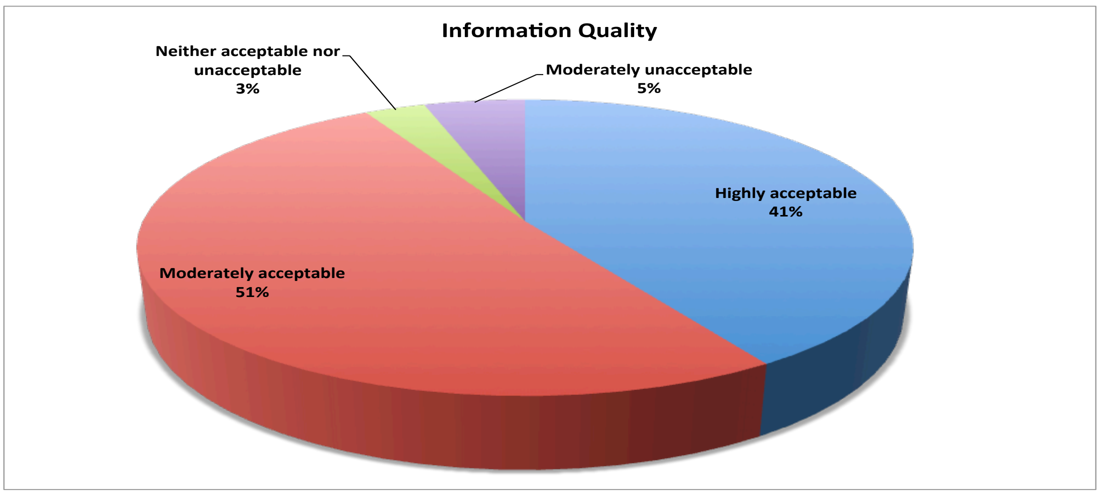


Figure 12. System Quality

Information quality: completeness, relevance, accuracy, format, comprehensiveness The majority of respondents (> 80%) found that VitalHub Chart provides real-time, accurate, and relevant information in acceptable format and layout. In terms of completeness, most of the respondents (62%) found the information within the VitalHub Chart app to be complete. However, close to one third of the respondents found VitalHub Chart application to be incomplete as it lacks access to images and action lists. In general, most of the respondents (92%) found the information within the VitalHub Chart application to be either highly or moderately acceptable (Figure. 13).



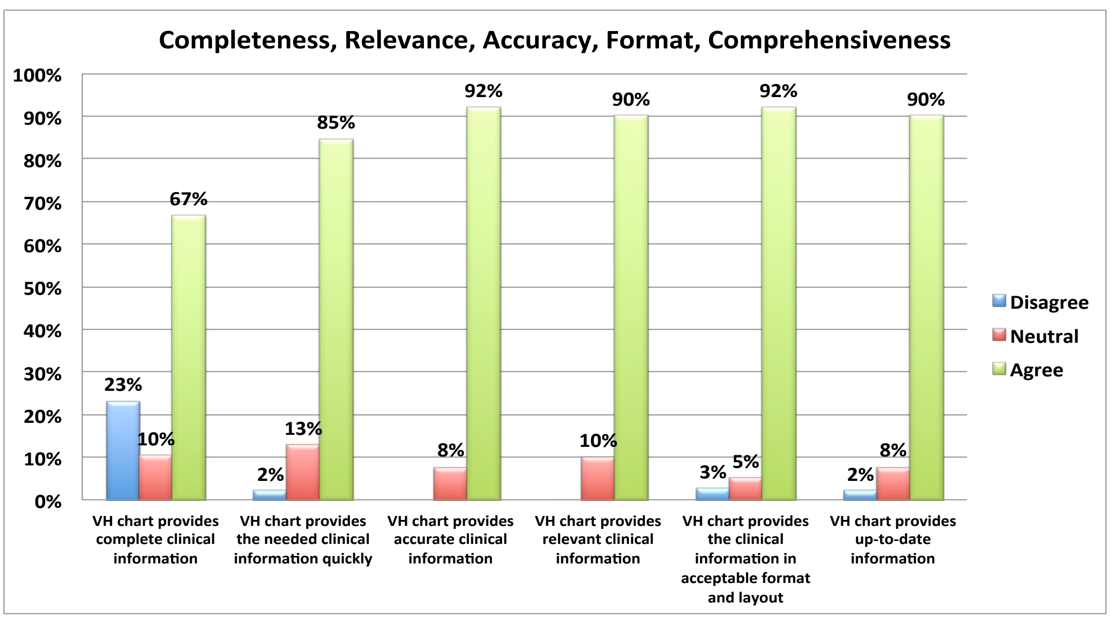
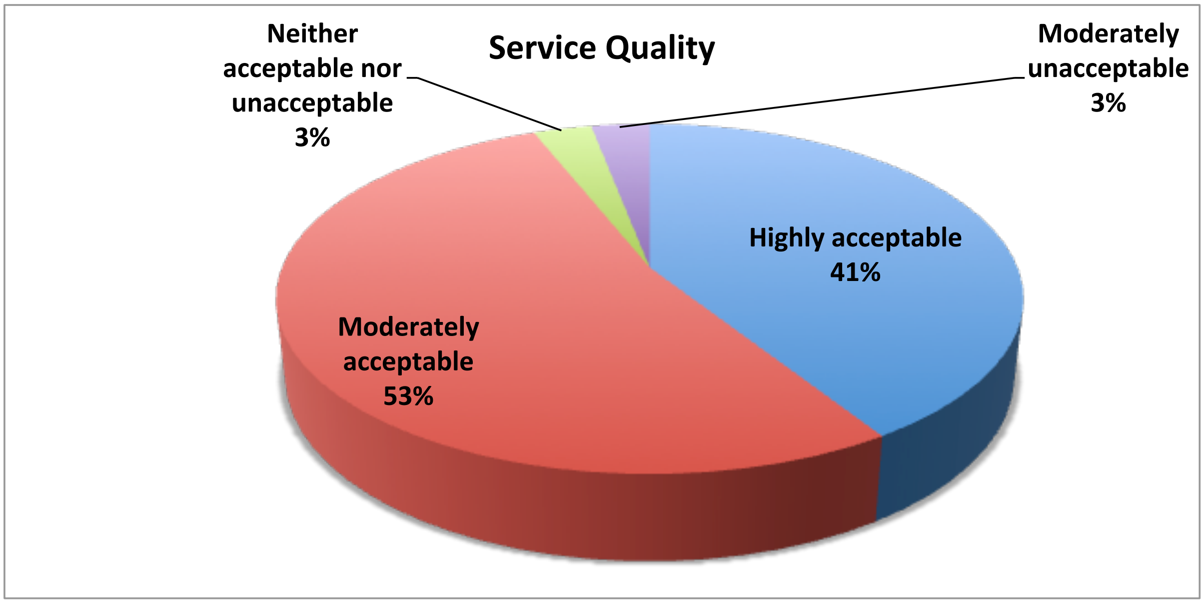


Figure 13. Information Qualities

Service Quality: Implementation process, Technical support, Training

Most participants (90%) agree that there were sufficient technical support and training resources for the iPad Mobility Project. In general, most of the respondents (95%) rated the project implementation process either moderately or highly acceptable (Figure. 14).



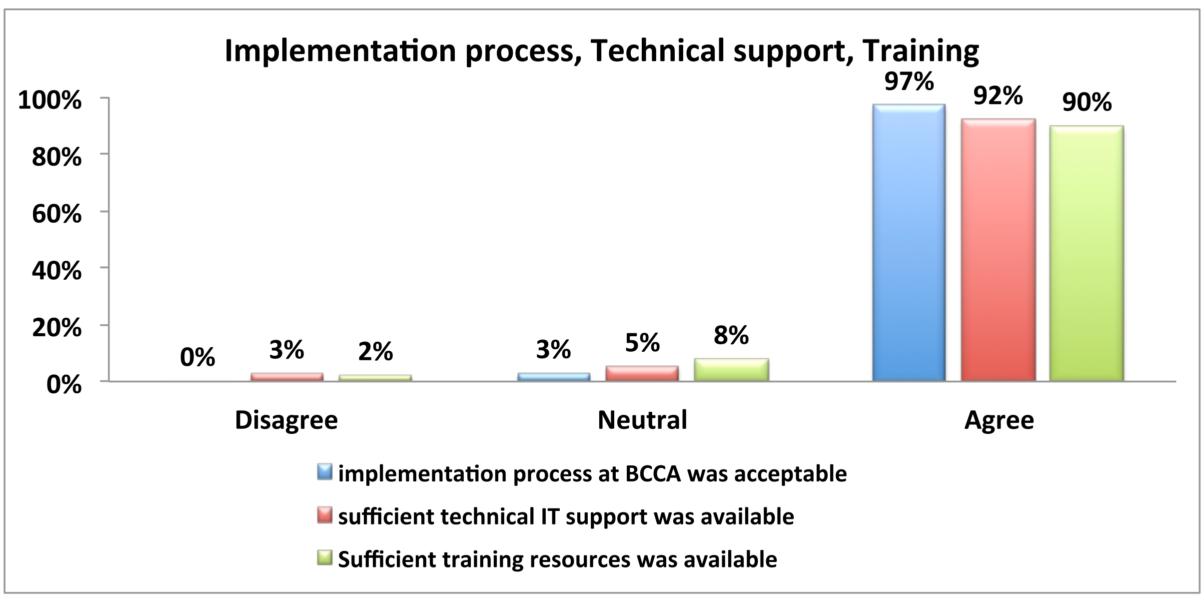


Figure 14. Service Quality

4.3 Observation Results

4.3.1 Baseline observation results

The results of the observational study are presented separately to distinguish the investigator own observations and field notes from those of the interview participants. However, the same data analysis approach was followed for both observations and interviews. The baseline line observations revealed the following:

- Clinicians do not have access to the Cancer Agency electronic records while they are in the exam rooms.
- The number of available desktop computers is less than the number of clinicians, especially in the radiation oncology ambulatory care setting.
- Most of the BCCA ambulatory care settings have limited physical space that does not allow the addition of further desktop computers. This is a major issue, especially in the radiation oncology ambulatory care setting.
- Clinical workflow in all BCCA ambulatory care clinics is a collaborative effort between various clinicians. However, most of the time residents do not have enough access to computerized resources and depend on reviewing patient information and writing paper notes before the start of the clinic.
- Currently, clinicians rely on multiple information resources (hybrid environment) to perform their daily tasks.
- BCCA clinicians' information needs cannot be met with only one of the current information resources available within the BCCA. Each information resource (desktop, paper chart) provides certain information that is not available in other resources.
- Clinicians rely heavily on their desktop computers to perform multiple tasks simultaneously. These tasks include accessing CAIS, accessing and responding to corporate emails, accessing and updating research databases, accessing online resources, and patient review and care planning tasks (for radiation oncologists who are using Varian, the radiation oncology system).
- The most common theme among all clinicians who participated in the observation sessions is that the paper chart is never up to date. It became apparent during the

observation sessions that the paper chart has been used as a way of collecting data from the computer system rather than as a source of the data. Furthermore, certain areas within BCCA, such as the Fairmont Ambulatory Care Clinic, did not have access even to the regular paper chart.

- Clinicians have developed workarounds to adapt to the lack of access to electronic patient records. One of the most common is to print the information that the clinicians believe they might need while with the patient. However, in many cases clinicians left the room to access other patient information because it either did not exist in the paper chart or was not expected before seeing the patient.
- The ambulatory care clinic environment is fast paced and requires instant access to patient information. Since cancer usually has profound effect on patients physical and psychological status, enhancing clinician access to the most updated patient information is essential to enable BCCA clinicians to address their patients concerns and needs in a timely manner, to better involve patients in their care, to provide better patient education, and to enhance patients experience and confidence in the quality of care they are receiving in the BCCA.

4.3.2 Post-implementation observations results

The post-implementation observational sessions revealed the following:

- The ability to access CAIS using the mobile system addressed the issue of inadequate desktop computers in the BCCA care setting, especially radiation oncology.
- The mobile system provided access to the electronic chart (CAIS) in the exam room.
- The mobile system provided access in areas where computers are not connected to the Internet for security reasons such as the physics planning area.
- The ability to access CAIS in the exam reduced visit interruption significantly.
- The ability to access CAIS in the exam room reduced the need for printing significantly.
- Clinicians integrated the mobile system easily into their workflow and did not require a lot of training and support, as most of the clinicians were already familiar with using the mobile device (iPad).

- As a result of having mobile access to CAIS, some of the BCCA clinicians were able to see more than one patient consecutively without the need to go back to the physician working area.
- The mobile system reduced the need for the paper chart as it provided clinicians an easier and quicker way to find the information than the paper charts.
- The mobile system enhanced residents' ability to work efficiently in the clinic as it allowed them to access CAIS and other online resources without the need to wait for an available computer. Also, it reduced the time spent transcribing notes from the desktop into the paper chart before seeing the patient.
- The ability to access diagnostic images and action lists was highly requested by most clinicians.
- Clinicians start asking if it would be possible to have mobile access to other computerized resources (Varian system, CareConnect).
- The multi-tasking functionality of the desktop computer seems easier than the multi-tasking functionality of the iPad.

4.4 Interviews

4.4.1 Interview results

The interview scripts were analyzed using grounded theory principles, which included collecting, coding and analyzing the data simultaneously and continually to decide what additional data are needed until saturation was achieved. During data analysis, the researcher examined the data and stopped at each word or phrase trying to bring to bear all possible underlying reasons for the data. This process allowed the researcher to develop abstract concepts and their descriptions through constant comparison and interaction with the data. The interviews and field notes were semi-structured in nature to ensure the most relevant topics were covered, while allowing for some flexibility. With permission from the participants and the project manager, they were recorded for the researcher to review using a digital voice recorder. During the interviews, the researcher took separate notes to focus on the key points during data analysis. Immediately after each interview was completed, the researcher reflected on the interview and wrote more detailed notes. Additionally, the researcher transcribed and reviewed the recorded sessions to produce more comprehensive notes.

The first level of coding (open coding) yielded several labels such as limited access, interruption, space constraints, computer availability, delays, ease of use. The labels were grouped together into higher-level concepts (codes) like resource availability, clinician productivity, and usability. These codes were further grouped into categories and sub-themes such as care coordination, challenges of the hybrid environment, benefits of mobile computing, and success factors for mobile computing. Axial coding was used to establish connection between these categories and their subcategories. The final coding level was accomplished when these categories were linked to each other and to the literature findings to develop the themes that explain the interview results and contribute to the final theory and recommendations. Only one researcher, the principal investigator in this study, conducted the data coding and analysis process.

The study findings showed an overwhelmingly positive attitude to the use of the iPad and the VitalHub Chart application to support BCCA clinicians' mobile workflow through enhanced access to CAIS. The iPad Mobility project addressed challenges related to existing hybrid environment (paper & desktop records) by providing mobile interface that allowed them to access the Cancer Agency Information system (CAIS). BCCA clinicians described the benefits of the iPad mobility project in terms of enhancing their workflow efficiency and productivity, data accessibility and inter-professional communication, and the quality and safety of patient care. The iPad and VitalHub Chart reduced workflow interruption, enhanced clinicians' ability to involve patients in their care, enhanced collaboration and coordination among team members, and supported better clinical time management. From clinicians' perspective, the iPad and VitalHub chart has the potential to enhance patient education efforts and the quality and safety of clinical decision-making process.

On the other hand, clinicians experienced some challenges when using the iPad application such as the inability to use the iPad application for data entry (view only) and the inability to access other patients' applications such as diagnostic images and action list. Time constraints did not allow adding these functionalities during the pilot project period. Other challenges were related to the BC Cancer Agency information system itself (CAIS), which is a legacy information system that lack the capability for computerized provider order entry (CPOE) and integration with other information systems currently used in the BCCA such as the Varian system and CareConnect. Also, clinicians experienced some challenges related to the data entry mechanism (Virtual keyboard) and multitasking features of the iPad (only two applications can be opened simultaneously). Even though clinicians highly requested the ability to access images, most radiation oncologist participants believed that they would use it for patient education purposes and not for the actual radiation planning process, which require bigger screen for displaying multiple images at the same time. Therefore, clinicians viewed the iPad and VitalHub chart app as complementary to and not as replacement for fixed computer workstations.

From clinicians' perspective, the success of the iPad mobility project was related to three major factors. First, the ergonomic features of the iPad and VitalHub chart such as user-friendly customizable interface, lightweight, and long battery life. The second factors which is mainly related to the use of the VitalHub Chart application that addressed workflow challenges by allowing them to access patients' electronic records in the exam room. The last factor is related to the iterative and participatory implementation approach that was adopted throughout the project, which allowed them to collaborate with and provide feedback to the system developers to enhance the VitalHub Chart application features and ensure that it met their needs.

Three major themes emerged from the analysis of the interviews scripts (Figure. 15): 1) perceived benefits of mobile computing technologies in relation to clinicians' information access and communication needs, patient care quality, and workflow efficiency and provider productivity; 2) perceived challenges of mobile computing technologies and application use in the BCCA; and 3) success factors of mobile computing technology at the BCCA. Detailed description of the each theme is presented in the following sections.

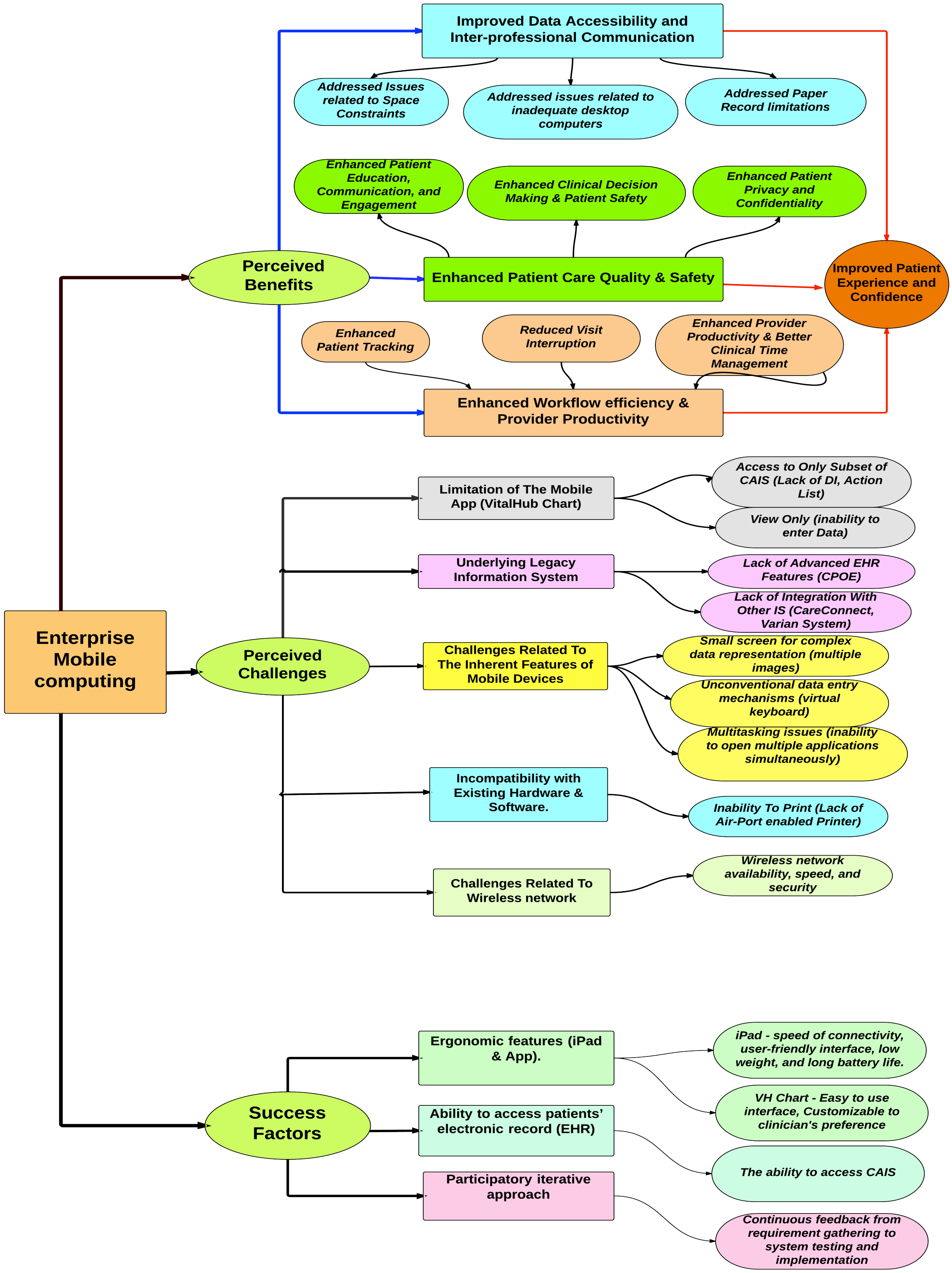


Figure 15. Major Themes

Perceived Benefits of Mobile Computing Technology

The following figure (16) summarizes the perceived benefits of mobile computing technology and its relation to workflow efficiency, information access and professional communication, and patient care quality and safety.

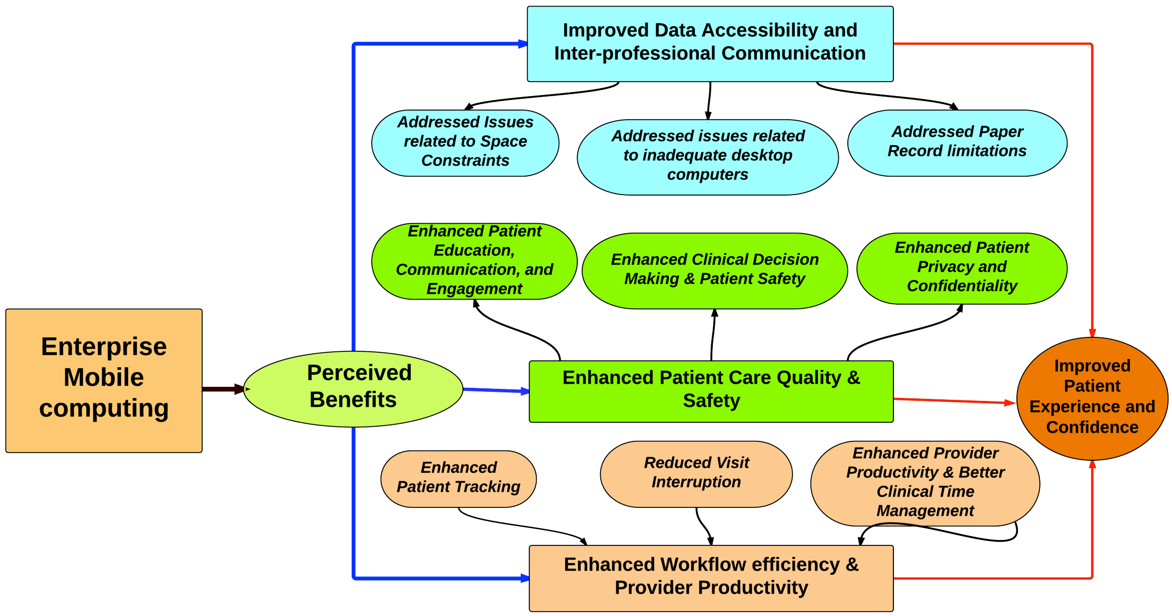


Figure 16. Perceived Benefits of Mobile Computing Technology

Clinicians' Information Access and Communication Needs

The effect of mobile computing on data accessibility is summarized in the following figure (17).

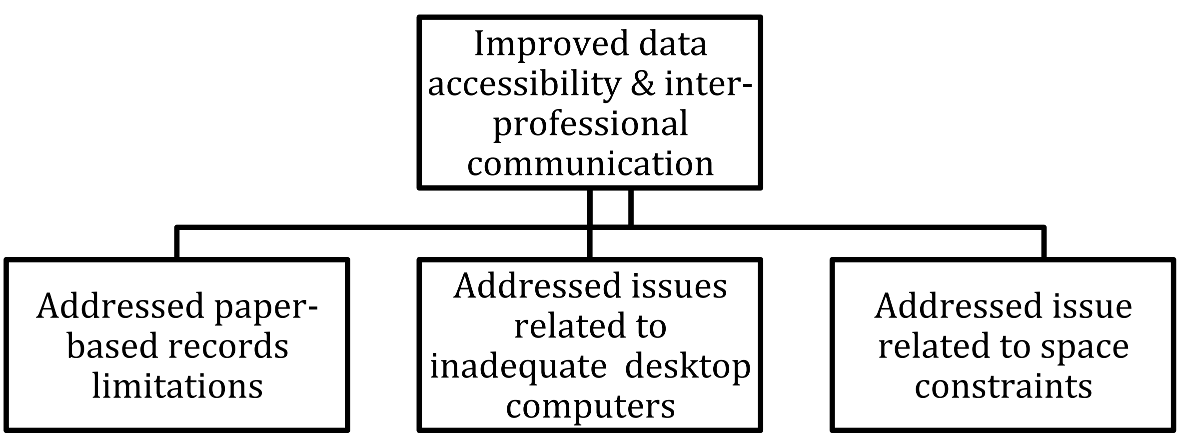


Figure 17. Improved Data Accessibility and Inter-professional Communication

Clinicians' information access

Most interview participants identified the role of the iPad and VitalHub Chart application in enhancing their access to CAIS and other computerized resources at the BCCA. From clinicians' perspective, limited access to CAIS is the biggest challenge they face.

> *"I used it in that context where I need access to CAIS and could not get to a desktop. The other way that I have used it is in the patient room because we don't have access to the electronic chart in the examination room with the patient."*

Participants identified three factors that negatively affect their information access: the limited number of available desktop computers and lack of access to computers in the patient examination room; limitations of paper-based records; and physical space constraints that exist in the BCCA, which prevent adding additional desktop computers.

Few participants (n=3) reported that introduction of the iPad was associated with limited information access in presence of the paper charts. Those clinicians found it confusing when they had to refer to both the paper chart and the iPad to update patient information from both resources.

> *"It is really confusing and troublesome, I have to look at both the iPad and the patient's file to make sure that I have all the latest information."*

Inadequate number of desktop workstations

BCCA clinicians rely on a hybrid recordkeeping system that includes electronic patient records and paper-based charts. The electronic record is the primary patient record and only accessible on regular computer workstations. However, computer workstations were only available in a shared doctors' room and the number of available computer workstations was less than the number of clinicians, who ended up sharing the workstation with other healthcare providers. These limitations led to workflow bottlenecks and delays while waiting for free computer workstations.

> *"The problem is in our outpatient area. Examination rooms are grouped by a pod and at the end of the pod there is a doctor's room, which is no bigger than this office, and there are only two computers and usually six doctors sharing two computers."*

Furthermore, clinicians did not have access to computer workstations in the patient exam room during patient visits. The only source of information that clinicians had while with the patient was the paper chart, which has several limitations and did not meet clinicians' information access needs. Consequently, clinicians found themselves leaving the exam room frequently to go to the doctors' room to access the patient electronic chart using a desktop computer.

> *"So what I used to have to do is to run in and out of the room back to the computer to look up such and such lab results. The patient says, "What [does] my such and such pathology report say?" I have to leave the room [and] walk back out because it is never in the paper chart anymore."*

Also, for security reasons, computer workstations available in the physics planning area were not connected to the Cancer Agency network and clinicians could not use these workstations to access CAIS. Computer workstations in the physics planning area were not connected to the Internet for security reasons as the organization tried to protect radiation planning software from potential malicious activity.

> *"The other places where I found it useful in places like in the physics planning area, where most of the computers there are not connected to CAIS on purpose, because of security concerns. They are trying to separate planning software from anything, which has Internet access, and there is usually one computer somewhere but you have to go and find it and then log on. So I am finding it actually really useful just to have my iPad with me and that's the other big change, this week I carried my iPad with me the whole time."*

The iPad and VitalHub Chart application addressed these issues of limited access to computer workstations in the BCCA ambulatory care settings. The iPad provided another interface that can be shared with other healthcare team members (e.g., residents) eliminating the need to wait for available desktop computers. Also, it provided access to CAIS in areas where desktop computers were not available (exam rooms, patient review areas) or were not connected to the network for security reasons.

> *"Today I went to the ward, for example, and I did not log on to a computer. I had already previewed what I needed in my office, but I was able to take the iPad in with the patient and access data with the patient as I was taking history."*

> *"To have it with you, if the patient says what was my PSA yesterday and you don't remember, to be able to get it quickly without having to leave the room, that's great and I think patients appreciate that."*

Limitation of the paper-based records

Clinicians described their negative experience with the paper chart. Most participants described the limited value of the paper chart, which does not support their information access needs as explained in the following quotes:

> *"Well I have not really wanted the paper chart for years and I still don't quite understand why we have it so I just saw a patient and they were looking for the paper chart and they said "We are sorry the paper chart is in Abbotsford." To me it makes no difference whatsoever because there is nothing in the paper chart that I wanted. In fact, I would say it is actually a hindrance having a paper chart. So from my point of view, I think we should have got rid of the paper chart years ago."*

Interview participants further explained the reasons behind their negative experiences. Most participants found the paper chart out of date and not always available, and sometimes they lacked access to the paper chart (e.g., Fairmont ambulatory clinics) as explained in the following quotes:

> *"I don't use the paper chart for two reasons. One is the paper chart is often unavailable, because it is in different location, and secondly the paper chart is usually not up to date…. So if you don't have the paper chart with you, or if the paper chart is not up to date and then they are asking you for a report, then you have to leave the room to go into CAIS. But now it is here."*

Participants believed that the use of the paper chart has created workflow inefficiencies by increasing interruption during patient encounters. Visit interruption occurred when patients asked questions of their physicians and the information was not available in the paper chart or when clinicians needed specific clinical information that was not anticipated before the visit. Also, clinicians described the process of looking up information using the paper chart as time consuming.

> *"The paper charts are useless because they are always out of date and many interactions with patients, probably I would say half, involve some reason for me to leave the room and walk out."*

Participants expressed their positive experiences with the use of the iPad and VitalHub Chart as opposed to the paper chart. Obviously, the iPad application (VitalHub Chart) reduced clinicians' need for the paper chart and addressed the challenges associated with its use:

> *"It certainly reduced my need to look through the paper chart for things that I know are in both the electronic and the paper chart. It definitely reduced scrolling through lab results, or imaging reports, because they are actually easier to find electronically."*

Physical space constraints

Interview participants, especially radiation oncologists, described the negative effect of the physical space constraints that exist in the BCCA on their ability to access available computerized resources. Space limitations did not allowing adding new computer workstations to accommodate the needs of all clinicians.

> *"The patient review area I think is ergonomically a disaster. I think it was not designed to be like that. I am very annoyed that other people took our space and we ended up I think in a very bad space. Obviously we don't have enough desktops due to space issue."*

Interaction and communication among healthcare providers

Interview participants described the role of mobile technology in enhancing their communication with each other and other BCCA staff. Clinicians highly appreciated the ability to access institutional emails and its effect on their ability to work as a team. However, the email value was connected to the ability to access patients' electronic records (CAIS). Having access to both emails and patient charts allowed clinicians to communicate more efficiently about the patient's conditions, progress, and treatment plans.

> *"Because I think the iPad value comes from the VitalHub plus the email situation, because we communicate quite a lot by email. It is so much [more] usable and user-friendly, communication is easier, you can always access others by email, so the iPad is here and I am still using it keeping an eye on my email or whatever while I am working on the clinical information."*

However, some participants experienced some challenges, as the iPad application (VitalHub Chart) did not allow them to copy and paste into their email, which they found limited their ability to use the email feature effectively.

> *"In VitalHub I have not figured out how to do this yet, but in CAIS you can just copy the patient ID and then copy it to the email and then I can type up the email."*

Having mobile access to patient charts during clinical conferences facilitated clinicians' communication and allowed them to better interact with each other as they have access to all the information that is related to the clinical case being presented. Therefore, clinicians are more active and engaged in the discussion and not just listening to the clinical conference presenter.

> *"I have used it in tumour conferences. So in tumour conferences there will be a list in CAIS and you can sit and listen to the video conference or you can pull up the information and if there is something that you want to look up, then it is right there in front of you, so it is useful to have again your own access to CAIS in the middle of a meeting."*

Workflow Efficiency and Provider Productivity

Interview participants expressed their perceptions about the iPad and VitalHub Chart application benefits in terms of workflow efficiency and provider productivity. These benefits were reducing visit interruptions; enhanced productivity through better use of clinical time; enhanced coordination and workload distribution; and timely completion of follow-up actions through the enhanced tracking of patient information. The effect of mobile computing on workflow efficiency and provider productivity is summarized in the following figure (18).

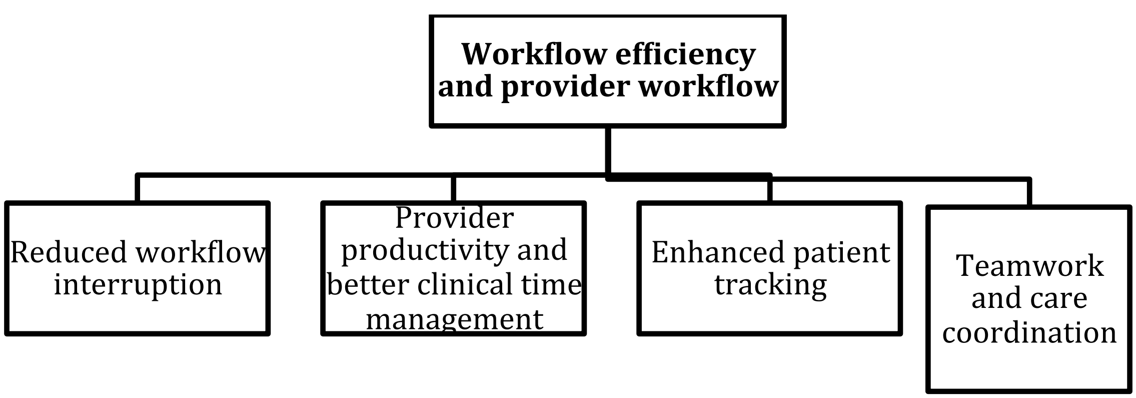


Figure 18. Workflow Efficiency and Provider Workflow

Reducing visit interruption

One of the immediate benefits to workflow efficiency that was mentioned by all interview participants is the significant decrease in visit interruptions after the implementation of the iPad Mobility Project. As described earlier, this benefit was related to the enhanced access to CAIS and other computerized resources allowing clinicians to answer patients' questions and address their concerns in a timely manner during patient encounters.

> *"The other way that I have used it is in the patient room because we don't have access to the electronic chart in the examination room with the patient. So it has been useful because sometimes the paper chart has not been updated necessarily, but I know there is a copy of it electronically. Instead of having to leave the exam room to go check, copy it down, or print it out and then bring it back to review it with the patient, I now have it in front of me and so that has been very useful."*

Enhanced provider productivity and clinical time management

Interview participants explained the potential benefits to their productivity. From the clinician's perspective, reducing interruption and time wasted while locating, accessing, or waiting for an available computer improved their efficiency. The following quotations are from the interview scripts:

> *"Yes potentially it improves productivity, because you don't have to run out of the room to check a report. If you don't have the paper chart with you, or if the paper chart is not up to date and then they are asking you for a report, then you have to leave the room to go into CAIS. But now it is here."*

Interview participants further described how the iPad and VitalHub Chart application replaced the inefficient workarounds that they used previously to adapt to the limited access to CAIS. For example, clinicians printed or transcribed or tried to memorize certain information that they believed they might need during the patient visit. Clinicians found this workaround inefficient, as they were not always able to anticipate all the information that they might need during the patient visit. Also, clinicians found this workaround leading to a duplication of efforts and inefficient use of their clinical time.

> *"For me, I don't have to memorize blood work anymore, I don't have to look at the screen and then try to memorize like 2 or 3 things and then the patient will ask me oh what was this and I forget and I go back. I have it there in my hand, it is up to date, I can pull up the CT Scan."*

The ubiquitous access to the Cancer Agency information allowed clinicians to better utilize their time to conduct other administrative and clinical activities regardless of their location in the BCCA. Clinicians believe that the mobile system allowed them to work whenever they had a chance to do so. This was very important for residents who are usually moving between different clinical settings in the BCCA. In other words, the mobile system allowed clinicians to maximize their ability to use their working hours and reduce wasted time while waiting for other activities.

> *"There is sometimes wasted time if you need to go to a conference or a meeting and you're sitting waiting for it to start. If you are in the building you can access your patients, you can be reading up for the next patient, or you can be sending emails or doing triage or other different things that would be available to do. I think that's definitely improving efficiency."*

> *"I think it will help productivity and efficiency simply because it increases again my ability to be multitasking. I could be waiting for the elevator and I can check my email or I can be walking up the stairs checking my email."*

In addition, clinicians believe that the mobile system allows them to find the required information quicker than searching the whole paper chart. Consequently, the mobile system allowed them to save time locating and accessing patient-specific information.

> *"It is nice to have access to the electronic chart with the patient. That was not available previously. It does make it easier to find the information that is in the paper chart that is available electronically, so for patients who ask "What did my previous scan show?" or something, it is a quicker way for me personally to find the information electronically than trying to find it in the paper chart."*

Teamwork and care coordination

Participants described how the iPad and VitalHub Chart positively affected their ability to coordinate and distribute the workload between team members and ultimately optimized their workflow. Having equal access to CAIS, clinicians and residents were able to coordinate their clinical tasks and distribute workload more efficiently. Having better access to patient charts, emails, and online resources allowed clinicians to have smoother interactions and facilitated the teaching and learning interactions between BCCA clinicians and their residents. Also, it allowed residents to better discuss care plans with BCCA clinicians after the visit. The following has been quoted from the interview scripts.

"When the resident and I go to the room together, I have the paper chart and the resident has his iPad and the resident if there is an issue that comes up like we need to check on a lab result, the resident can pull it up on his iPad while I am continuing to talk to the patient."

Tracking tool (follow-up actions)

Participants described how they used the iPad and VitalHub Chart application to take notes of clinical tasks that needed follow-up. The mobile system provided a master-tracking tool that was easier to update and track than the multiple different paper notes. Clinicians perceived this function as more efficient and easy way that enhanced their productivity, as explained in the following quotes:

"Outside the clinic I use it more to track things, so things for me to follow up on. I know now VitalHub actually has a patient list and you can star patients and try to figure out what to follow up on. Before what I did, I used the notes and typed it out "please follow up on this blah blah blah."

Patient Care Quality And Safety

Participants described how the iPad and VitalHub Chart application enhanced patient care quality and safety. These potential improvements were related to enhanced patient communication, patient education, and patient involvement in care planning and decision-making, and enhanced patient experience and confidence (Figure 19).

Figure 19. Enhanced patient care quality & Safety

Patient education, communication, and engagement

Participants described how the use of the iPad and VitalHub Chart application enhanced patient communication and education. Having mobile access to the most updated clinical information (CAIS) allowed clinicians to answer patient questions and address their concerns in a timely manner. In addition, it enhanced clinicians' ability to deliver effective patient education in terms of the nature of their conditions, progress, care plans, and the effect of the different therapeutic interventions. For example, clinicians used the mobile system to graph laboratory results to help patients better understand their conditions and how they were responding to the different therapeutic interventions. Clinicians believe that in the future they will be using a drawing tool to explain patients' conditions and to enhance patient education. The following quotations are from the interview scripts:

> *"So patients ask "Oh what was my last CT report?" and I can show them or "What was my blood work?" then I can show them. Sometimes they ask me oh, when is this and that, I have access to that, so, that I find actually quite helpful*

Participants further identified the ability to access diagnostic images as an essential component to improve communication and patient education and to better involve patients in their care. The current application (VitalHub Chart) did not allow clinicians to access images and the project team was not able to incorporate images due to project time constraints. The following has been quoted from the interview scripts.

> *"We are using it to educate patients about their own care. I think it's really helpful to show them the results, particularly imaging. You can read a report from anything but sometimes it's hard to understand without actually seeing the evidence, which would be the actual images portfolio, that's one thing."*

Participants also were aware of the potential negative effect of the iPad on their communication with the patient. Participants highlighted the potential distraction as a result of focusing on the mobile device. They further explained that how and when a clinician uses the iPad is important and determines the positive or negative effect on patient education and communication. Participants believed that the iPad should be used when a patient asks a question or when there is a need to access specific clinical information. The investigator was not able to observe patients' encounters, as patients were not included in the study ethics approval. The following has been quoted from the interview:

> *"It may give the patient information that the doctor is more interested in whatever on the iPad than what he is telling the doctor. So I am very wary about that aspect."*

Clinical decision making and patient safety

Participants viewed the iPad and VitalHub Chart application as having the potential to enhance their clinical decision making and further explained that having access to the most updated information in CAIS has a direct effect on their ability to make more informed clinical decisions. The ability to access online resources has been another aspect that enhances clinicians' and especially residents' decision-making process.

> *"Beside having access to the most updated records, I am using it as a springboard to the Internet to look something up, in that sense it would be helpful with decision making."*

Patient privacy and confidentiality

Interview participants believe that the ability to use the iPad and VitalHub Chart has enhanced their ability to protect patient privacy and confidentiality. Participants identified privacy concerns associated with bringing patients from the exam room to the shared office area were computers are located. The primary concern was that while the patient was in the office area, he/she might see other patients' information being accessed by other clinicians. Therefore, if a clinician wants to share some information with a patient, he/she has to inform other clinicians before bringing the patient. Also, since generic (shared) logins were used to overcome the otherwise time-consuming process of login and logout, clinicians usually keep other patients' charts open when they go to see their patients. Therefore, if a clinician brings a patient into the clinicians' working area while the other clinician in the exam room with their patient there is a potential risk that the patient might view other patients' information displayed on the workstation.

> *"Because of privacy issues it is very hard to bring a patient to look at their films while somebody is dictating or looking at other patients' information."*

Improved patient experience and confidence

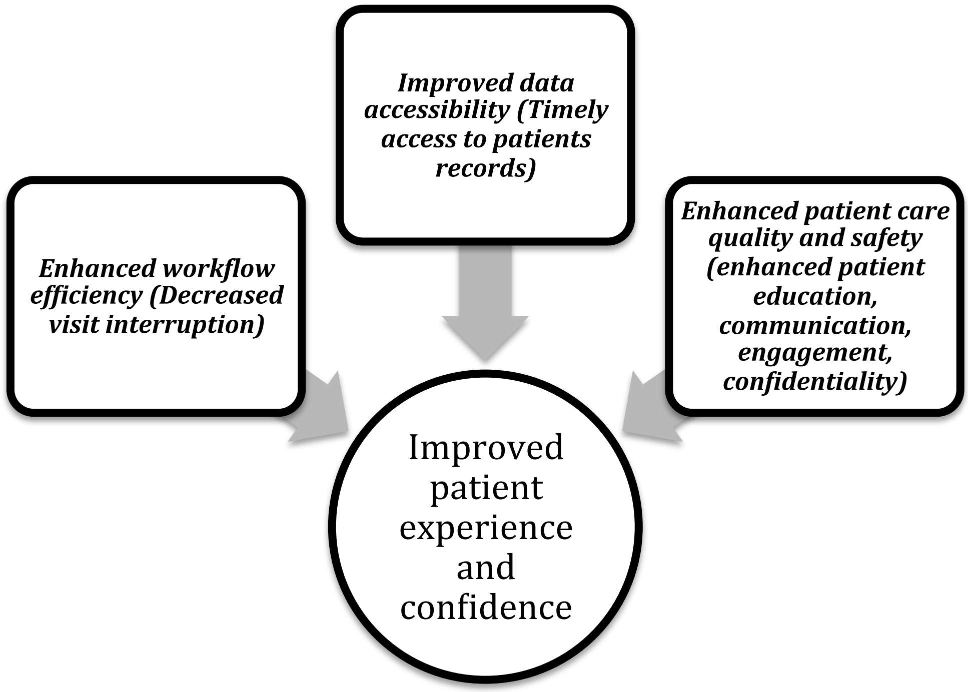


Figure 20. Improved patient experience and confidence

Interview participants believe that timely access to patients' information, decreased visit interruption, the ability to involve patients in their care, and enhanced communication collectively enhance patients' confidence and the quality of care clinicians are able to provide to cancer patients (figure. 20).

> *"The patients are very impressed that we are adopting new technology, I have had a few comments on "Oh wow it is nice to see that you are using new technology."*

Challenges of the iPad Project

Clinicians noted many benefits of the iPad in terms of improved information access, improved workflow efficiency, patient care quality and safety as well as patient satisfaction. However, many clinicians perceived challenges related to introduction of the iPad technology into the clinical setting, some were related to the inherit features of the mobile device, others related to the underlying legacy systems. All participants also noted the challenges related to the VitalHub application (figure. 21).

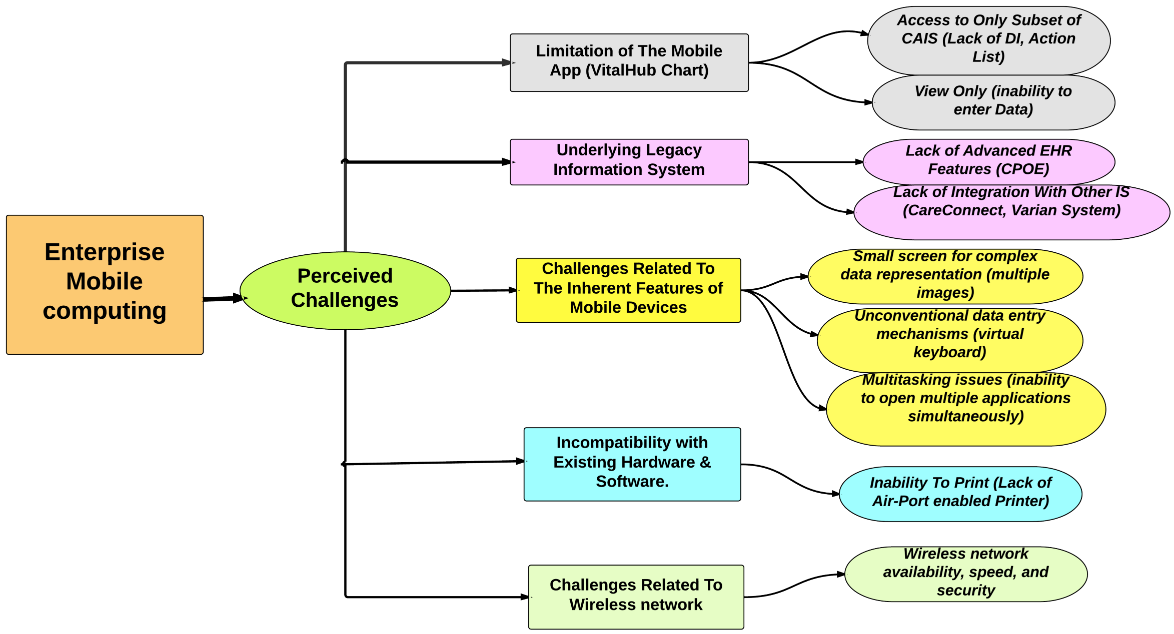


Figure 21. Perceived Challenges of the iPad Project

Software-related challenges were related to the VitalHub Chart application and the underlying legacy information system (CAIS). Hardware related issues were related to the iPad ergonomics and lack of AirPort-enabled printer. Network infrastructure challenges were related to the Cancer Agency wireless network.

Limitations of the mobile application (VitalHub)

Interview participants described the limitations of the iPad application (VitalHub Chart) and how they affected their ability to use the system more efficiently. One of the main limitations is that the iPad application provided access to only a subset of CAIS. For example, participants were not able to access the actual diagnostic images, which they viewed as essential features for better communication and patient education.

> *"The only downside I find is that you can not look at the images directly, you can look up at reports but not the actual images. Showing images would be a big help, that type of thing is helpful."*

Despite the fact that most participants requested the ability to access images, most described how the small screen size of the iPad does not support heavier imaging tasks (e.g., radiation planning) that require displaying multiple images simultaneously.

"There are two issues with the iPad. One is the screen is not big enough to look at all imaging at once, and the other issue it does not currently have imaging connections."

The application (VitalHub Chart) was view only and did not support data entry, which participants described as another limitation. This feature was closely related to the physician "action list" that was also not available. Even though the action list (lab results and reports that need to be signed off) function was not available through the iPad application, the ability to enter data was viewed as an important feature that will allow them to sign off action list items that need to be acknowledged.

"When I am doing the action list, I am viewing my action list all the time and between patients, before clinics, after clinics, so it needs to be on here for it to be useful…. I am sort of doing my action list no matter where I am working. My action list is always open and I am always chipping it out all the time, so if it is there on the iPad, it will be really useful."

Underlying legacy information system

Participants described the limitation of the underlying legacy information system (CAIS) as a barrier for realizing the full benefits of the mobile system. For example, CAIS does not support computerized provider order entry (CPOE), which was viewed as another barrier to the effective use of the iPad, leaving physicians with the need to manually fill out required paper-based examination and laboratory requisitions.

"So the pre-printed orders we cannot get away from it until we have electronic order entry, and the weight we cannot get away from until we have an electronic order entry, so we will always have some small piece of paper."

Also, participants described how the lack of integration between CAIS and other clinical applications like the Varian system and CareConnect affects the effective use of mobile computing technology.

"Previously we had a separate paper-based chart for radiotherapy that was separate from the Agency chart and separate from CAIS and none of that was captured electronically. In 2008 we started using the Varian applications to basically switch to EMR for radiotherapy as well, so it is sort of the parallel EMR to the BC CAIS and

> *hopefully eventually it will be more integrated into the Cancer Agency EMR, not possible with CAIS."*

Challenges related to the inherent features of the mobile device

In general participants were happy with the ergonomic features of the iPad. However, participants described some of the challenges related to the inherent characteristics of mobile computing technology such as the small screen size, unconventional data entry mechanism, and the multitasking features of the iPad. As described earlier, radiation oncologists believed that the screen size does not allow presentation of complex data simultaneously (e.g. multiple images at the same time).

Participants further described the multitasking functionalities of the iPad, which they found a lot easier on the desktop. Participants related their ability to multitask to the number of applications that can be opened simultaneously on the iPad as well as the data entry mechanism using a virtual keyboard. However, most clinicians believed that their ability to navigate and use the iPad and VitalHub Chart application would improve as they pass their learning curve, and if the application allows them to copy and paste. The following has been quoted from the interview scripts

> *"Where I am still trying to adjust is on the desktop. I have access to my email and CAIS, I am very used to, when the email pops up, if it's a clinical thing that my secretary sends, I can access, I can multitask a lot easier, because I know how to just navigate. So again there is a learning process…. In CAIS you can just copy the patient ID and then copy it to the email and then I can type up the email. The multitasking functionality is a lot easier, but that because I am used to a desktop versus the iPad."*

Inability to print and lack of AirPort-enabled printer:

Most participants believed that the iPad and VitalHub Chart reduced their need for printing, as described in the following quotes:

> *"Another thing that it helps me is in cutting down printing or being more environment-friendly. The reason is I no longer print any conference schedules. Every three days I have a conference called medical advisory committee. That conference always sends an agenda and these documents, which are 25–30 pages*

long, and sometimes, presentations. I had to print it previously to go to the conference, because I don't have computer access in front of the media conference, then I have to sit back and join the meeting. Here I can look up the monitor and just whatever they are talking about I can pull up that document and I don't have to print it, so I am saving trees."

However, given the lack of order entry features, other participants found the ability to print essential. The challenge with the iPad is that it was not compatible with the existing printers and required special AirPort-enabled printers that were not available during the project period.

"Obviously I don't like printing but only if the patient insists or only if there are pre-printed orders for the chemotherapy that we have to print, so those are the only items would be helpful to print."

"Being able to print would be nice, because, for example, a lot of these guys are retired engineers and whatever and they love copies of their PSA report and I almost always go in with one for them. I don't know, I guess it is okay but it would be nice to be able to do that from the iPad at times."

Wireless network availability, speed, and security

Some of the interview participants experienced some challenges related to network availability. For example, participants described some blind spots where they were not able to use the iPad to access patient charts. Also, some participants found the download speed for images slow when they tried to access images using Citrix desktop virtualization software. However, since images were not available in this project through VitalHub Chart application, the study could not confirm whether it will be faster to use a native application to access images.

"Well, there have been a couple of occasions where I have gone to use it and then wireless is being down, and I would imagine that would be a problem for everybody not just me."

Project Success Factors

Interview participants described what they believed to be the success factors for the iPad

Mobility Project. These factors were the ergonomic features of the mobile device (the Apple iPad) and VitalHub Chart application; integrating the VitalHub Chart with the agency information system (CAIS) to access patients electronic records; and the participatory iterative methodology that was followed throughout the project (figure. 22).

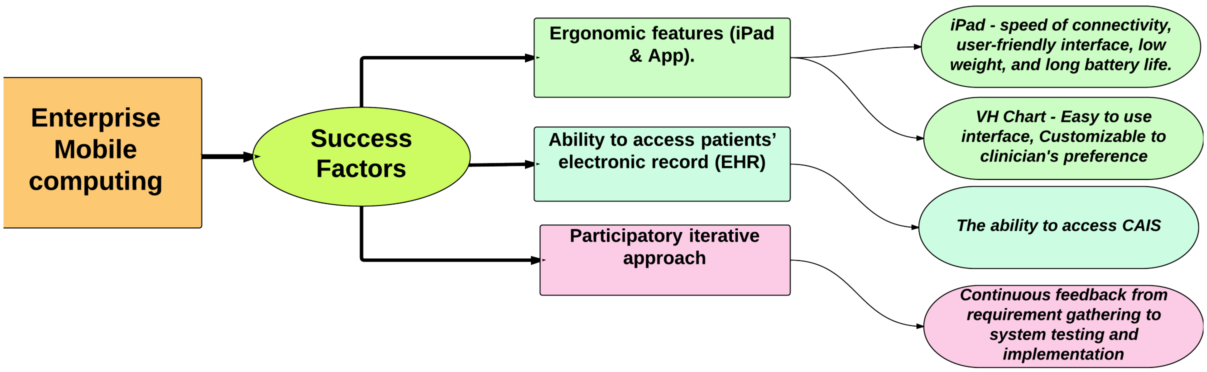


Figure 22. Project Success Factors

Ergonomic features

Almost all of the interview participants considered the ergonomic features of the iPad and VitalHub Chart application as one of the project success factors. Also, participants highly appreciated the visual presentation of the iPad and VitalHub Chart application and considered it an intuitive, easy-to-use technology that allowed them to access CAIS. In general, most interview participants had positive experiences with the use of the iPad and VitalHub Chart application. Most rated the iPad project between 4 and 5, with 5 being extremely positive

The following has been quoted from the interview scripts.

> *"I think it works better than I expected in terms of its interface with CAIS and its ability to pull information from CAIS, I was a bit skeptical at first. It has a very stable connection to the wireless, much more stable than my wireless laptop ever does and a much more efficient wireless connection. I love the visual imagery on the iPad. It's far better than my laptop, and for CT quality images the resolution is adequate… So if I have to get give it a whole number, lets say 4. If I could go a fraction, I will probably go 4.5."*

The iPad and VH Chart ergonomic features

Interview participants were impressed with the ergonomic features of the iPad, including speed of connectivity, user-friendly interface, low weight, and long battery life. Also, participants greatly appreciated the multi-purpose feature of the iPad as it allowed them to access CAIS, institutional emails, online resources, and other administrative applications available at the BCCA. The following are quotes from the interviews.

> *"I have an iPad at home so I am very used to how iPad works and I think the iPad is fantastic… On scale of 1 to 5, I would say it is a 4."*

Similarly, participants highly appreciated the ergonomic features of the native iPad application (VitalHub Chart). Participants found the application interface easy to use and appreciated the ability to customize the interface to their preferences and needs while maintaining the ability to access the full patient chart. The following has been quoted from the interview script.

> *"I actually find it the way that it is broken down into the various sections, it is using the same headings that I am used to in CAIS, so that's very nice, and it got the schedule, the results. I think it is fine. I don't have any concern about it."*

Even though most interview participants were impressed with the iPad and VitalHub Chart application, they believe that mobile computing technology should be complementary to the regular desktop computer and not a replacement, as expressed in the following quotes:

> *"At this point, I see it as complementary, because on our desktops, we have all these electronic applications for electronic prescriptions and the chemo calculator, which is not available on the iPad because it is a separate system. I have developed a workflow that uses the desktop a lot, and so for now the iPad is complementary."*

> *"The iPad in general I could see myself using more if I have access to what I use now on my desktop, so if I could access CareConnect, which I know they are working an application for, if I could access my prescription pad, my electronic prescription pad, all of these things on a server separately here."*

Ability to access the patient's Electronic Health Record (EHR)

Participants related the value of the iPad to its native application (VitalHub Chart), which enhanced their access to CAIS. They particularly appreciated the ability to use the mobile application to access patients' electronic records stored in CAIS. Participants further explained that the VitalHub Chart application added clinical value to the iPad as a mobile device and addressed many of the challenges that exist in BCCA clinical workflow.

> *"Before I have the VitalHub app, I find the iPad most useful for an email tool so I was not using it as much clinically…. I would say with the iPad alone, it would be 3, more 3.5. With the iPad plus VitalHub I think it's a 5. Because it is so much usable and because it is user-friendly, it's accessible, it can be used for patient care… I think having the VitalHub app made a big difference in how much I use the iPad."*

Participatory iterative system evaluation methodology

Interview participants described how the collaboration between clinicians and the project team contributed to the success of the project. They greatly appreciated that they were involved in the project from the very beginning and had the chance to provide feedback to improve the system features.

> *"I was surprised when I heard that we are developing a CAIS app for the iPad. I thought that was actually very much more proactive than I was expecting from the IT department. I really appreciate that we were involved in the whole process from the beginning."*

To summarize, physicians perceived that iPads would enhance patient-physician interactions by enhancing patient communication, improving patient education and increasing patient satisfaction. They also felt that using the iPad to access CAIS would improve their workflow by improving access to vital information, reducing redundancy, enabling physician mobility and helping to speed up work processes.

Physicians perceived iPads as an integral part of their ideal workflow and were optimistic about future developments in the EHR software, which would enable customization to suit their needs. Based on their personal experience using iPads, physicians were able to discern structural benefits of iPads over desktops and laptops like the touch screen functionality and ability for instinctive learning. Physicians were able to easily grasp the concept of touch screen systems and perceived it as easier to use compared to computers and desktops.

More than 80% of the clinicians owned and used iPads for their personal use. Satisfaction from personal use of a particular technology is a strong impetus for users to employ the same technology for their professional use.

4.5 Summary of Findings

The study findings showed an overwhelmingly positive attitude to the use of the iPad and the VitalHub Chart application to support BCCA clinicians' mobile workflow through enhanced access to CAIS. The iPad Mobility project addressed challenges related to existing hybrid environment (paper & desktop records) by providing mobile interface that allowed them to access the Cancer Agency Information system (CAIS). BCCA clinicians described the benefits of the iPad mobility project in terms of enhancing their workflow efficiency and productivity, data accessibility and inter-professional communication, and the quality and safety of patient care. The iPad and VitalHub Chart reduced workflow interruption, enhanced clinicians' ability to involve patients in their care, enhanced collaboration and coordination among team members, and supported better clinical time management. From clinicians' perspective, the iPad and VitalHub chart has the potential to enhance patient education efforts and the quality and safety of clinical decision-making process.

On the other hand, clinicians experienced some challenges when using the iPad application such as the inability to use the iPad application for data entry (view only) and the inability to access other patients' applications such as diagnostic images and action list. Time constraints did not allow adding these functionalities during the pilot project period. Other challenges were related to the BC Cancer Agency information system itself (CAIS), which is a legacy information system that lack the capability for computerized provider order entry (CPOE) and integration with other information systems currently used in the BCCA such as the Varian system and CareConnect. Also, clinicians experienced some challenges related to the data entry mechanism (Virtual keyboard) and multitasking features of the iPad (only two applications can be opened simultaneously). Even though clinicians highly requested the ability to access images, most radiation oncologist participants believed that they would use it for patient education purposes and not for the actual radiation planning process, which require bigger screen for displaying multiple images at the same time. Therefore, clinicians viewed the iPad and VitalHub chart app as complementary to and not as replacement for conventional computer workstations.

From clinicians' perspective, the success of the iPad mobility project was related to three major factors. First, the ergonomic features of the iPad and VitalHub chart such as user-friendly customizable interface, lightweight, and long battery life. The second factors which is mainly related to the use of the VitalHub Chart application that addressed workflow challenges by allowing them to access patients' electronic records in the exam room. The last factor is related to the iterative and participatory implementation approach that was adopted throughout the project, which allowed them to collaborate with and provide feedback to the system developers to enhance the VitalHub Chart application features and ensure that it met their needs.

Chapter 5: Discussion

5.1 Introduction

This chapter will discuss the major findings that emerged from the multiple methods used to evaluate the BC Cancer Agency (BCCA) mobility project. These findings will be discussed in the context of relevant literature. After discussing the results, the chapter presents how the study findings address the research questions, study limitations, and results generalizability and credibility. The results will be discussed based on BCCA clinicians' perceptions about and experiences with the use of a native iPad application (VitalHub Chart) to improve access to the Cancer Agency Information System (CAIS). The main themes that will be discussed are the perceived benefits of the BCCA mobility project, the associated challenges that clinicians experienced during the project period, and the factors that contributed to the success of the project. Both qualitative and quantitative results will be used to discuss the various aspects associated with each of the major themes. In the following section we will discuss each theme and compare it to the literature.

5.2 Aligning the Results with the Literature

5.2.1 Benefits of the mobile computing technology

BCCA clinician perceptions about mobile computing benefits were related to several subthemes including enhanced information accessibility and inter-professional communication; workflow efficiencies and provider productivity; and improved patient care quality and safety.

Data Accessibility and Inter-professional Communication

Clinicians' information access needs

Health information systems (HIS) have been advocated as improving healthcare delivery by allowing healthcare providers to access more accurate patient clinical information and other computing resources when and where they need it. However, many HIS projects have relied mainly on static workstations that did not match clinicians' mobility needs. In other words, healthcare providers are tethered to a single location even though they might be needed somewhere else (Gurses & Xiao, 2006). Also, clinicians usually end up sharing a limited number of available desktop computers, which leads to workflow inefficiencies and delays while waiting for an available workstation. While HIS are supposed to replace paper-based records, lack of access to computers at the point of care has forced clinicians to rely on paper-based records to support their information access needs. However, the paper records have several limitations including lack of complete, updated information and inability to support simultaneous access by multiple providers.

The results of the baseline observational sessions revealed that the biggest challenges BCCA clinicians faced were related to the limited access to the BCCA computerized resources and space constraints that did not allow adding new workstations. Furthermore, most clinicians described the paper charts as out of date and even not available in certain locations (e.g., Fairmont ambulatory clinics). The limitations of desktop computers and paper charts created workflow inefficiencies and increased the number of visit interruptions and patient delays. From clinicians' perspective, these limitations had negative effects on the quality and safety of patient care at the BCCA.

Mobile computing technology has been proposed to overcome the limitations of both desktop computers and paper-based record keeping systems. The use of mobile computing technologies to support health professionals' information needs has been discussed by many studies (Baldwin, Low, Picton, & Young, 2007; Gurses & Xiao, 2006; VanDenKerkhof, Goldstein, Lane, Rimmer, & Dijk, 2003). Positive results were reported about using mobile technology to access standalone applications for online medical resources, decision support, evidence-based guidelines, and drug reference, etc. In a recent systemic review by Prgomet et al. (2009), handheld technologies were found to positively affect information accessibility and data management in healthcare settings. However, most of the studies argued that realizing the full benefits of mobile computing technologies and application depends on integrating mobile technology with centralized clinical information systems and patients' electronic records (Househ, 2012).

In 2006, Lau, Yang, Pereira, Daeninck, and Aherne conducted a Web survey to investigate

PDA use by physicians involved in palliative care across Canada. The results supported the increasing trend in use of mobile computing technology by healthcare providers to support their information access needs. However, the results showed that 77% of mobile technology use came from individual initiative rather than as part of an organizational initiative. Based on the survey results, the authors believed that mobile technology should be considered as part of healthcare organizations' overall information system strategy. In particular, the authors emphasized the need to explore the feasibility of using mobile computing technology to support access to patients' electronic records to help advance palliative patient care (Lau, Yang, Pereira, Daeninck, & Aherne, 2006).

The current study results support this argument. The results revealed strong relationship between clinicians' ability to access CAIS and the mobile system's ability to support their workflow. In the baseline questionnaires, when correlating the use of the iPad during patient visits to its ability to support clinicians' workflow, the results were negative (Kendal–Tau -0.109, P Value 0.389). In contrast, positive and statistically significant results were obtained in the post-implementation results (Kendal–Tau 0.404, P value 0.004). The exact same positive and statistically significant results (Kendal–Tau 0.404, P value 0.004) were obtained when correlating workflow fit to the use of the VitalHub Chart mobile application during patient visits. The research team concluded that the mobile app, which allowed clinicians to access CAIS, was the key factor that changed clinicians' negative expectation in the baseline to positive experience after the project implementation. Therefore, the ability of the mobile computing technology to support access to accurate and up-to-date patient electronic records is the major determinant in supporting clinicians' workflow and facilitating more complete and timely patient management.

Interaction and communication among healthcare providers

The results of the current study revealed that the iPad and VitalHub Chart application has positive effect on the clinicians' communication and interaction with each other. For example, when correlating BCCA clinicians' expectations for using the iPad for communication with other clinicians and their actual use after the implementation, the results revealed positive increase that is statistically significant (Kendall's tau .393, P Value .004). These results were explained based on the analysis of the interview results. BCCA clinicians believed that the iPad project allowed them to better communicate with each other in many ways. The iPad provided them with ongoing access to their organizational email at any time and place. This instant access positively affected their ability to follow up on patients' progress and the organization of work activities among healthcare team members. Also, having mobile access to patient charts during clinical conferences facilitated clinicians' communication and allowed them to better interact with each other as they had access to all the information related to the clinical case being presented. Therefore, clinicians were more active and engaged in the discussion than just listening.

Healthcare work is highly interconnected and healthcare practitioners usually depend on their colleagues' skills, knowledge, and expertise. Hence, improving communication with and accessibility to coworkers allows clinicians to deliver faster and efficient patient care, with potential benefits to patient outcomes (Aziz et al., 2005; Niazkhani, Pirnejad, Berg, & Aarts, 2009). The role of mobile technology in improving accessibility to team members and staff has been confirmed in many studies (Aziz et al., 2005; Coiera & Tombs, 1998; Eisenstadt et al., 1998; Reddy, 2005). For example, Aziz et al. (2005) compared the effectiveness of using mobile PDA and traditional pagers to support inter-professional communication. When physicians used the mobile PDA rather than a pager, the average response time and the average failure to respond rate were lower (Aziz et al., 2005). Therefore, the study concluded that the mobile PDA is easy to adopt and more efficient in supporting inter-professional communication than pagers.

Workflow Efficiency and Provider Productivity

Reducing workflow interruption

The potential negative effects of HIS on workflow efficiency have been described in many studies (Niazkhani et al., 2009). For example, the computerized provider order entry system (CPOE) has been found to be time consuming (Lindenauer et al., 2006; Massaro, 1993). These perceptions were confirmed in many studies that found that significant increase in time spent on ordering occurred after CPOE implementation in comparison to conventional paper-based systems (Evans, Benham, & Garrard, 1998; Tierney, Miller, Overhage, & McDonald, 1993). Clinicians perceived that they had less time to spend with the patient after CPOE system implementation (Weiner et al., 1999).

The hybrid environment (desktops and paper charts) that exists in the BCCA created similar challenges to clinicians during patient visits. Visit interruptions were reported by most of the interview participants. Due to the physical space constraints and lack of access to computerized resources in the exam room, clinicians relied on the paper chart to access patient information during patient visits. However, the most common description that was repeated by all participants is that the paper chart is out of date and does not provide all the required information they might need during the patient encounter. Therefore, clinicians frequently left the exam room and went back to their workstation either to answer the patient's questions or to find out information that they did not anticipate needing before seeing the patient. From the clinicians' perspective, this created inefficient workflow and limited their productivity and ultimately their ability to provide high quality care for their patients.

BCCA clinicians used workarounds to adapt to these challenges, such as printing the anticipated information or transcribing the information in the paper chart before seeing the patient. Clinicians found this workaround inefficient, as they were not always able to anticipate all the information they might need during the patient visit. Printing and transcribing also led to duplication of efforts and inefficient use of clinical time, and ultimately increased the cost of healthcare by wasting paper resources and time required to access needed clinical information.

The introduction of the mobile system provided a solution to these workflow inefficiencies as it allowed clinicians to access patient electronic charts while with the patient. As confirmed by the interviews and direct observations, the mobile system reduced visit interruptions by allowing clinicians to be able to answer patients' questions and address their concerns in a timely manner. The results showed positive relationship that is statistically significant when correlating provider productivity with the use of the iPad and VitalHub Chart during patient visits (Kendall's tau .399, P Value 002). Analogous results were obtained with timeliness of patient care services, information accessibility, and reduced need for paper charts, as was presented in the results chapter.

Teamwork and care coordination

The workflow in the BCCA ambulatory care setting is a collaborative effort that involves different teams including clinicians, residents, nurses, and others. The baseline observations revealed that the limited available resources negatively affected care coordination and workload distribution among healthcare team members. Based on the post-implementation observations and interview results, the mobile system enhanced care coordination and workload distribution between clinicians and their residents by addressing issues related to resource availability. Also, having equal access to CAIS and online resources allowed residents to function as efficient team members in the clinic, have better interaction with their patients, and better discuss care plans with their clinicians. Consequently, the iPad and VitalHub Chart app facilitated residents' learning experience. Furthermore, the device mobility allowed clinicians and residents to stay connected with each other regardless of their location.

The literature concerning the effect of HIS on collaboration among healthcare providers and coordination of care activities has shown that HIS usually do not take these aspects into consideration when HIS were designed and implemented. Studies of the use of CPOE have shown that HIS are designed based on simple workflow models that tend to conceptualize healthcare delivery in a predefined, stepwise approach (Hazlehurst, McMullen, Gorman, & Sittig, 2003; Wears & Berg, 2005). Also, HIS projects have not accounted for the mobility dimension for healthcare providers and most HIS were implemented on the basis of one user interacting with the system in a static location. However, clinical work is not a linear process but rather a collaborative practice that involves a team of providers who are actively engaged in multitasking, interruptions, interpretations, responses, and reactions.

Some studies argued that HIS failures and workflow interruptions are caused by such simplistic views of healthcare delivery (Hazlehurst et al., 2003; Wears & Berg, 2005). To give an example, the results of a field study by Gorman et al. (2003) revealed that clinicians' orders develop from interactions among clinicians, nurses, patients, and others, employing a variety of technologies, information, and resources. Therefore the authors argued that CPOE systems should be designed based on understanding the multidisciplinary collaboration that occurs between healthcare team members (Gorman, Lavelle, & Ash, 2003). Furthermore, socially aware human computer interaction models such as the distributed cognitive model discuss the need for information systems to support collaboration and coordination among end-users (Price, 2008). The distributed cognition model expands the individual cognitive model by describing a larger functional unit, a collection of actors, and artefacts that are required to complete a specific goal or task (Hollan, Hutchins, & Kirsh, 2000).

Tracking tool that led to timely completion of follow-up actions

The evolving nature of healthcare delivery requires efficient tools that support clinicians in tracking patient care activities. Given the nature and complexity of cancer, this is particularly important for healthcare providers involved in cancer care, who require ongoing tracking of patients' results, investigations, and follow-up actions. Using mobile computing technology for tracking patient tasks is one of the early reported uses of handheld PDA technology (Fischer, 2003). However, early attempts to utilize handheld mobile technologies for these purposes were challenged by ergonomic limitations and the data entry mechanisms of the mobile device.

Previously, BCCA clinicians used paper notes for tracking actions related to their patients. However, clinicians ended up with multiple notes that required constant updating and reconciling, which they considered a time-consuming and error-prone process. In contrast, tracking features were integrated with the mobile app (VitalHub) and allowed clinicians to highlight patients who required follow up and the actions required, and created a list of patients that was easy to update. Clinicians perceived this function as a more efficient and easy method that enhanced their productivity and ability to provide high quality care. The ergonomic improvements in the screen size and data entry mechanism as well as clinicians' prior experience with the device were behind the perceived improvements.

Patient Care Quality and Safety

Patient education, communication, and involvement in their care

In general, BCCA clinicians believed that the mobile system enhanced their ability to share more updated and accurate information with their patient. Consequently, this encouraged patients to ask more questions, which in turn allowed clinicians to better understand their concerns and needs, and ultimately to provide better patient-centred care. For instance, clinicians used the system to graph patients' laboratory results over time and to explain how they were responding to therapeutic interventions. Some clinicians started utilizing mobile patient education applications (e.g., drawing applications) to facilitate and enhance patient education. Also, the reduction in visit interruptions meant that communication interruption was reduced and clinicians were able to spend more time with their patients.

Both survey questionnaires and interviews revealed that implementation of the iPad project had a positive effect on clinicians' ability to engage and involve patients in their care. The majority of BCCA clinicians (64%) believed that the mobile system had enhanced their ability in this respect. When correlating the use of the iPad app (VitalHub Chart) for patient education and communication with clinicians' ability to involve patients in their care, strong positive relationships were found and results were statistically significant (Kendall's tau-b .479, P value .000). Similar results were obtained when the use of the iPad for patient education and communication was correlated with patient care quality, overall safety, and workflow fitness. However, the percentage of clinicians in the baseline survey who expected to use the iPad to facilitate communication with their patients (74%) dropped to 46% after the implementation of the system. To explain these results, the interview results were examined and revealed that two main factors influenced clinicians' perceptions of mobile technology effect on quality of communication with the patient. First, BCCA clinicians had high expectations for the mobile system and believed that they would be able to access all of the applications available through the BC Cancer Agency information system. Given that the iPad applications (VitalHub) did not provide access to diagnostic images, clinicians who relied heavily on images in their daily clinical tasks (e.g., radiation oncologists) were not able to utilize the mobile application for patient communication and education as they expected.

The second factor is related to clinicians' concerns about the way mobile technology is being used during patient encounters and the potential negative effects on their relationship with their patients. Clinicians were aware that when and how the iPad is being used during patient encounters determines the positive or negative effect of the mobile device on the quality of communication. For example, if a clinician is more focused on the device screen, he/she might not be able to observe patients' non-verbal cues and body language. Therefore, when clinicians used the mobile device during the patient visit, they were careful to use it only when they needed to and in a shared way with the patient. In another words, the mobile system is not the focus but rather a tool that supports information exchange, shared decision making, and trust and confidence. On the other hand, clinicians preferred the mobile system to desktops because it supports micro-mobility, similar to the paper chart. While the desktop screen can be moved toward the patient, it is hard to find a spatial configuration that supports non-verbal communication (eye contact) and at the same time provides equal access to the information (McGrath, Arar, & Pugh, 2007).

End-user concerns about the potential negative effect of mobile technology on patient-provider relationship have been reported in the literature (Alsos, Das, & Svanæs, 2012; Andersen, Lindgaard, Prgomet, Creswick, & Westbrook, 2009a). A recent observational study of physicians' use of tablet computers during ward rounds demonstrated that while the tablet computers provided the ability to access and document information at a patient's bedside, physicians chose to complete most computer tasks on the tablet in the corridor of the ward (Andersen et al., 2009a).

Clinical decision making and patient safety

While the underlying clinical information system (CAIS) that the iPad app (VitalHub Chart) was interfaced with lacked any clinical decision support capabilities, the questionnaire results showed the percentage of clinicians who said that they used the iPad for clinical decision making increased from 54 % (n=23) in the baseline to 61% (n=24) in the post-implementation survey. Also, when correlating the iPad fitness to workflow with the use of the iPad for clinical decision making positive strong relationship was found and the results were statistically significant (Kendall's tau .357 P value .011).

To explain these results, interview transcripts were examined. The analysis of the results revealed that BCCA clinicians perceived that the iPad and VitalHub Chart app enhanced their clinical decision making in different ways. BCCA clinicians believe that the mobile system supported their clinical decision making by improving data accessibility. Such results are consistent with literature finding that the quality of clinical decision-making might suffer if clinicians based their clinical decisions on incomplete information. Also, clinicians perceived that the improved access to CAIS and online resources and enhanced communication with other clinicians through the mobile system, allowed them to make more informed decisions and ultimately enhanced the safety of their clinical decision making. Consistent results were obtained when correlating the use of VitalHub Chart for clinical decision making with the overall safety of patient care (Kendall's tau .438 P value .001).

Previous studies reported the role of HIS in enhancing patient safety through enhancing access to patients' electronic records as well as communication among healthcare professionals (Fisher & Koren, 2007; Kubose et al., 2001; McKnight et al., 2001; Stetson et al., 2002). The mobile application included a feature that allowed clinicians to pull up all recently received results, highlight abnormal results, and graph results over time, which has a positive effect on clinicians' ability to react quickly to critical changes in patients' conditions. The mobile system provided clinicians with easy and quick access to online resources and available medical apps, which they recognized as enhancing their decision-making process. From clinicians' perspective, having a tool that supports their mobility, information access, and communication has a positive effect on the safety and the quality of clinical decision-making and ultimately the patient's safety.

Enhanced patient privacy and confidentiality

While privacy refers to individuals' rights related to the acquisition, uses, or disclosures of identifiable health data, confidentiality refers to the obligations and respect of the privacy interests of those individuals. Security refers to the physical, technological, or administrative safeguards used to protect identifiable health data from unwarranted access or disclosure (Cohn, 2006). For the iPad Mobility Project, security measures were tested and evaluated. The confidentiality of patient data was protected through different measures including the iOS hardware device encryption, ensuring that the mobile application (VitalHub Chart) does not store any patient data on the application, and the ability to wipe the device remotely. Most participating clinicians were aware of PHSA remote and mobile information security policy and completed the e-learning online course "PHSA Patient Confidentiality."

One of the interesting results that the study found is that mobile computing technology has the potential to enhance the privacy and confidentiality of patients' data. Clinicians believe that bringing a patient out of the exam room to the office area poses a potential risk not only to that patient's privacy but also to other patients' privacy and confidentiality. Therefore, clinicians perceived that having access to the patient electronic chart in the exam room enhanced patients' confidentiality and privacy.

Improved patient experience and confidence

Modern cancer care approaches emphasize the need for empowering patients and providing patient-centred care that is responsive to patients' needs, preferences, and values (Institute of Medicine (U.S.). Committee on Quality of Health Care in America, 2001). Almost all of the interview participants perceived that the mobile system has the potential to improve patients' experience at the BCCA. They regarded the ability to answer the patient's questions and address their concerns in timely manner as having the potential to improve the patient's experience and confidence in the quality of care they are receiving at the BCCA.

Clinicians believed that all of the benefits they perceived in terms of decreased visit interruptions, enhanced patient education and communication, better patient engagement in their own care, and enhanced patient confidentiality collectively have a positive effect on patients' experience and confidence in their healthcare providers and the BC Cancer Agency as an organization. The questionnaire results support this argument. For example, when correlating the timeliness with which patient care services are provided with the overall quality improvements, strong positive relationship was found and the results were statistically significant (Kendall's tau 0.506, P value < 0.000). Similar results were found when correlating overall quality of patient care with the amount of time spent directly with patients, the ability to involve patients and their families in the care planning process, and patient education and communication.

5.2.2 Challenges of the mobile computing technology

The study results revealed a number of challenges that impeded realization of the full benefits of the iPad Mobility Project to support clinical workflow and improve patient care quality and safety. These challenges were classified into five major categories:

Mobile Application Limitations

The iPad Mobility Project provided access to only a subset of the applications available in CAIS. In general, clinicians considered adding the ability to view diagnostic images to the iPad application (VitalHub Chart) as one of the most desirable features that would allow them to share more information with their patients. Images functionality was more important to radiation oncologists as it represents an essential component in the radiation care planning process. However, it was not requested for the actual care planning but to show patients the progress of their treatments and for educational purposes. The ability to access the clinicians' "action list" in CAIS was also requested by most of the participating clinicians. This functionality will allow clinicians to work on their action list items (e.g., reviewing results, signing off documents and reports) whenever they have the opportunity to do so. Since the piloted iPad application was view only, this feature was not included in the scope for the pilot.

Most clinicians viewed the mobile app limitations as a barrier to realizing the full benefits of the iPad Mobility Project. Therefore, the success of mobile computing technology in supporting clinicians' workflow will depend on its ability to provide end users with multiple functionalities. Ammenwerth et al. (2000) reported similar results in a simulation study that evaluated a mobile prototype's suitability to support clinical work. One of the major results that came out from their study is that mobile technology success depends on its ability to support end users' multiple roles and tasks. Mobile technology needs to support information access, documentation, knowledge access, communication, and personal organization functions. This highlights the importance of adopting participative iterative design methodology as it allows end users to participate in defining and testing of HIS functional requirements to minimize the chances of system implementation failures (Ammenwerth et al., 2000; Househ, 2012; J. Wu et al., 2007).

Underlying Legacy Information System

The IMITS Mobility Project involved interfacing a native iPad (VitalHub Chart www.vitalhub.com) application (app) with the Cancer Agency Information System (CAIS).

CAIS is a collection of electronic applications that provide access to laboratory results, medical documents and reports, images, an "action list," patients' registration information, appointments, and clinicians' schedules (Henkelman, 2003). However, CAIS does not support computerized provider order entry (CPOE) and all orders are still based on paper-based requisitions and forms. Also, CAIS is not integrated with other computerized resources that clinicians use at the BCCA such as the Varian system used by radiation oncologists and the provincial diagnostic images and laboratory system (CareConnect). Clinicians viewed the limitations of the underlying legacy information system (CAIS) as a barrier to exploiting the full benefits of the mobile system and ultimately having a complete electronic health record in the BCCA.

Network Infrastructure Variations

Several studies identified that having a reliable wireless network is one of the prerequisites for the success of mobile computing technology in healthcare settings (Varshney, 2003). Mobile computing performance issues (slow download speed, traffic) and their reliability has important implications for healthcare workers' adoption behaviours and patient outcomes (Istepanian, Jovanov, & Zhang, 2004; Lu, Xiao, Sears, & Jacko, 2005; Varshney, 2006). In general clinicians were happy with the wireless network performance, but a few clinicians experienced issues related to availability of the network (blind spots) and download speed. For security reasons, clinicians were not able to use the iPad unless the device was connected to the Agency wireless network. The inability to use the iPad using other wireless networks has been a barrier to using the system outside the Agency premises, an issue beyond the scope of this study.

These results reflect the variation in the quality of wireless infrastructure in the multiple BCCA centres that could affect clinicians' ability to use the iPad and VitalHub Chart app. Also, it highlights the importance of having a backup plan in case of wireless network failure. The ability to use other networks has been identified as essential to allow the use of the mobile system outside the BCCA facilities. However, this requires ensuring the confidentiality of patient information and raises the security measures that need to be in place if the device is connected to other networks.

Mobile Device Limitations

While the questionnaire showed positive results for the mobile system usability measures, clinicians experienced some challenges related to the small screen size, data entry mechanisms, and multitasking features of the iPad device. For example, radiation oncologists found the device screen inadequate for presentation of complex information such as viewing multiple images. Even though clinicians requested the ability to enter data on the iPad, they found the desktop faster for data entry. For example, clinicians who used the iPad for emails or note taking during meetings found using the iPad virtual keyboard to be cumbersome compared to the traditional QWERTY keyboard of a desktop or laptop computer. The number of applications that can be opened simultaneously on the mobile device was another issue. Therefore, clinicians viewed the iPad as a complementary to regular computer workstations, not a replacement option. Nevertheless, the results do indicate that fewer desktops are needed than would be required without iPads. Most clinicians believed that their ability to navigate and use the mobile system would improve as they pass their learning curve.

Mobile device limitations in terms of data entry speed and multitasking features have been reported in the literature. For example when comparing user speed and typing error for handheld PDA and laptop computers, Haller et al. (2009) found the users preferred to use a laptop computer for data entry since it is easier and faster. Also, the results showed that entering data into a PDA is more erroneous than entering data via a keyboard (Haller, Haller, Courvoisier, & Lovis, 2009). These results raised concerns about the safety of using mobile computing technology for data entry purposes in healthcare settings, which is beyond the scope of this study.

Lack of AirPort-Enabled Printer

Even though most clinicians believed that the use of the iPad reduced their need for printing, they believe it is still important to have the ability to print. The BCCA need for printing is related to the existing hybrid environment in which clinicians are still using paper-based orders and requisitions, as they are not available through CAIS. The challenge with using the iPad for printing is that it requires using a specific type of printers (AirPort-enabled printer) that was not available during the project period.

5.2.3 Project success factors

The IMITS Mobility Project success measures were derived from the Canada Health Infoway benefit evaluation framework (Lau, Hagens, & Muttitt, 2007). The evaluation framework is based on DeLone and McLean's model for information system success. The framework was used to evaluate two dimensions of system usage (use and user satisfactions), three dimensions of quality (system, information, and service), and three dimensions of net benefits (quality, access, and productivity).

Both the iPads and the VitalHub Chart application were well received by BCCA clinicians. The majority of the post-implementation survey respondents (92%) were either highly or moderately satisfied with the iPad and VitalHub Chart application. In terms of system quality, most of the post-implementation survey respondents (92%) found the response time, security, and reliability of the iPad and the VitalHub Chart application to be either moderately or highly acceptable. Similarly, most of respondents (92%) found the information within the VitalHub Chart application to be either highly or moderately acceptable. Most of the respondents (95%) rated the project implementation process either moderately or high acceptable. Most (66%) reported that they used the iPad and VitalHub Chart daily with an average of 9.2 and 8 (times/day) respectively. The remaining respondents reported using the system always (26%) compared with only 8% who rarely used the system. In the future, if given a choice, more than 90% of the respondents would like to increase their use of the iPad and VitalHub Chart application either significantly or moderately.

Most of the survey respondents (> 80%) believe that the iPad and VitalHub Chart application improved their workflow as it facilitated the retrieval of information from CAIS. This allowed the clinicians to involve their patients in care planning, increased collaboration with other healthcare providers, and enhanced support in decision making while providing patient care. Clinicians reported reduction in the number of interruptions during patient visits and the need for printing (reports, conference documents). Consequently, the mobile project improved productivity, made work easier, and increased professional satisfaction. Clinicians believe the use of the iPad and VitalHub Chart improved the quality of patient care and promoted patient safety because the clinicians had better access and more time with their patients. When comparing the results of the current project with the results of previous mobile computing projects at the BCCA we found that the iPad was a better fit with BCCA clinicians' workflow (Murphy, Wong, Martin, & Edmiston, 2009)

Clinicians believed that the success of the project was related to three main factors: the ergonomics features of the iPad and VitalHub Chart application, the ability to access the electronic patient chart, and the iterative participative approach that was used for the implementation of the mobile system.

Ergonomic Features

The questionnaire results showed that clinicians have already embraced mobile computing technology in their personal life and clinical practice, even before the start of the IMITS Mobility Project. In general, the survey results revealed that clinicians at BCCA are among the early adopters of mobile computing technology according to Rogers' Diffusion Theory (with more than 90% of the respondents using mobile computing technology in their clinical practice). The current study results support previous studies that revealed a growing trend in healthcare professionals' use of mobile computing technology (Lau et al., 2006; Martin, 2003; Miller et al., 2004). Moreover, almost all respondents (98%) expect that the iPad and other mobile computing technology will become a larger part of the cancer care experience for both clinicians and patients. The majority of the respondents (> 80%) are either very comfortable or comfortable with using mobile computing technology. The apple iPad and iPhone are the dominant mobile devices that have been adopted by the majority of the respondents (69%, 60% respectively).

From BCCA clinicians' perspective, the iPad is an intuitive easy-to-use mobile device with high speed of connectivity, long battery life, and low weight. The iPad application (VitalHub Chart) visual interface, multiple functionalities, and ease of use were the main drivers for clinicians' positive feedback. Also, clinicians highly appreciated the ability to customize the VitalHub Chart application interface to their preference and needs. Customizability allowed clinicians to select the information that was more relevant to their roles and responsibilities while maintaining the ability to access the full electronic patient chart if needed.

In 2007, Wu et al. developed a conceptual model based on the revised technology acceptance model and Rogers' innovation diffusion theory to determine the success factors of mobile computing technology (J. Wu et al., 2007). The survey study was used to test the model and the results revealed that compatibility, perceived ease of use, and perceived usefulness significantly affected healthcare professionals' behavioural intention to use mobile health technologies. Compatibility refers to the degree to which the innovation is perceived to be consistent with potential users' existing values, prior experiences, and needs (Rogers, 1995).

The ergonomic limitations of early mobile computing technology and applications have been identified as one of the major barriers for the wide adoption of these technologies. The evaluation of the Palm-based Clinical Information System (PalmCIS) at New York Presbyterian Hospital (NYPH) identified ergonomic challenges such as the system speed, user interface problems, limited functionalities, and cumbersome sign-on function as major limitations to PalmCIS use and success (Chen, 2003) The effect of the device ergonomic features on mobile computing technology success was also demonstrated in a previous project that evaluated the usefulness and ease of use of a tablet computer (Toshiba 200M Portégé) in supporting oncologists' needs at the BCCA (Murphy, 2007).

The literature showed that despite the progress achieved in terms of technological advancements, there are still some limitations for mobile computing device interfaces due to inherent characteristics of mobile devices (screen size, non-traditional input methods, etc.) (Nah, Siau, & Sheng, 2005; Ping Yu, Wu, Yu, & Xiao, 2006). The current study supports these results and highlights the importance of understanding the nature of clinical tasks and end users' roles when deploying mobile computing technology. For example, while clinicians requested the ability to access images, BCCA clinicians believed that the iPad could be beneficial for showing patients images but not for actual radiation planning, which requires viewing multiple images simultaneously and would be hard to do on a small screen. Therefore, the clinicians believe that mobile computing technologies should be viewed as complementary to rather than replacements for regular desktop computers. However, new mobile apps are being developed to allow better viewing features for diagnostic images, which may solve the problem of viewing multiple images. For example, ResolutionMD

Mobile (http://www.calgaryscientific.com/resolutionmd/mobile-resmd/) has received Health Canada and FDA approval for medical use, which means that clinicians can rely on this new application for diagnosis and decision-making.

The Ability to Access Patients' Electronic Health Record (EHR)

The current study showed that clinicians appreciated the iPad as multi-purpose device. They were able to access their Outlook emails, online resources, and patient records. However, what made the difference for BCC clinicians was the ability to access patients' electronic health records (EHR) stored in CAIS. From the perspective of BCCA clinicians, having mobile access to CAIS not only addressed the inefficiencies that resulted from the lack of access to CAIS in the exam room but also allowed them to provide higher quality patient care.

The literature supports the viewpoint that the value of mobile computing technology depends on our ability to integrate the current stand-alone applications with more complex systems in general and the EHR in specific. This integration largely depends on our ability to understand the human aspects of mobile health technologies and the complex work activities and practices that exist in different healthcare settings (Househ, 2012). The importance of allowing clinicians to access electronic patients records on a mobile platform can be seen by the growing trend in the number of healthcare organizations utilizing mobile computing tablets to provide access to their central clinical information systems. In 2010, the Ottawa Hospital developed and successfully deployed a clinical mobile app (CMA) that allows physicians and residents to access patient lab results, diagnostic-imaging reports, and transcribed documents at the patient bedside. The application has been enhanced with a PACS viewer to allow access to images, and recently the Ottawa Hospital became the first hospital in the world to go live with CPOE on an iPad (Geiger & Maisonneuve, 2012).

Participatory Iterative System Evaluation Methodology

The BCCA Mobility Project followed a participatory rapid prototyping iterative approach. BCCA clinicians were involved from the early stages of system analysis and design to the final stages of the project. A representative group of clinicians participated as part of the project team in needs assessment and requirements gathering that was used in building the first prototype of the system. Also, throughout the project, clinicians participated in three clinical testing sessions that were used to obtain clinicians' feedback on any changes or alterations to the user interface and system functionalities. Furthermore, clinicians provided feedback through the multiple data collection methods used in the current study that occurred throughout the mobile system development life cycle. BCCA highly appreciated the participative and iterative design methodology that was used to design, build, and evaluate the VitalHub Chart app with continuous collaboration and feedback from clinicians. This approach ensured that the mobile system adequately met BCCA clinicians' requirements and information processing needs and identified how mobile technology could be utilized to support clinician workflow in the BCCA.

The above approach represents a shift from the traditional evaluation approaches, which focused on summative evaluation to assess how completed information systems meet a predefined set of criteria and goals (Kushniruk, 2004). The new approach focuses on the use of iterative formative evaluation methods during the system development life cycle (SDLC) with the objective of improving the design and deployment of HIS to obtain effective systems that meet the end-user needs (Kushniruk, 2002). Based on this approach, a wide range of evaluation methods can be utilized throughout the SDLC, including systems engineering methods (interviews, questionnaires, and observation) and social and cognitive evaluation methods (workflow and cognitive task analysis). In addition, usability-engineering methods such as usability testing and usability inspection are increasingly being used in formative system evaluation.

For BCC clinicians, formative evaluation methods used throughout the project allowed them to communicate all of the design issues instantly to project developers who provided immediate feedback to clinicians. This feedback has enhanced the relationship between the end-users (BCCA clinicians) and the IMITS project team, which laid the foundation for improving the iPad application and features through joint collaboration and continuous feedback. Therefore, it is not surprising that clinicians expressed high interest in expanding the scope of the project to involve access to other electronic resources at the BCCA such as the Varian system and CareConnect.

5.3 Addressing the Research Questions

This evaluation study set out to evaluate the success of the iPad Mobility Project in BC Cancer Agency ambulatory care settings. The IMITS Mobility Project involved the use of a native iPad application (VitalHub Chart) to allow clinicians to access patients' electronic records. Also, clinicians were able use the iPad to access their institutional emails and other available medical apps and online resources at their discretion. Understanding the end-user perspective on what constitutes technology usefulness is both distinct and complementary to the perspective of system developers. The study focused on exploring clinicians' perspectives about the effects of the iPad and VitalHub Chart application on their workflow and on patient cares quality and safety. The study has also sought to identify the opportunities and challenges of using mobile technology in BC Cancer Agency ambulatory care settings. In specific, the study sought to answer the following two questions:

1- How do BCCA clinicians perceive the effect of the iPad and VitalHub Chart on their workflow and patient care?
2- What are the opportunities and challenges of using mobile technology in BC Cancer Agency ambulatory care settings

Several data collection and analysis methods were used throughout the project to address the research questions, including pre- and post-implementation surveys, pre- and post-implementation observation, and semi-structured interviews. The study findings were classified according to three main themes: the perceived benefits, the perceived challenges, and the success factors for mobile computing technology implementation.

The mobile system addressed the main challenges that BCCA faced, which were limited access to CAIS in a hybrid environment, physical space constraints, and inadequate number of available workstations. These challenges created inefficiencies and bottlenecks in BCCA clinicians' workflow and had a negative effect on their productivity and on patient care. The attitude of BCCA clinicians concerning the implementation of mobile computing technology to access CAIS was overwhelmingly positive. Perceived benefits of mobile computing can be classified into three categories: information accessibility and inter-professional communication; workflow efficiency and provider productivity; and patient care quality and safety.

In terms of data accessibility, the mobile system allowed clinicians to access CAIS in areas where regular workstations were not available (e.g., the exam room and the physics planning area) or were limited in number and availability. Also, patient care at the BCCA is a collaborative process that requires efficient communication between healthcare team members. Consequently, BCCA clinicians highly appreciated having mobile access to their institutional email through a mobile platform.

In terms of workflow efficiency and provider productivity, the mobile system significantly reduced visit interruptions that were predominantly caused by lack of access to CAIS in the exam room. Also, having equal access to CAIS, clinicians and their residents were better able to distribute their workload, coordinate activities, stay connected with each other, and work as a team regardless of their location. Having mobile access to CAIS reduced clinicians' need to print documents such as lab results and consultation reports, which clinicians had been using as a workaround to facilitate interaction with their patients during the visit. The mobile application (VitalHub Chart) provided a tracking feature that allowed clinicians to track and complete follow up actions in a timely manner instead of depending on the time-consuming process of reconciling and updating multiple paper notes.

Having mobile access to patient records was the major contributor to improving patient care quality and safety. Besides reducing visit interruptions, the mobile system allowed clinicians to share more updated and accurate information with their patient. Utilizing the VitalHub app as well as other patient education mobile apps, clinicians used the mobile system as an education tool to encourage patients' involvement in their care. For example, clinicians used the VitalHub app to graph patients' laboratory results to educate patients about their condition and progress. Another dimension of improving patient care quality is that improved access to patient charts and online medical resources has a positive effect on clinicians' decision making. The quality of decision-making may suffer if clinicians base their clinical decisions on incomplete information. Several studies confirmed that inadequate access to information and ineffective communication among patient care team members are potential proximal causes of medical errors (Kubose et al., 2001; McKnight et al., 2001; Stetson et al.,

2002) Lastly, since the mobile system eliminated the need to bring patients out of the exam room into the shared office area, having mobile access improved patient care quality through enhanced patient confidentiality and privacy.

Clinicians experienced certain challenges while using the iPad and VitalHub Chart applications. Some of these challenges were related to the limitations of the mobile application (VitalHub) such as the inability to enter data (view only) and lack of access to images and the clinician's action list. While these features were highly requested, time constraints for the project team did not allow incorporating them in the project scope. Other challenges were related to the underlying legacy information system (CAIS) that did not, for example, have CPOE features, which forced clinicians to continue to rely on paper-based forms and requisitions for laboratory tests and diagnostic imaging investigations. Another challenge, which was reported only on a specific area of one of the BCCA centres, was wireless network infrastructure issues such as blind spots and download speed.

Based on the study findings, several factors contributed to the success of the IMITS Mobility Project. These factors include the ability to access electronic patient records, the ergonomic features of mobile computing technologies and applications, and the participatory iterative approach that was used throughout the project. The first success factor was the integration of mobile computing technology with the patient electronic records. The literature supports the argument that the success of mobile computing technology depends on our ability to integrate the current stand-alone applications with more complex systems in general and the EHR in specific (Househ, 2012).

The second success factor related to the ergonomic features of the deployed mobile computing technology and application. BCCA clinicians found the iPad an intuitive and easy-to-use mobile device with high connectivity speed, long battery life, and low weight. The VitalHub Chart visual interface, multiple functionalities, ease of use, and customizability were highly appreciated by the study participants. However, it is important to remember that despite the progress in technological advancements, there are still some limitations for mobile computing interfaces due to their inherent characteristics. Therefore, it is important to understand the clinical tasks and end users' needs. Mobile computing technologies should be deployed within multi-device architecture and should be viewed as complementary to and not replacement for desktop computers.

The third success factor was the iterative participative approach followed for the implementation of the mobile system in the BCCA. Clinicians believed that their participation throughout the project ensured that the mobile system met their expectations and they ultimately contributed to the success of the project and identified how mobile technology could be utilized to support clinicians' workflow in the BCCA.

5.4 Study Limitations and credibility

Although this research was carefully prepared, I am still aware of its limitations and shortcomings. The research lasted for eight weeks and opinions and level of comfort with the new information system change over time. There is a learning curve and it would be better if the study were conducted over a longer period. Also, the study focused on oncologists' perspectives and excluded other healthcare providers' perspectives, which limits the ability to generalize the study findings to other healthcare providers such as nurses and other allied healthcare professionals. This is especially important since clinical workflow was found to be a collaborative process between multiple healthcare providers form different backgrounds. Time limits and resource limitations did not allow investigation other user groups' perspectives. Also, the study was conducted in the BCCA ambulatory settings, which prevent generalizing the results to other healthcare settings such as acute or extended care facilities with differing workflows, roles, and characteristics.

Since the investigator joined the project in the middle of design phase, the study could not investigate the reasons behind the choices of the device (iPad) and the application (VitalHub Chart app). Therefore, the study could not investigate the effect of using other mobile technologies and applications, which limited the ability to generalize the results to other mobile platforms and applications. Furthermore, the study took place in the BCCA ambulatory clinics that have a hybrid paper-electronic environment and the results may therefore not be applicable to other healthcare settings that may use a predominately paper-based system or electronic environment.

The response rate was high for both the baseline and post-implementation questionnaires. While the organization did not make any promise to provide iPads to clinicians, there is a potential that participants may have hoped for receiving iPad for a longer period if the pilot is successful, and this may have biased their feedback. Also, the IMITS Mobility Project was a proof of concept project and only limited numbers of clinicians were able to participate, which made the pool of eligible participants small. The recruitment process may have been subject to a selection bias as the participants who volunteered to participate in the project most likely were enthusiastic for mobile technology. Furthermore, this study reflects only the views of BCCA clinicians regarding their experience with the use of mobile computing technology to access the CAIS.

The study did not investigate patients' perceptions and opinions about using mobile technology and applications in their care. For example, clinicians believed that the mobile system improved communication with the patient, which needs to be verified with patients in future research. Also, while observations allowed the investigator to observe how and when clinicians used the mobile system, for patient privacy reasons, the investigator was not able to attend patients' visits and could not confirm the effect of using the mobile system on patient-provider relationship.

The study's credibility is established through triangulation of the mixed data collection and analysis methods: questionnaires, observations, and interviews. During interviews, participants had to recall past events, which can introduce bias into their responses as far as the experiences they do and do not remember. However, conducting an observational session before the interview and the short period between the observations and interviews helped to alleviate this issue by allowing the researcher to relate, reflect, and probe the participants about their experience immediately after the observation.

In terms of qualitative data analysis, coding is a subjective activity where the researcher codes the data themselves directly (Hsieh & Shannon, 2005). As user of Apple computing products (iPhone, and Mac computer), I needed to pay attention to reflexivity. My personal experience may have influenced the conceptualization of the study and had an impact on data collection and analysis. As a researcher, I was aware of these personal biases and I applied different mechanisms to maximize the study credibility and validity through reflexivity, bracketing and methodological triangulation. For example, by using different data collection methods, I was more confident that the concepts and categories reflect the participant meanings. Also, I have confirmed my interpretations with some of the study participants particularly after the interview, which gave me another way of confirming what the participants meant. I have reflected on my experience and feeling by writing memos and compared my notes to the data interpretation. In general, other mobile computing technologies for large healthcare organizations with similarity to the BCCA ambulatory care settings could benefit from this research. Overall, other areas in healthcare could utilize concepts from this study.

Chapter 6: Conclusion

6.1 Introduction

The current study demonstrated the ability to utilize mobile computing technology to overcome the limitations and challenges associated with the traditional approach for health IT solutions deployment based on using fixed computer workstations. This situation was not different for BCCA clinicians and although the Cancer Agency Information System (CAIS) is the primary patient record repository, it is only accessible on traditional computer workstations. The BCCA clinics have significant space limitations resulting in multiple healthcare professionals sharing each workstation. Furthermore, workstations are not available in the exam rooms, or during clinical conferences or grand rounds. During patient encounters, clinicians rely on paper charts (hybrid environment) that are either out of date or not available when needed.

To address the these challenges, the BCCA launched a pilot project to evaluate BCCA clinicians' perceptions about using the Apple iPad and a native iPad app (VitalHub) to support clinicians' information access and communication needs, and to identify potential benefits and related challenges. A multi-method approach was used to evaluate the project including baseline and post-implementation surveys, observations, and semi-structured interviews.

The study has shown that clinicians' attitude to the use of the iPad to support their clinical workflow was overwhelmingly positive. Perceived benefits of mobile computing were related to three main areas: information accessibility and inter-professional communication (access to CAIS, online resources, institutional emails, and other medical apps); workflow efficiency and provider productivity (reduced visit interruption, enhanced team work and care coordination, better tracking of patient care activities); and patient care quality and safety (patient education, communication, and involvement, enhanced clinical decision making, enhanced patient privacy, and improved overall patient experience). However, clinicians believed that the major benefits were mainly related to their enhanced access to CAIS using a mobile platform that matched their mobile workflow. Clinicians attributed the success of the mobility project to the ability to access patients' electronic records (CAIS), the ergonomic features of the iPad and the VitalHub Chart app, and the participatory iterative methodology that allowed them to collaborate with and provide feedback to the system developers and other project team members.

BCCA clinicians experienced some challenges related to limitations of the VitalHub application (lack of access to images and physician action list, view only and inability to enter data); limitations of the underlying legacy information system (lack of CPOE, lack of integration with other information systems like the Varian system and CareConnect); wireless network infrastructure limitations (availability, download speed, blind spots); and the nature of the mobile device (small screen for presentation of complex data, unconventional data entry mechanism through touch screen keyboard , lack of available compatible printers).

6.2 Study Implications

The current study has several implications for future mobile computing deployment projects in healthcare organizations as well as the field of health informatics in general and mHealth in specific.

6.2.1 Implications for future mobile health projects

1. The success of the mobility project in the BCCA indicates that the recent advancements in mobile computing technology and application are creating new opportunities for healthcare organizations to improve data accessibility, communication mechanisms, patient care quality, and workflow efficiency.
2. Integrating mobile applications with patients' electronic records and other complex information systems is a key factor for the success of mobile computing projects and for benefits realization.
3. Central to this integration is the ability to understand end users' characteristics (clinical roles, expectations and needs), the nature of the clinical tasks, and clinical

workflow. Therefore, end-user participation in mobile computing projects is essential to build systems that meet end-user needs.

4. Mobile computing technology has inherent limitations (small screen size). Therefore, mobile computing projects should be considered within a multi-device architecture and as complementary to and not replacement of regular workstations.
5. Implementers of mobile computing projects need to consider contemporary implementation methodologies. Participatory iterative methodologies proved to be effective in the current project as they allowed clinicians to participate and provide feedback while the system was being developed. The traditional approach for system analysis and design does not support the flexibility required in mobile computing projects, which require considering the various complex human, organizational, and contextual factors in the implementation process.
6. Hospital management/administrators who are considering mobile computing technology at their healthcare organization could use the study findings to help with their decision-making process regarding the value of mobile health computing technology.

6.2.2 Future directions

Mobile health (mHealth) is a new research area in the field of health informatics, especially the use of mobile computing technology at the enterprise level. While this study adds a contribution to the limited available evaluation studies in the mHealth domain, it calls for further research. The current study findings support the anticipated benefits of mobile computing technology reported in the literature. However, it reflects only the perceptions and experience of BCCA clinicians at the BCCA ambulatory care settings. More evaluation studies carried out over a longer period of time in different healthcare settings will be necessary to confirm the study findings.

The current study found that mobile application usability largely influenced clinicians' perceptions and experience. However, there were no formal usability methods and only the post-implementation questionnaire contained general usability questions. Moreover, research has shown that usability problems of mobile computing technologies, especially when used for data entry, could facilitate medical errors and endanger patient safety (Kushniruk et al., 2005). It is therefore important to ensure the safety of mobile applications through formal usability evaluation studies.

Even though most of clinicians reported positive reactions from their patients to the use of the iPad during the visit, most of them were aware of the potential negative effect on their relationship with the patient. Therefore, clinicians used the iPad only if they needed to and shared the screen with the patients. For privacy reasons, the current study could not validate these perceptions. Further research is needed to understand the effect of mobile computing technologies on the patient-provider relationship.

While the scope of the project did not include access to images, clinicians experienced download speed issues when they used desktop virtualization software (Citrix) to access images on the iPad. Future studies need to investigate whether a native iPad imaging application will provide faster access than Citrix and how it affects end users' experience and perception.

References

Agency for Healthcare Research and Quality (AHRQ). (2012a). Canada health infoway system and use assessment survey. Retrieved 05/23, 2012, from http://healthit.ahrq.gov/portal/server.pt/document/954138/canadahealthinfowaysystem_pdf

Agency for Healthcare Research and Quality (AHRQ). (2012b). Employee / staff *Pre-go-live* Expectations / perceptions clinical information systems survey. Retrieved 05/21, 2012, from http://healthit.ahrq.gov/portal/server.pt/document/954318/cisexpectations-experiencessurvey-pre-go-live_pdf

Alsos, O. A., Das, A., & Svanæs, D. (2012). Mobile health IT: The effect of user interface and form factor on doctor-patient communication. *International Journal of Medical Informatics, 81*(1), 12-28. doi:10.1016/j.ijmedinf.2011.09.004

Ammenwerth, E., Buchauer, A., Bludau, B., & Haux, R. (2000). Mobile information and communication tools in the hospital. *International Journal of Medical Informatics, 57*(1), 21-40. doi:10.1016/S1386-5056(99)00056-8

Ammenwerth, E., Gräber, S., Herrmann, G., Bürkle, T., & König, J. (2003). Evaluation of health information systems—problems and challenges. *International Journal of Medical Informatics, 71*(2–3), 125-135. doi:10.1016/S1386-5056(03)00131-X

Andersen, P., Lindgaard, A., Prgomet, M., Creswick, N., & Westbrook, J. I. (2009b). Mobile and fixed computer use by doctors and nurses on hospital wards: Multi-method study on the relationships between clinician role, clinical task, and device choice. *Journal of Medical Internet Research, 11*(3), e32. doi:10.2196/jmir.1221

Anderson, J. G., & Aydin, C. (2005). *Evaluating the organizational impact of health care information systems* Springer.

Ash, J. S., Lyman, J., Carpenter, J., & Fournier, L. (2001). A diffusion of innovations model of physician order entry. *Proceedings of the AMIA Symposium,* 22.

Ash, J. S., Sittig, D. F., Campbell, E. M., Guappone, K. P., & Dykstra, R. H. (2007). Some unintended consequences of clinical decision support systems. *AMIA ...Annual Symposium Proceedings / AMIA Symposium.AMIA Symposium, 2007*, 26-30.

Ash, J. S., Sittig, D. F., Poon, E. G., Guappone, K., Campbell, E., & Dykstra, R. H. (2007). The extent and importance of unintended consequences related to computerized provider order entry. *Journal of the American Medical Informatics Association, 14*(4), 415-423. doi:10.1197/jamia.M2373

Aydin, C. E. (2005a). Overview: Theoretical perspectives and methodologies for the evaluation of healthcare information systems. (pp. 5-29). New York, NY: Springer New York. doi:10.1007/0-387-30329-4_1

Aydin, C. E. (2005b). Survey methods for assessing social impacts of computers in healthcare organizations. (pp. 75-128). New York, NY: Springer New York. doi:10.1007/0-387-30329-4_4

Aziz, O., Panesar, S. S., Netuveli, G., Paraskeva, P., Sheikh, A., & Darzi, A. (2005). Handheld computers and the 21st century surgical team: A pilot study. *BMC Medical Informatics and Decision Making, 5*(1), 28-28. doi:10.1186/1472-6947-5-28

Baldwin, L. P., Low, P. H., Picton, C., & Young, T. (2007). The use of mobile devices for information sharing in a technology-supported model of care in A&E. *International Journal of Electronic Healthcare, 3*(1), 90-106.

Balen, R., & Jewesson, P. (2004). Pharmacist computer skills and needs assessment survey. *Journal of Medical Internet Research, 6*(1), unknown-unknown. doi:10.2196/jmir.6.1.e11

Ball, M. J., & Lillis, J. (2001). E-health: Transforming the physician/patient relationship. *International Journal of Medical Informatics, 61*(1), 1-10. doi:10.1016/S1386-5056(00)00130-1

Baumgart, D. C. (2005). Personal digital assistants in health care: Experienced clinicians in the palm of your hand? *The Lancet, 366*(9492), 1210-1222. doi:10.1016/S0140-6736(05)67484-3

BC Cancer Agency. (2011). Working toward a cancer-free society. Retrieved Aug/22, 2012, from www.phsa.ca/NR/.../BCCancerAgencyInformationSheet.pdf

Berg, M. (2001). Implementing information systems in health care organizations: Myths and challenges. *International Journal of Medical Informatics, 64*(2), 143-156.

Berg, M. (1999). Patient care information systems and health care work: A sociotechnical approach. *International Journal of Medical Informatics, 55*(2), 87-101. doi:10.1016/S1386-5056(99)00011-8

Berner, E. S., Houston, T. K., Ray, M. N., Allison, J. J., Heudebert, G. R., Chatham, W. W., . . . Maisiak, R. S. (2006). Improving ambulatory prescribing safety with a handheld decision support system: A randomized controlled trial. *Journal of the American Medical Informatics Association : JAMIA, 13*(2), 171-179. doi:10.1197/jamia.M1961

Borycki, E. (2010). Towards an integrative cognitive-socio-technical approach in health informatics: Analyzing technology-induced error involving health information systems to improve patient safety~!2009-04-08~!2009-11-11~!2010-09-14. *The Open Medical Informatics Journal, 4*(4), 181-187. doi:10.2174/1874431101004040181

Britten, N. (1995). Qualitative interviews in medical research. *BMJ (Clinical Research Ed.), 311*(6999), 251-253.

Bürkle, T., Ammenwerth, E., Prokosch, H. U., & Dudeck, J. (2001). Evaluation of clinical information systems. what can be evaluated and what cannot? *Journal of Evaluation in Clinical Practice, 7*(4), 373-385. doi:10.1046/j.1365-2753.2001.00291.x

Burton, K. (2013). The medium and the message. Retrieved October/22, 2013, from http://www.mdanderson.org/publications/promise/issues/summer-2013/the-medium-and-the-message.html

Canadian Cancer Society. (2012). General cancer statistics. Retrieved Aug/7, 2012, from http://www.cancer.ca/canada-wide/about%20cancer/cancer%20statistics/stats%20at%20a%20glance/general%20cancer%20stats.aspx

Canadian Health Infomatics Association. (n.d). COACH defintion of health informatics: Health infomrmatics is the intersection of clinical, IM/IT and management practices to achieve better health. Retrieved 05/10, 2012, from http://coachorg.com/en/healthinformatics/abouthealthinformatics.asp

Canada Health Infoway (Organization). (2012). Benefit Evaluation Indicators. Retrieved November, 15, 2013, from https://www.infoway-inforoute.ca/index.php/programs-services/benefits-evaluation

Cancer Care Ontario. (2013). App library - CCO. Retrieved October/22, 2013, from https://www.cancercare.on.ca/toolbox/applibrary/

Carlow, D. R. (2000). The british columbia cancer agency: A comprehensive and integrated system of cancer control. *Hospital Quarterly, 3*(3), 31-45.

Cassey, M. Z. (2007). Keeping up with existing and emerging technologies: An introduction to PDAs. *Nursing Economic, 25*(2), 121.

Chen, E. S., Mendonça, E. A., McKnight, L. K., Stetson, P. D., Lei, J., & Cimino, J. J. (2004). PalmCIS: A wireless handheld application for satisfying clinician information needs. *Journal of the American Medical Informatics Association, 11*(1), 19-28. doi:10.1197/jamia.M1387

Clauser, S. B., Wagner, E. H., Aiello Bowles, E. J., Tuzzio, L., & Greene, S. M. (2011). Improving modern cancer care through information technology. *American Journal of Preventive Medicine, 40*(5), S198-S207. doi:10.1016/j.amepre.2011.01.014

Clevenger, N. C, (2011). *iPad in the enterprise: Developing and deploying business applications*. Indianapolis, IN: Wiley Pub.

Cohn, S. P. (2006). PRIVACY AND CONFIDENTIALITY IN THE
NATIONWIDE HEALTH INFORMATION NETWORK. Retrieved 05/17, 2013, from http://www.ncvhs.hhs.gov/060622lt.htm

Coiera, E.Guide to health informatics. 2003. *London: Arnold,*

Coiera, E., & Tombs, V. (1998). Communication behaviours in a hospital setting: An observational study. *BMJ (Clinical Research Ed.), 316*(7132), 673-676.

Corbin, J., & Strauss, A. (2008). Basics of qualitative research: Techniques and procedures for developing grounded theory. *Sage, Thousand Oaks, CA,*

Corbin, J. M. J. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology, 13*(1), 3-21.

Crelinsten, G. L. (2004). The intern's palmomental reflex. *The New England Journal of Medicine, 350*(10), 1059-1059. doi:10.1056/NEJM200403043501022

Creswell, J. W., Fetters, M. D., & Ivankova, N. V. (2004). Designing a mixed methods study in primary care. *Annals of Family Medicine, 2*(1), 7-12. doi:10.1370/afm.104

Cronin, P., Ryan, F., & Coughlan, M. (2008). Undertaking a literature review: A step-by-step approach. *British Journal of Nursing (Mark Allen Publishing), 17*(1), 38-43.

Cullen, D. J., Sweitzer, B. J., Bates, D. W., Burdick, E., Edmondson, A., & Leape, L. L. (1997). Preventable adverse drug events in hospitalized patients: A comparative study of intensive care and general care units. *Critical Care Medicine, 25*(8), 1289-1297. doi:10.1097/00003246-199708000-00014

Cummings, E., & Borycki, E. M. (2011). Grounded theory evolution and its application in health informatics. *Studies in Health Technology and Informatics, 164*, 286-292.

Dala-Ali, B. M., Lloyd, M. A., & Al-Abed, Y. (2011). The uses of the iPhone for surgeons. *The Surgeon, 9*(1), 44-48.

Dasari, K. B., White, S. M., & Pateman, J. (2011). Survey of iPhone usage among anaesthetists in england. *Anaesthesia, 66*(7), 630-631. doi:10.1111/j.1365-2044.2011.06747.x

Davies, B. S., Rafique, J., Vincent, T. R., Fairclough, J., Packer, M. H., Vincent, R., & Haq, I. (2012). Mobile medical education (MoMEd)-how mobile information resources contribute to learning for undergraduate clinical students-a mixed methods study. *BMC Medical Education, 12*(1), 1.

Delone, W. H. & McLean, E.R. (2003). The DeLone and McLean model of information systems success: A ten-year update. *Journal of Management Information Systems, 19*(4), 9-30.

Denton, G. D., Williams, R. W., & Pangaro, L. (2003). Core problems reported by students in a palm OS and internet-based problem entry system predicts performance on the third-year internal medicine clerkship. *AMIA ...Annual Symposium Proceedings / AMIA Symposium.AMIA Symposium, 2003*, 827-827.

Doll, W. J., & Torkzadeh, G. (1988). The measurement of end-user computing satisfaction. *MIS Quarterly, 12*(2), 259-274.

Edson, R. S., Beckman, T. J., West, C. P., Aronowitz, P. B., Badgett, R. G., Feldstein, D. A., . . . McDonald, F. S. (2010). A multi-institutional survey of internal medicine residents' learning habits. *Medical Teacher, 32*(9), 773-775.

Eisenstadt, S. A., Wagner, M. M., Hogan, W. R., Pankaskie, M. C., Tsui, F. C., & Wilbright, W. (1998). Mobile workers in healthcare and their information needs: Are 2-way pagers the answer? *Proceedings / AMIA ...Annual Symposium.AMIA Symposium,* , 135-139.

Embi, P. J. (2001). Information at hand: Using handheld computers in medicine. *Cleveland Clinic Journal of Medicine, 68*(10), 840-842.

Engum, S. A. (2003,). Do you know your students’ basic clinical skills exposure? *The American Journal of Surgery*, pp. 175-181. doi:10.1016/S0002-9610(03)00182-X

Evans, K. D., Benham, S. W., & Garrard, C. S. (1998). A comparison of handwritten and computer-assisted prescriptions in an intensive care unit. *Critical Care, 2*(2), 73.

Executive Office of the President President's Council of Advisors on Science and Technology. (2010). Realizing The Full Potential Of Health Information Technology To Improve Healthcare For Americans: The Path Forward. Retrieved July/19, 2012, from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-health-it-report.pdf

Fischer, S., Stewart, T. E., Mehta, S., Wax, R., & Lapinsky, S. E. (2003). Handheld computing in medicine. *Journal of the American Medical Informatics Association, 10*(2), 139-149. doi:10.1197/jamia.M1180

Fisher, K., & Koren, A. (2007). Palm perspectives: The use of personal digital assistants in nursing clinical education. A qualitative study. *Online Journal of Nursing Informatics, 11*(2)

Fitch, C. (2004). Information systems in healthcare: Mind the gap. *System Sciences, 2004. Proceedings of the 37th Annual Hawaii International Conference On,* 8 pp.

Fjeldsoe, B. S., Marshall, A. L., & Miller, Y. D. (2009). Behavior change interventions delivered by mobile telephone short-message service. *American Journal of Preventive Medicine, 36*(2), 165-173. doi:10.1016/j.amepre.2008.09.040

Franklin, V. L., Waller, A., Pagliari, C., & Greene, S. A. (2006). A randomized controlled trial of sweet talk, a text-messaging system to support young people with diabetes. *Diabetic Medicine : A Journal of the British Diabetic Association, 23*(12), 1332.

Franko, O. I. (2011). Smartphone apps for orthopaedic surgeons. *Clinical Orthopaedics and Related Research, 469*(7), 2042-2048. doi:10.1007/s11999-011-1904-0

Garritty, C., & EI Emmam, K. (2006). Who's using PDAs? estimates of PDA use by health care providers: A systematic review of surveys. *Journal of Medical Internet Research, 8*(2), 0-0. doi:10.2196/jmir.8.2.e7

Geiger, G., & Maisonneuve, C. (2012). Impact of hospital wide deployment of iPads. Paper presented at the *E-Health 2012,* Retrieved from http://www.e-healthconference.com/2012presentations.html

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research* Aldine de Gruyter.

Gliem, J. A., & Gliem, R. R. (2003). Calculating, interpreting, and reporting cronbach's alpha reliability coefficient for likert-type scales.

Gorman, M. B. Lavelle, & J. S. Ash. (2003). Order creation and communication in healthcare. *Methods of Information in Medicine, 42*(4), 376-385.

Green, B. N., Johnson, C. D., & Adams, A. (2006). Writing narrative literature reviews for peer-reviewed journals: Secrets of the trade. *Journal of Chiropractic Medicine, 5*(3), 101-117. doi:10.1016/S0899-3467(07)60142-6

Gremy, F., Fessler, J., & Bonnin, M. (1999). Information systems evaluation and subjectivity. *International Journal of Medical Informatics, 56*(1), 13-23.

Gurses, A. P., & Xiao, Y. (2006). A systematic review of the literature on multidisciplinary rounds to design information technology. *Journal of the American Medical Informatics Association, 13*(3), 267-276. doi:10.1197/jamia.M1992

Haller, G., Haller, D. M., Courvoisier, D. S., & Lovis, C. (2009). Handheld vs. laptop computers for electronic data collection in clinical research: A crossover randomized trial. *Journal of the American Medical Informatics Association, 16*(5), 651-659. doi:10.1197/jamia.M3041

Hammond, E. J., & Sweeney, B. P. (2000). Electronic data collection by trainee anaesthetists using palm top computers. *European Journal of Anaesthesiology, 17*(2), 91-98. doi:10.1046/j.1365-2346.2000.00608.x

Hauser, S. E. S. E. (2007). Using wireless handheld computers to seek information at the point of care: An evaluation by clinicians. *Journal of the American Medical Informatics Association : JAMIA, 14*(6), 807-815.

Hazlehurst, B., McMullen, C., Gorman, P., & Sittig, D. (2003). How the ICU follows orders: Care delivery as a complex activity system. *AMIA Annual Symposium Proceedings, 2003*, 284-288.

Healthcare Information and Management Systems Society. (2011). 2011 HIMSS mobile technology survey. Retrieved Dec/19, 2013, from http://www.mhimss.org/sites/default/files/resource-media/pdf/HIMSS%20Mobile%20Technology%20Survey%20FINAL%20Revised%20120511%20Cover.pdf

Heathfield, H., Pitty, D., & Hanka, R. (1998). Evaluating information technology in health care: Barriers and challenges. *BMJ: British Medical Journal, 316*(7149), 1959-1961.

Henkelman, D. (2003). The evolution of a health information brokering service in the province of british columbia.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human-computer interaction research. *ACM Transactions on Computer-Human Interaction (TOCHI), 7*(2), 174-196. doi:10.1145/353485.353487

Househ, M. M. (2012). mHealth A passing fad or here to stay? *Telemedicine and E-health services, policies, and applications: Advancements and developments* (pp. 151-178) Medical Information Science Reference.

Hsieh, H., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research, 15*(9), 1277-1288.

Hsu, J., Huang, J., Fung, V., Robertson, N., Jimison, H., & Frankel, R. (2005). Health information technology and physician-patient interactions: Impact of computers on communication during outpatient primary care visits. *Journal of the American Medical Informatics Association, 12*(4), 474-480. doi:10.1197/jamia.M1741

Hunter, T., Hardwicke, J., & Rayatt, S. (2010). The smart phone: An indispensable tool for the plastic surgeon? *Journal of Plastic, Reconstructive & Aesthetic Surgery, 63*(4), e426-e427.

Hurling, R., Catt, M., Boni, M. D., Fairley, B. W., Hurst, T., Murray, P., . . . Sodhi, J. S. (2007). Using internet and mobile phone technology to deliver an automated physical activity program: Randomized controlled trial. *Journal of Medical Internet Research, 9*(2), e7. doi:10.2196/jmir.9.2.e7

Institute of Medicine (U. S.) Committee on Psychosocial Services to Cancer Patients / Families in a Community Setting. (2008). *Cancer care for the whole patient: Meeting psychosocial health needs*. Washington, D.C: National Academies Press.

Institute of Medicine (U.S.). Committee on Quality of Health Care in America. (2001). Crossing the quality chasm: A new health system for the 21st century. Washington, D.C: National Academies Press.

Istepanian, R. S. H., Jovanov, E., & Zhang, Y. T. (2004). Guest editorial introduction to the special section on M-health: Beyond seamless mobility and global wireless health-care connectivity. *IEEE Transactions on Information Technology in Biomedicine, 8*(4), 405-414. doi:10.1109/TITB.2004.840019

Istepanian, R. S. H., & Lacal, J. C. (2003). Emerging mobile communication technologies for health: Some imperative notes on m-health. *Engineering in Medicine and Biology Society, 2003. Proceedings of the 25th Annual International Conference of the IEEE, , 2* 1414-1416 Vol.2.

ITU World Telecommunication/ICT Indicators Database. (2012). Key statistical highlights: ITU data release june 2012. Retrieved Jan/13, 2013, from http://www.itu.int/ITU-D/ict/statistics/material/pdf/2011%20Statistical%20highlights_June_2012.pdf

Jackson, W., & Verberg, N. (2007). *Methods: Doing social research*

Johnson, J. D., Meyer, M., Woodworth, M., Ethington, C., & Stengle, W. (1998b). Information technologies within the cancer information service: Factors related to innovation adoption. *Preventive Medicine, 27*(5 Pt 2), S71-83.

Johnston, J. M., Leung, G. M., Tin, K. Y. K., Ho, L., Lam, W., & Fielding, R. (2004). Evaluation of a handheld clinical decision support tool for evidence-based learning and practice in medical undergraduates. *Medical Education, 38*(6), 628.

Kabachinski, J. (2013). From COWs to BYOD. *Biomedical Instrumentation & Technology / Association for the Advancement of Medical Instrumentation, 47*(3), 254.

Kaplan, B. (1997). Addressing organizational issues into the evaluation of medical systems. *Journal of the American Medical Informatics Association : JAMIA, 4*(2), 94-101. doi:10.1136/jamia.1997.0040094

Kho, A. A. (2006). Use of handheld computers in medical education A systematic review. *Journal of General Internal Medicine : JGIM, 21*(5), 531-537.

Koeniger-Donohue, R. (2008). Handheld computers in nursing education: PDA pilot project. *The Journal of Nursing Education, 47*(2), 74.

Koppel, R., Wetterneck, T., Telles, J. L., & Karsh, B. (2008). Workarounds to barcode medication administration systems: Their occurrences, causes, and threats to patient safety. *Journal of the American Medical Informatics Association, 15*(4), 408-423. doi:10.1197/jamia.M2616

Krauskopf, P. B., & Farrell, S. (2011). Accuracy and efficiency of novice nurse practitioners using personal digital assistants. *Journal of Nursing Scholarship, 43*(2), 117-124. doi:10.1111/j.1547-5069.2011.01385.x

Kubose, T. T., Cimino, J. J., & Patel, V. L. (2001). Assessment of information needs for informed, coordinated activities in the clinical environment. *Proceedings of the AMIA Symposium,* , 948-948.

Kurth, R. J., Silenzio, V., & Irigoyen, M. M. (2002). Use of personal digital assistants to enhance educational evaluation in a primary care clerkship. *Medical Teacher, 24*(5), 488-488. doi:10.1080/0142159021000012513

Kushniruk, A. W. (2004). Cognitive and usability engineering methods for the evaluation of clinical information systems. *Journal of Biomedical Informatics, 37*(1), 56.

Kushniruk, A. (2002). Evaluation in the design of health information systems: Application of approaches emerging from usability engineering. *Computers in Biology and Medicine, 32*(3), 141-149. doi:10.1016/S0010-4825(02)00011-2

Kushniruk, A. W., Triola, M. M., Borycki, E. M., Stein, B., & Kannry, J. L. (2005). Technology induced error and usability: The relationship between usability problems and prescription errors when using a handheld application. *International Journal of Medical Informatics, 74*(7-8), 519-526. doi:10.1016/j.ijmedinf.2005.01.003

Kwon, H., Lee, K., Son, H., Kang, S., Lee, W., Yoon, K., . . . Cha, B. (2004). Development of web-based diabetic patient management system using short message service (SMS).

Diabetes Research and Clinical Practice, 66 Suppl 1, S133-S137. doi:10.1016/j.diabres.2003.10.028

Lau, F., Hagens, S., & Muttitt, S. (2006). A proposed benefits evaluation framework for health information systems in canada. *Healthcare Quarterly (Toronto, Ont.), 10*(1), 112-6, 118.

Lau, F. (2009). Extending the infoway benefits evaluation framework for health information systems. *Studies in Health Technology and Informatics, 143*, 406.

Lau, F., Yang, J., Pereira, J., Daeninck, P., & Aherne, M. (2006). A survey of PDA use by palliative medicine practitioners. *Journal of Palliative Care, 22*(4), 267.

Lau, F., Price, M., & Keshavjee, K. (2011). From benefits evaluation to clinical adoption: Making sense of health information system success in canada. *Healthc Q, 14*(1), 39-45.

Lazarou, J., Pomeranz, B. H., & Corey, P. N. (1998). Incidence of adverse drug reactions in hospitalized patients: A meta-analysis of prospective studies. *JAMA : The Journal of the American Medical Association, 279*(15), 1200-1205. doi:10.1001/jama.279.15.1200

Leape, L. L., Laffel, G., Nemeskal, R., Petersen, L. A., Porter, K., Servi, D., . . . ADE Prevention Study Group. (1995). Systems analysis of adverse drug events. *JAMA: The Journal of the American Medical Association, 274*(1), 35-43. doi:10.1001/jama.1995.03530010049034

Lee, J. S., Sineff, S. S., & Sumner, W. (2002). Validation of electronic student encounter logs in an emergency medicine clerkship. *Proceedings / AMIA ...Annual Symposium.AMIA Symposium,* , 425-429.

Lefever, S., Dal, M., & Matthíasdóttir, Á. (2007). Online data collection in academic research: Advantages and limitations. *British Journal of Educational Technology, 38*(4), 574-582. doi:10.1111/j.1467-8535.2006.00638.x

Leung, G. M., Johnston, J. M., Tin, K. Y. K., Wong, I. O. L., Ho, L., Lam, T., & Lam, W. W. T. (2003). Randomised controlled trial of clinical decision support tools to improve learning of evidence based medicine in medical students. *BMJ: British Medical Journal, 327*(7423), 1090-1093. doi:10.1136/bmj.327.7423.1090

Lindenauer, P. K., Ling, D., Pekow, P. S., Crawford, A., Naglieri‐Prescod, D., Hoople, N., . . . Benjamin, E. M. (2006). Physician characteristics, attitudes, and use of computerized order entry. *Journal of Hospital Medicine, 1*(4), 221-230.

Lo, S. H.User resistance of information systems.

Lu, Y., Xiao, Y., Sears, A., & Jacko, J. A. (2005b). A review and a framework of handheld computer adoption in healthcare. *International Journal of Medical Informatics, 74*(5), 409-422. doi:10.1016/j.ijmedinf.2005.03.001

Lyytinen, K. K. (1988). Expectation failure concept and systems analysts' view of information system failures: Results of an exploratory study. *Information & Management, 14*(1), 45-56.

Marceglia, S., Bonacina, S., Zaccaria, V., Pagliari, C., & Pinciroli, F. (2012). How might the iPad change healthcare? *Journal of the Royal Society of Medicine, 105*(6), 233.

Martin, S. (2003). More than half of MDs under age 35 now using PDAs. *CMAJ : Canadian Medical Association Journal = Journal De L'Association Medicale Canadienne, 169*(9), 952.

Marano, Murianni, & Sticchi. (2005). To err is human. building a safer health system. *Italian Journal of Public Health, 2*(3-4)

Massaro, T. A. (1993). Introducing physician order entry at a major academic medical center: I. impact on organizational culture and behavior. *Academic Medicine : Journal of the Association of American Medical Colleges, 68*(1), 20-25. doi:10.1097/00001888-199301000-00003

McGrath, M. J., Arar, H. N., & Pugh, A. J. (2007). The influence of electronic medical record usage on nonverbal communication in the medical interview. *Health Informatics Journal, 13*(2), 105-117. doi:10.1177/1460458207076466

McKnight, L., Stetson, P. D., Bakken, S., Curran, C., & Cimino, J. J. (2001). Perceived information needs and communication difficulties of inpatient physicians and nurses. *Proceedings / AMIA ...Annual Symposium.AMIA Symposium,* , 453-457.

MD Anderson Cancer Centre. (2011). Mobile & web apps to prevent cancer. Retrieved October/22, 2013, from http://www.mdanderson.org/publications/focused-on-health/issues/2011-july/mobileappscancer.html

Miller, R. H., Hillman, J. M., & Given, R. S. (2004). Physician use of IT: Results from the deloitte research survey. *Journal of Healthcare Information Management : JHIM, 18*(1), 72-80.

Moehr, J. R. (2002). Evaluation: Salvation or nemesis of medical informatics? *Computers in Biology and Medicine, 32*(3), 113-125. doi:10.1016/S0010-4825(02)00009-4

Mosa, A. S. M., Yoo, I., & Sheets, L. (2012). A systematic review of healthcare applications for smartphones. *BMC Medical Informatics and Decision Making, 12*(1), 67.

Moyer, J. E. (2013). Managing mobile devices in hospitals: A literature review of BYOD policies and usage. *Journal of Hospital Librarianship, 13*(3), 197-208.

Murphy, K. C. (2007). Evaluating the use of tablet PCs in an ambulatory clinic setting. *Med Comput Rev, 7*(7), 2-8.

Murphy, K. C., Wong, F. L., Martin, L. A., & Edmiston, D. (2009). Ongoing evaluation of ease-of-use and usefulness of wireless tablet computers within an ambulatory care unit. *Studies in Health Technology and Informatics, 143*, 459-464.

Nah, F., Siau, K., & Sheng, H. (2005). *The value of mobile applications: A utility company study*. New York: ACM. doi:10.1145/1042091.1042095

Neville, D., Gates, K., MacDonald, D., Barron, M., Tucker, S., Cotton, S., . . . O'Reilly, S. (2004). Towards an evaluation framework for electronic health records initiatives: A proposal for an evaluation framework. *Newfoundland, Canada: Memorial University of Newfoundland,* Niazkhani, Z., Pirnejad, H., Berg, M., & Aarts, J. (2009). The impact of computerized provider order entry systems on inpatient clinical workflow: A literature review. *Journal of the American Medical Informatics Association : JAMIA, 16*(4), 539-549. doi:10.1197/jamia.M2419

Nosrati, M., Karimi, R., & Hasanvand, H. A. (2012). Mobile computing: Principles, devices and operating systems.

Obermayer, J. L., Riley, W. T., Asif, O., & Jean-Mary, J. (2004). College smoking-cessation using cell phone text messaging. *Journal of American College Health : J of ACH, 53*(2), 71-78. doi:10.3200/JACH.53.2.71-78

Patel, B. K., Chapman, C. G., Luo, N., Woodruff, J. N., & Arora, V. M. (2012). Impact of mobile tablet computers on internal medicine resident efficiency. *Archives of Internal Medicine, 172*(5), 436.

Patlak, M., Balogh, E., Nass, S. J., National Cancer Policy Forum (U.S.), Institute of Medicine (U.S.), & National Coalition for Cancer Survivorship (U.S.). (2011). *Patient-centered cancer treatment planning: Improving the quality of oncology care : Workshop summary*. Washington, D.C: National Academies Press.

Patton, M. Q. (1987). *How to use qualitative methods in evaluation*. Newbury Park, Calif: Sage Publications.

Payne, K. F. B., Wharrad, H., & Watts, K. (2012). Smartphone and medical related app use among medical students and junior doctors in the united kingdom (UK): A regional survey. *BMC Medical Informatics and Decision Making, 12*(1), 121-121. doi:10.1186/1472-6947-12-121

Peute, L. W. L. (2010). Anatomy of a failure: A sociotechnical evaluation of a laboratory physician order entry system implementation. *International Journal of Medical Informatics (Shannon, Ireland), 79*(4), e58-e70.

Ping Yu, Wu, M. X., Yu, H., & Xiao, G. Q. (2006). The challenges for the adoption of M-health. 181-186. doi:10.1109/SOLI.2006.329059

Prgomet, M., Georgiou, A., & Westbrook, J. I. (2009). The impact of mobile handheld technology on hospital physicians' work practices and patient care: A systematic review. *Journal of the American Medical Informatics Association, 16*(6), 792. doi:10.1197/jamia.M3215

Price, M. (2008). A bio-psycho-social review of usability methods and their applications in healthcare. *Human, social, and organizational aspects of health information systems* (pp. 23-48) IGI Global. doi:10.4018/978-1-59904-792-8.ch002

Rao, A. S., Adam, T. J., Gensinger, R., & Westra, B. L. (2012). Study of the factors that promoted the implementation of electronic medical record on iPads at two emergency departments. *AMIA ...Annual Symposium Proceedings / AMIA Symposium.AMIA Symposium, 2012*, 744.

Reddy, M. C. M. C. (2005). Technology, work, and information flows: Lessons from the implementation of a wireless alert pager system. *Journal of Biomedical Informatics, 38*(3), 229-238.

Reuss, E., Menozzi, M., Büchi, M., Koller, J., & Krueger, H. (2004). Information access at the point of care: What can we learn for designing a mobile CPR system? *International Journal of Medical Informatics, 73*(4), 363-369. doi:10.1016/j.ijmedinf.2004.02.003

Rhea, S. (2010). Going mobile. wireless devices and technology bring surge in advanced applications for health monitoring and treatment, but legal and privacy issues remain. *Modern Healthcare, 40*(18), 28.

Rigby, M. (2006). Essential prerequisites to the safe and effective widespread roll-out of e-working in healthcare. *International Journal of Medical Informatics, 75*(2), 138-147. doi:10.1016/j.ijmedinf.2005.06.006

Rodgers, A., Corbett, T., Bramley, D., Riddell, T., Wills, M., Lin, R., & Jones, M. (2005). Do u smoke after txt? results of a randomised trial of smoking cessation using mobile phone text messaging. *Tobacco Control, 14*(4), 255-261. doi:10.1136/tc.2005.011577

Rogers, E. M. (1995). *Diffusion of innovations* Simon and Schuster.

Rossi, P. H., Freeman, H. E., & Lipsey, M. W. (2003). *Evaluation: A systematic approach* Sage Publications, Incorporated.

Rothschild, J. M., Fang, E., Liu, V., Litvak, I., Yoon, C., & Bates, D. W. (2006). Use and perceived benefits of handheld computer-based clinical references. *Journal of the American Medical Informatics Association, 13*(6), 619-626. doi:10.1197/jamia.M2103

Rothschild, J. M., Lee, T. H., Bae, T., & Bates, D. W. (2002). Clinician use of a palmtop drug reference guide. *Journal of the American Medical Informatics Association, 9*(3), 223-229. doi:10.1197/jamia.M1001

Schneider, S., Kostecke, R., & Tokazewski, J. (2001). Buying your first PDA. *Family Practice Management, 8*(7), 50.

Seago, B. L., Schlesinger, J. B., & Hampton, C. L. (2002). Using a decade of data on medical student computer literacy for strategic planning. *Journal of the Medical Library Association : JMLA, 90*(2), 202-209.

Serafeimidis, V. (2002). A review of research issues in evaluation of information systems. *Information Systems Evaluation Management,*

Shrestha, R. (2012). Mobility in healthcare and imaging: Challenges and opportunities. *Applied Radiology (1976), 41*(9), 25.

Siegel, R., Naishadham, D., & Jemal, A. (2012). Cancer statistics, 2012. *CA: A Cancer Journal for Clinicians, 62*(1), 10-29. doi:10.3322/caac.20138

Sintchenko, V., Iredell, J. R., Gilbert, G. L., & Coiera, E. (2005). Handheld computer-based decision support reduces patient length of stay and antibiotic prescribing in critical care.

Journal of the American Medical Informatics Association, 12(4), 398-402. doi:10.1197/jamia.M1798

Skinner, B. J. (2007). Long-term or short-term, public health insurance is not sustainable: A reply to CUPE about health spending trends in canada. Retrieved Sep/5, 2012, from http://www.fraserinstitute.org/WorkArea/DownloadAsset.aspx?id=3190

Smith, R. (1996). What clinical information do doctors need? *BMJ: British Medical Journal, 313*(7064), 1062-1068.

Stetson, McKnight, Bakken, Curran, & et al. (2002). Development of an ontology to model medical errors, information needs, and the clinical communication space. *Journal of the American Medical Informatics Association, 9*(6), S86-91. doi:10.1197/jamia.M1235

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Procedures and techniques for developing grounded theory.

Stroud, S. D., Smith, C. A., & Erkel, E. A. (2009). Personal digital assistant use by nurse practitioners: A descriptive study. *Journal of the American Academy of Nurse Practitioners, 21*(1), 31-38. doi:10.1111/j.1745-7599.2008.00368.x

Tierney, W. M., Miller, M. E., Overhage, J. M., & McDonald, C. J. (1993). Physician inpatient order writing on microcomputer workstations. *JAMA: The Journal of the American Medical Association, 269*(3), 379-383.

Torkzadeh, G., & Doll, W. J. (1991). Test-retest reliability of the end-user computing satisfaction instrument. *Decision Sciences, 22*(1), 26-37. doi:10.1111/j.1540-5915.1991.tb01259.x

U.S. Department of Health and Human Services Food and Drug Administration. (2013). Mobile medical applications: Guidance for industry and food and drug administration staff. Retrieved November/10, 2013, from http://www.fda.gov/downloads/MedicalDevices/DeviceRegulationandGuidance/GuidanceDocuments/UCM263366.pdf

U.S. Department of Health and Human Services Food and Drug Administration. (2013). Mobile medical applications. Retrieved 12/18, 2013, from http://www.fda.gov/medicaldevices/productsandmedicalprocedures/connectedhealth/mobilemedicalapplications/default.htm

U.S. Department of Health & Human Services. (2012). Alaska Medicaid settles HIPAA security case for $1,700,000. *Information Technology Newsweekly,* , 384.

United Nations. (2008). The millennium development goals report. Retrieved 05/04, 2012, from www.un.org/millenniumgoals/pdf/The%20Millennium%20Development%20Goals%20Report%202008.pdf

UPMC brings key patient records to the bedside using BlackBerry smartphones. (2010). *Biotech Business Week,* , 5296.

Van Der Meijden, M. J., Tange, H. J., Troost, J., & Hasman, A. (2003b). Determinants of success of inpatient clinical information systems: A literature review. *Journal of the American Medical Informatics Association : JAMIA, 10*(3), 235-243. doi:10.1197/jamia.M1094

VanDenKerkhof, E. G., Goldstein, D. H., Lane, J., Rimmer, M. J., & Dijk, J. P. (2003). Using a personal digital assistant enhances gathering of patient data on an acute pain management service: A pilot study. *Canadian Journal of Anesthesia/Journal Canadien D'Anesthésie, 50*(4), 368-375. doi:10.1007/BF03021034

Varshney, U. (2006). Using wireless technologies in healthcare. *International Journal of Mobile Communications, 4*(3), 354-368.

Varshney, U. (2003). Pervasive healthcare. *Computer, 36*(12), 138-140. doi:10.1109/MC.2003.1250897

Vital Wave Consulting. (2009). mHealth for development: The opportunity of mobile technology for healthcare in the developing world. Retrieved 06/07, 2012, from http://www.globalproblems-globalsolutions-files.org/unf_website/assets/publications/technology/mhealth/mHealth_for_Development_full.pdf

Wallace, S., Clark, M., & White, J. (2012). 'It's on my iPhone': Attitudes to the use of mobile computing devices in medical education, a mixed-methods study. *BMJ Open, 2*(4)

Waton, K. (2006). Going mobile. A tablet PC is the core patient care device at a new digital, wireless hospital in wisconsin. *Health Management Technology, 27*(7), 28, 31.

Wears, R. L., & Berg, M. (2005). Computer technology and clinical work: Still waiting for godot. *JAMA : The Journal of the American Medical Association, 293*(10), 1261-1263. doi:10.1001/jama.293.10.1261

Weiner, M., Gress, T., Thiemann, D. R., Jenckes, M., Reel, S. L., Mandell, S. F., & Bass, E. B. (1999). Contrasting views of physicians and nurses about an inpatient computer-based provider order-entry system. *Journal of the American Medical Informatics Association, 6*(3), 234-244.

WHO Global Observatory for eHealth. (2011). *mHealth: New horizons for health through mobile technologies : Based on the findings of the second global survey on eHealth.* (No. 3). Geneva: World Health Organization.

Wittmann-Price, R. A., Kennedy, L. D., & Godwin, C. (2012). Use of personal phones by senior nursing students to access health care information during clinical education: Staff nurses' and students' perceptions. *The Journal of Nursing Education, 51*(11), 642. doi:10.3928/01484834-20120914-04

Wu, J., Wang, S., & Lin, L. (2005). What drives mobile health care? an empirical evaluation of technology acceptance. *System Sciences, 2005. HICSS'05. Proceedings of the 38th Annual Hawaii International Conference On,* 150a-150a.

Wu, J., Wang, S., & Lin, L. (2007). Mobile computing acceptance factors in the healthcare industry: A structural equation model. *International Journal of Medical Informatics, 76*(1), 66-77. doi:10.1016/j.ijmedinf.2006.06.006

Wu, J., Waldron, J., Hood, S., Kahnamelli, A., Khan, M., Barnett, J., . . . Shabestari, O. (2013). The introduction and evaluation of mobile devices to improve access to patient records: A catalyst for innovation and collaboration at BCCA. *Studies in Health Technology and Informatics, 183*, 232-237.

Yusof, M. M., Papazafeiropoulou, A., Paul, R. J., & Stergioulas, L. K. (2008). Investigating evaluation frameworks for health information systems. *International Journal of Medical Informatics, 77*(6), 377-385. doi:10.1016/j.ijmedinf.2007.08.004

Appendix A: Letter of Invitation to Participants and Evaluation Framework

Letter of Invitation

Shadi Bani Melhem, BSN

Graduate Student, Health Information Science

University of Victoria

Tel: (778) 968-6685

Email: shadi.melhem@phsa.ca

Subject: Initial Contact Letter for Graduate Thesis—An Evaluation of the Mobile Computing Effects on the Workflow of Oncologists in Ambulatory Care Settings

Dear Potential Research Participant,

This letter is an invitation for you to participate in a research study of the effect of iPad technology and application on clinicians' workflow within BCCA ambulatory care settings. This research study is conducted for my master's degree thesis in Health Information Science program from the University of Victoria. You have been identified by the project manager of the iPad Mobility Project as one of the project pilot users.
Your participation is voluntary. You have the right to refuse to participate in this study. If you decide to participate, you may still choose to withdraw from the study at any time without any consequences. Your contact information is only available to authorized BCCA personnel for specified purposes. In keeping with provincial legislation your right to privacy and confidentiality is protected. This legislation allows BCCA researchers to send you information about research opportunities. It is for this reason that you are being invited to participate in this research project.

The purpose of the study is to gain an in-depth understanding of clinicians' expectations and the possible effect of mobile computing technology. The study will evaluate the effectiveness of using an iPad application (VitalHub Chart application) to support clinicians' workflow within BCCA ambulatory care settings. The iPad application (VitalHub) will allow BCCA clinicians to access patients' clinical data stored in the Cancer Agency Information System (CAIS) at any time and location within the BCCA facilities. Specifically, the study will evaluate the ability of the iPad application to meet BCCA clinicians' information and communication needs while maintaining the quality and safety of patient care.

The research methods used for this study include survey, observation, and interview. You may participate in at least one or all of the research methods described. You will have access to the iPads in the pilot project, regardless of your participation in the study. If you complete the survey, consent for completing the survey will be assumed to be given. The research co-investigator Shadi Bani Melhem will contact you via email to set up an appointment to conduct an interview or observation session and will provide further information regarding the study surveys. For further information, please contact Mel through Email: shadi.melhem@phsa.ca or Tel: 778-968-6685

On behalf of the research team, we thank you for your interest.

Regards,
Shadi Bani Melhem,
Co-Investigator, Graduate Student
MSc, Health Information Science, University of Victoria

Evaluation Framework

Data collection method	Goal	Indicators/Measures
Pre-pilot survey questionnaire	To capture baseline data related to expectation and experience	1-Prior experience with using mobile device 2-Level of comfort in using mobile devices 3-Users' expectations for the mobile system use 4-Users' expectations for the mobile system functionalities 5-Users' expectations for the system usefulness 6-Users' expectations of the effect on their relationship with clinicians/patients 7-Users' background information
Pre-pilot (observation)	To capture baseline data related to clinicians' productivity/data access	1-Data accessibility, availability during patient visits. 3-Problems/issues encountered in accessing patient data.
Post-implementation (observation)	To capture actual real-time data related to the iPad VH Chart effect on clinicians' productivity/data access	1- Data accessibility, availability during patient visits. 2-Problems/issues encountered in accessing patient data.
Post-implementation interviews	To gather more detailed and thorough feedback and through qualitative data	1-The quality of the system in terms of functionality and performance 2-The quality of data contained within the system in terms of content and availability 3-The quality of the system in terms of serving clinicians' everyday needs in the practice 4-The effect the iPad application has in managing patient conditions. 5-Major changes in clinicians' day-to-day work 6-The biggest challenges with respect to the iPad deployment 7-Opportunities in relation to using the iPad app as compared to how things were done previously 8- Other comments and feedback
Post-implementation survey	To gather post-pilot data to compare against interview results and evaluate the success of the pilot.	1- System quality: usability, reliability, security 2-Information quality: *Content*: completeness, accuracy, and relevance. *Availability*: speed, format, and layout of information. 3- Service quality: *Responsiveness*: Overall quality of the service provided to the system, implementation process, training, ongoing support. 4- System use: *Self-reported use*: use per day, use per week, use for patients (%) *Intention to use:* recommendation to others to use the system 5- User Satisfaction: overall satisfaction, productivity, etc.

Appendix B: Baseline, Post-training Questionnaire and Interview Questions

BCCA Baseline Survey

Instructions to Participants:

This survey will take approximately 10 minutes to complete. All responses will be kept strictly confidential. No individual data or responses will be reported, as only aggregated data will be reported. If you complete the survey, consent for completing the survey will be assumed to be given. Your participation in this pilot project and survey is voluntary. If you have any questions about the survey, please contact Mel: (778) 968 6685 or email shadi.melhem@phsa.ca. The following survey is intended to achieve better understanding of PHSA staff perceptions of the current use of and/or need for mobility as well as the attitudes about the steps taken to prepare for implementing IMITS Mobility proof of concept (iPad pilot). Specifically we are interested in learning about your expectations and understanding what effect the iPad deployment will have on patient care and clinician workflow within PHSA's unique environment.

1) I have agreed to participate in the IMITS Mobility Pilot Project Baseline Survey

○ Yes

○ No

2) Please indicate your level of agreement with the following statements after the iPad is implemented.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) I believe that using an iPad would fit into my workflow.	○	○	○	○	○
b) I believe that using an iPad would improve my productivity.	○	○	○	○	○
c) I expect that using an iPad would enhance the overall quality of patient	○	○	○	○	○

care.

d) I expect that using an iPad would enhance the overall safety of patient care.	○	○	○	○	○
e) I believe that using an iPad would make my job easier.	○	○	○	○	○
f) I believe using an iPad increases the amount of professional satisfaction I get out of my job.	○	○	○	○	○
g) I intend to use the iPad frequently in my clinical workflow.	○	○	○	○	○
h) I plan to use the iPad before and during the patient visit.	○	○	○	○	○

3) How would you intend to use the iPad? (Check all that apply)

☐ For clinical decision making

☐ To access patient information

☐ For patient education and communication

☐ To communicate with other clinicians

☐ Other, please specify... ______________________

4) When do you intend to use the iPad? (Check all that apply)

☐ Before patient visit

☐ During patient visit

☐ After patient visit

☐ Between patient visits

☐ Office preparation and planning time

5) Please indicate your level of agreement with the following statements after the iPad is implemented.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a) I will spend less time looking for information after the iPad is implemented.	○	○	○	○	○
b) I expect that using the iPad would allow me to involve patients and families in the care planning process.	○	○	○	○	○
c) I expect that using the iPad would enhance the timeliness with which patient care services are provided.	○	○	○	○	○
d) I expect that using the iPad would increase the amount of time I can spend directly with patients.	○	○	○	○	○
e) I expect that using the iPad will improve communications between physicians and BCCA staff.	○	○	○	○	○
f) I am looking forward to using the iPad in my clinical practice.	○	○	○	○	○
g) I think patients are starting to expect more mobile devices and a greater presence of information technology as a part of their healthcare experience.	○	○	○	○	○
h) I expect that the iPad and other similar mobile applications will become a larger part of the cancer care experience for patients as well as healthcare professionals.	○	○	○	○	○
i) I expect that the iPad would have a positive effect on the BC Cancer Agency to recruit and retain high	○	○	○	○	○

quality staff.					
j) I expect that learning to operate the iPad would be easy for me.	○	○	○	○	○
k) I am aware of PHSA remote and mobile information security policy.	○	○	○	○	○
l) I have done the e-learning "PHSA Patient Confidentiality" on the learning hub.	○	○	○	○	○
m) Overall, the feedback I hear about iPads in clinical practice is positive.	○	○	○	○	○
n) I expect that the iPad will lessen my use of paper chart.	○	○	○	○	○
o) I expect that the iPad will reduce my use of desktop computers.	○	○	○	○	○

Mobile computing experience:

6) I would describe my comfort with using mobile devices (iPad, PDA, Blackberry, tablet) as

○ Very comfortable

○ Comfortable

○ Somewhat comfortable

○ Not very comfortable

7) I find mobile devices ________ in my personal life.

○ Extremely useful

○ Useful

○ Somewhat useful

○ Not at all useful

8) I would say that mobile devices are ________ in my clinical practice.

○ Extremely useful

○ Useful

○ Somewhat useful

○ Not at all useful

9) In my personal life, I use a mobile device:

○ Every day

○ A few times a week

○ A few times a month

○ Never

10) In my clinical practice, I use a mobile device:

○ Every day

○ A few times a week

○ A few times a month

○ Never

11) If a device is currently used, please specify type. (Check all that apply)

☐ iPad

☐ iPhone

☐ Blackberry

☐ Windows-based tablet

☐ Laptop in mobile environment

☐ Other, please specify... ________________________

12) Overall how would you rate your computer and mobile device proficiency?

○ None

○ Basic

○ Average

○ Advanced

○ Expert

Background information:

13) Age

- ○ Under 30
- ○ 30–40
- ○ 40–50
- ○ 50–60
- ○ 60+

14) Sex

- ○ Male
- ○ Female
- ○ Prefer not to identify

15) Professional discipline

- ○ Radiation Oncologist
- ○ Medical Oncologist
- ○ OGP
- ○ Resident
- ○ Nursing
- ○ Pharmacist
- ○ Other, please specify... ________________________

16) Location

- ○ Vancouver Centre
- ○ Fraser Valley Centre
- ○ Kelowna Centre
- ○ Abbotsford Centre
- ○ Vancouver Island Centre

Post-implementation Survey for the IMITS Mobility Pilot Project

Instructions to Participants:

The survey will take approximately 10 minutes to complete. All responses will be kept strictly confidential. No individual data or responses will be reported, as only aggregated data will be reported. Your participation in this survey is voluntary. If you complete the survey, consent for completing the survey will be assumed to be given. If you have any questions about the survey, please contact Mel through Email: shadi.melhem@phsa.ca or Tel: 778-968-6685. Based on your experience in using the iPad and VH chart, as part of the IMITS Mobility Pilot Project, please answer the following questions. NOTE: “VH Chart” is a native iPad app made available through the Apple App store to pilot participants that provides access to view CAIS data.

SECTION 1. USER SATISFACTION AND WORKFLOW EFFECT

A) Please indicate your level of agreement with the following statements after the iPad is implemented.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.Use of the iPad fits into my workflow.	○	○	○	○	○
2.Use of VH Chart fits into my workflow.	○	○	○	○	○
3.The iPad improves my productivity.	○	○	○	○	○
4.VH chart improves my productivity.	○	○	○	○	○
5.The iPad improves the quality of patient care I can provide.	○	○	○	○	○
6.VH chart improves the quality of patient care I can provide.	○	○	○	○	○
7.The iPad improves the safety of patient care I can provide.	○	○	○	○	○
8.VH chart improves the safety of patient care I can provide.	○	○	○	○	○
9.The iPad makes my job easier.	○	○	○	○	○
10.VH chart makes my job easier	○	○	○	○	○
11.The iPad increases the amount of	○	○	○	○	○

professional satisfaction I get out of my job.					
12.VH Chart increases the amount of professional satisfaction I get out of my job.	○	○	○	○	○
13.The iPad allows me to involve patients and families in the care planning process.	○	○	○	○	○
14.VH chart allows me to involve patients and families in the care planning process.	○	○	○	○	○
15.The iPad improves sharing of patient information amongst providers.	○	○	○	○	○
16.VH chart improves sharing of patient information amongst providers.	○	○	○	○	○
17.The information content in VH chart meets my needs.	○	○	○	○	○
18.The output of VH chart is presented in a useful format.	○	○	○	○	○
19.The iPad is easy to use.	○	○	○	○	○
20.VH chart is easy to use.	○	○	○	○	○
21.The iPad is easy to learn with little support required.	○	○	○	○	○
22.VH chart is easy to learn with little support required	○	○	○	○	○
23.The iPad enhances the timeliness with which patient care services are provided.	○	○	○	○	○

24.VH chart enhances the timeliness with which patient care services are provided.	○	○	○	○	○
25.The iPad increases the amount of time I can spend directly with patients.	○	○	○	○	○
26.VH chart increases the amount of time I can spend directly with patients.	○	○	○	○	○
27.I expect that the iPad would have a positive effect on the hospital to recruit and retain high quality staff.	○	○	○	○	○
28.I expect that VH chart would have a positive effect on the hospital to recruit and retain high quality staff.	○	○	○	○	○
29.The iPad improves communications between physicians and BCCA staff.	○	○	○	○	○
30.VH chart improves communications between physicians and BCCA staff.	○	○	○	○	○
31.The iPad reduced my use of paper chart.	○	○	○	○	○
32.VH chart reduced my use of paper chart.	○	○	○	○	○
33.The iPad reduced my use of desktop computers.	○	○	○	○	○
34.VH Chart reduced my use of desktop computers.	○	○	○	○	○
	○	○	○	○	○

SECTION 1. USER SATISFACTION AND WORKFLOW EFFECT

35. How often did the iPad reduce your use of desktop computer?

- ○ Every patient visit
- ○ Most patient visits
- ○ Some patient visits
- ○ A small number of patient visits
- ○ Outside of patient visits

36. How often did the VH Chart reduce your use of desktop computers?

- ○ Every patient visit
- ○ Most patient visits
- ○ Some patient visits
- ○ A small number of patient visits
- ○ Outside of patient visits

37. Are there aspects or functionality to the iPad that you would change, and if so, which ones would they be? Please describe:

38. Are there enhancements to VH chart that you would make, if so, what would they be? Please describe:

39. In general, how satisfied are you overall with the iPad and VH chart you are currently working with? By "the iPad and VH chart" we mean the ease and functionality of the iPad and VH chart itself, the quality of the information given, and the quality of the services provided for the iPad and VH chart.

- ○ Highly satisfied
- ○ Moderately satisfied
- ○ Neither satisfied nor dissatisfied
- ○ Moderately dissatisfied

○ Not at all satisfied

SECTION 2. SYSTEM QUALITY

B) Please indicate your level of agreement with the following statements after the iPad is implemented.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.VH chart response time is acceptable.	○	○	○	○	○
2.VH chart integrated with my workflow.	○	○	○	○	○
3.The iPad security is acceptable.	○	○	○	○	○
4.VH chart security is acceptable.	○	○	○	○	○
5.The iPad features enable me to perform my work well.	○	○	○	○	○
6.VH chart features enable me to perform my work well.	○	○	○	○	○
7.The iPad is reliable in its performance.	○	○	○	○	○
8.VH chart is reliable in its performance.	○	○	○	○	○

9. Based on your experiences to date with the iPad and VH chart, how acceptable is the quality of the system itself? Would you say it is:

○ Highly acceptable

○ Moderately acceptable

○ Neither acceptable nor unacceptable

○ Moderately unacceptable

○ Not at all acceptable

SECTION 3. INFORMATION QUALITY

C) Please indicate your level of agreement with the following statements after the iPad is implemented.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.VH chart provides complete clinical information.	○	○	○	○	○
2.VH chart provides the needed clinical information quickly.	○	○	○	○	○
3.VH chart provides accurate clinical information.	○	○	○	○	○
4.VH chart provides precise clinical information.	○	○	○	○	○
5.VH chart provides relevant clinical information.	○	○	○	○	○
6.VH chart provides the clinical information in acceptable format and layout.	○	○	○	○	○
7.VH chart provides up-to-date information.	○	○	○	○	○

8. In general, when thinking about the quality of the information provided by VH chart, do you find the quality of the information to be:

○ Highly acceptable

○ Moderately acceptable

○ Neither acceptable nor unacceptable

○ Moderately unacceptable

○ Not at all acceptable

SECTION 4. SERVICE QUALITY

D) Please indicate your level of agreement with the following statements after the iPad is implemented.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.The iPad and VH chart	○	○	○	○	○

implementation process at BCCA was acceptable.					
2.Sufficient technical IT support was available to operate the iPad and VH chart.	○	○	○	○	○
3.Sufficient resources were provided for me to learn to use the iPad and VH chart.	○	○	○	○	○
4.I know how to get support for the iPad and VH Chart.	○	○	○	○	○
5.I needed support for the iPad during the pilot.	○	○	○	○	○
6.I needed support for VH Chart during the pilot.	○	○	○	○	○
7.I accessed support/training available at go-live.	○	○	○	○	○
8.I accessed support/training available during the pilot.	○	○	○	○	○
9.The level of training provided at go-live for the iPad and VH chart project is acceptable.	○	○	○	○	○
10.The level of support provided during the pilot for the iPad and VH chart project is acceptable.	○	○	○	○	○

11. In general, when thinking about the quality of the services (i.e., technical support and training services) provided for the system, do you find the quality of these services to be:

○ Highly acceptable

○ Moderately acceptable

○ Neither acceptable nor unacceptable

○ Moderately unacceptable

○ Not at all acceptable

SECTION 5. SYSTEM USAGE:

1. In a typical day, how many times do you use the iPad?

○ Number of times, a day ______________________

○ Always

○ Rarely

2. In a typical day, how many times do you use VH Chart?

○ Number of times, a day ______________________

○ Always

○ Rarely

3. In a typical week, how many days did you use the iPad?

○ Number of days, a week ______________________

4. In a typical week, how many days did you use the VH Chart?

○ Number of days, a week ______________________

5.Please estimate what percent of your patients you use the iPad with,

○ % Patients (FILL IN) ______________________

○ Don't know

6. Please estimate what percent of your patients you use VH chart with

○ % Patients (FILL IN) ______________________

○ Don't know

7. How would you describe your "use" of the iPad? (Check all that apply)

☐ For clinical decision making

☐ To access patient information

☐ For patient education and communication

☐ To communicate with other clinicians

☐ Other, please specify... ______________________

8. How would you describe your "use" of VH Chart? (Check all that apply)

☐ For clinical decision making

- ☐ To access patient information
- ☐ For patient education and communication
- ☐ To communicate with other clinicians
- ☐ Other, please specify... ______________________

9. When did you use the iPad? (Check all that apply)

- ☐ Before patient visit
- ☐ During patient visit
- ☐ After patient visit
- ☐ Between patient visits
- ☐ Office preparation and planning time

10. When did you use the VH Chart? (Check all that apply)

- ☐ Before patient visit
- ☐ During patient visit
- ☐ After patient visit
- ☐ Between patient visits
- ☐ Office preparation and planning time

11. How likely are you to recommend the iPad and VH chart to other healthcare providers at other Hospitals or Centres?

- ○ Definitely
- ○ Probably
- ○ May or may not
- ○ Probably not
- ○ Definitely not

12. Given a choice, would you like to increase or decrease your future use of the iPad and VH chart that you are currently working with? Would that be a significant or moderate increase/decrease, or would you like your future use to stay the same?

- ○ Significant increase

- ○ Moderately increase
- ○ Moderately decrease
- ○ Significant decrease
- ○ Remain the same

SECTION 6. Background:

1. Age

- ○ Under 30
- ○ 30–40
- ○ 40–50
- ○ 50–60
- ○ 60+

2. Sex:

- ○ Male
- ○ Female
- ○ Prefer not to identify

3. Professional discipline:

- ○ Radiation Oncologist
- ○ Medical Oncologist
- ○ OGP
- ○ Resident
- ○ Nursing
- ○ Pharmacist
- ○ Other, please specify... ________________________

4. Location of practice:

- ○ Vancouver BCCA Centre
- ○ Fraser Valley BCCA Centre
- ○ Abbotsford BCCA Centre

- ○ Kelowna BCCA Centre
- ○ Vancouver Island Centre

5. How long have you been using a mobile device?

- ○ Less than a month
- ○ 1–3 months
- ○ 4–6 months
- ○ 7–12 months
- ○ 1–2 years
- ○ 3–5 years
- ○ Other, please specify... ________________________

6. Specify device type

- ○ iPad
- ○ iPhone
- ○ Blackberry
- ○ Windows-based tablet
- ○ Laptop in mobile environment
- ○ Other, please specify... ________________________

7. How would you rate your computer proficiency?

- ○ None
- ○ Basic
- ○ Average
- ○ Advanced
- ○ Expert

8. Do you have any other comments you would like to make regarding the system?

Interview Questions Guide

Introduction

The purpose of this interview is to get information and feedback that will help in evaluating the effectiveness of using the iPad and VitalHub application to support clinicians' workflow. As one of the pilot project users, you are in a unique position to describe what the iPad project does and how it affects clinicians. And that's what the interview is about: your experience with the iPad and your thoughts and perspectives about the iPad and VH chart application benefits, any challenges, satisfaction, and how it could be improved. The answers from all clinicians we interview will be combined in our evaluation report. Nothing that you say will ever be identified with you personally. As we go through the interview, if you have any questions about why I am asking something, please feel free to ask. Or if there is anything you do not want to answer, just say so. Are you ready?

This question is really important because it will allow us to understand how clinicians use the iPad application to support their clinical workflow, so could you please:

1. Describe your experience with using mobile technology to support your clinical workflow. In answering this question you could think "If I was observing you using the iPad in a typical day, what I would see you doing? What experience would I observe you having?" (The feedback should be what the clinician is actually doing with the iPad and VitalHub).
    - For what tasks you use it? When? How often?
    - What about using it to access patient records in EVE, to facilitate or explain to your patients their condition, progress?
    - To communicate with other clinicians in BCCA.
    - To access online resources.
    - For research purposes.
2. What do you think about using the iPad and VitalHub to support clinicians' workflow?
    - What do you think of the quality of the iPad in terms of functionality and performance?
    - What do you think of the quality of data contained within the VitalHub Chart

application in terms of content and availability?

- What do you think about the quality of the iPad and VitalHub application in serving your everyday needs in the practice?
- How does it affect your need for regular desktop computers and paper chart?

3. What are your thoughts/opinions about using the iPad and VitalHub for patient care in Sunny Hill? Alternative: what effect has the iPad and VitalHub application had in managing your patients' conditions?
   - How does it relate to your ability to involve patients/their families in decisions regarding their care?
   - The quality of care you can provide: explain progress, treatment plans.
   - Decision making.
   - Productivity and efficiency because of the reduced need to print patient data, better access while with the patient in the exam room.
4. What major changes have you seen in your day-to-day work with the deployment of the iPad and VitalHub Chart application?
5. What have the biggest challenges been with respect to the iPad and VitalHub?
6. What opportunities do you see with the use of the iPad and VitalHub Chart application as compared to how things were previously done?
7. On a scale of 1–5 with 5 being strongly positive, how would you rank your overall experience with the introduction of the iPad and VitalHub application? Why?
8. Do you have any other comments or feedback you would like to share?

Appendix C: Consent Form for Participants

Participant Information and Consent Form

An Evaluation of the Mobile Computing Effects on the Workflow of Oncologists in Ambulatory Care Settings

Principal Investigator: Jeff Barnett, BSc, MSc
BCCA Director of Clinical Informatics
Vancouver Island, BCCA
(250) 519-5519

Academic supervisor: Omid Shabestari, MD, PhD
School of Health Information Science
University of Victoria
(250) 721-8582

Co-Investigator: Shadi Bani Melhem, BSN
Graduate Student, Health Information Science
University of Victoria
(778) 968-6685

For emergencies only: Call the centre nearest you and ask for your study doctor or, if he or she is not available, ask for your usual oncologist or the oncologist on-call.

Vancouver Centre	(604) 877-6000
Vancouver Island Centre	(250) 370-8000
Fraser Valley Centre	(604) 581-2211
Abbotsford Centre	(604) 581-2211
Centre for the Southern Interior	(250) 862-4000

For non-emergency contact numbers: Contact the research team or University of British Columbia Office of Research Services by e-mail at RSIL@ors.ubc.ca or by phone at 604-822-8598 (Toll Free: 1-877-822-8598).

1. INVITATION

You have been invited to take part in this research study because you are identified as one of the mobility project pilot users. We are interested in recruiting participants who are currently practising as a radiation oncologist, medical oncologist, oncology resident, or oncology general practitioner in one of the British Columbia Cancer Agency (BCCA) centres.

This research is an evaluation of the Information Management/Information Technology Services (IMITS) Mobility Project, focusing on the effect of the iPad on clinicians' workflow in an ambulatory setting. It will facilitate an understanding of the clinicians' expectations and the possible effects of mobile computing on clinicians' workflow and patient care.

2. YOUR PARTICIPATION IS VOLUNTARY

You have the right to refuse to participate in this study. If you decide to participate, you may still choose to withdraw from the study at any time without any consequences to the medical care, education, or other services to which you are entitled or are presently receiving.

Before you decide, it is important for you to understand what the research will involve. This consent form provides details about the study including why the research is being done, what your part would entail, and the possible benefits, risks, and discomforts. Nevertheless, the researchers have a duty of care for all participants and will inform you of any information that may affect your willingness to remain in the study. If you wish to participate in this study, you will be asked to sign this form. Please take the time to read the following information carefully before making your decision.

3. WHO IS CONDUCTING THE STUDY

This study is conducted by Shadi Bani Melhem toward the partial fulfilment of the Master of Health Information Science degree at the University of Victoria (UVic) under the academic supervision of Dr. Omid Shabestari of UVic and Professor Jeff Barnett of BCCA. This study is not funded by any external agencies or sponsors.

4. BACKGROUND

The demand for mobile solutions that align with current electronic health record systems across BC health authorities continues to grow exponentially. Clinicians at different Provincial Health Services Authority (PHSA) organizations are moving forward by procuring iPads and using them to access clinical information systems to support their clinical workflow activities. This, however, creates a non-standard approach to the procurement and implementation of mobile solutions and poses potential security risks. Consequently, the IMITS Centre for Innovation, Validation and Coordination (CIViC) is undertaking this project in collaboration with the Health Shared Services of British Columbia (HSSBC), BCCA, Children & Women's Hospital (C&W), IBM, Apple, and UVic to evaluate the use of iPads to support clinical workflow.

5. WHAT IS THE PURPOSE OF THIS STUDY

The study will evaluate the effectiveness of using the iPad VitalHub Chart application to support clinicians' workflow within BCCA ambulatory care settings. The VitalHub application will allow BCCA clinicians to access patients' clinical data stored in the Cancer Agency Information System (CAIS) at any time and any location within BCCA facilities. Specifically, the study will evaluate the ability of the VitalHub application to meet BCCA clinicians' information and communication needs while maintaining the quality and safety of patient care.

The proposed study will answer the following questions:

- How will physician practice change in ambulatory care settings within the BC Cancer Agency upon the implementation of the iPad and VitalHub application?
- How do the iPad and the VitalHub application affect physicians' workflow in BC Cancer Agency ambulatory care settings?
- How do physicians perceive the effect of the iPad and VitalHub application on providing patient care within BC Cancer Agency ambulatory care settings?

6. WHO CAN PARTICIPATE IN THIS STUDY

You may be able to participate in this study if you:

- Are currently working at the BCCA as a Medical Oncologist, Radiation Oncologist, Oncology Resident, or Oncology General Practitioner (OGP).
- Can read, write, and speak in English.
- Are able to give informed consent.
- Are participating in the iPad pilot project.
- Are currently working in one of the BCCA centres.

7. WHAT DOES THE STUDY INVOLVE?

Overview of the Study

This is a multi-method evaluation study that involves completing survey questionnaires, direct observations, and interviews. You have the right to participate in all or parts of the study phases and activities.

In the pre-implementation period (before the iPad deployment), direct observation will be used to capture the time needed to access patient data using the current available resources (desktop computer, paper charts, etc.) and the common challenges that clinicians face at BCCA while accessing patient clinical data.

The baseline observation will take place in BCCA ambulatory clinics. Before the start of any observation activity, the observer will explain the nature of the activities to be observed and the type of data collected. You will be identified using an alphanumerical code. The codes will be kept in a locked cabinet, separate from the observation data. You will be observed for one clinic day before the implementation of the iPad in order to record the time required to access patient data using the current resources available (e.g. desktop computers). For the protection of patient confidentiality and privacy, the observer will not observe the computer screens. You will be required to report any challenges you face while accessing patient data to the observer. In addition, the observer will record the turnaround time between patient visits so that it can be compared to the post-implementation observation data when the iPad is implemented. The data will be collected using paper-based Excel spreadsheets. After the observation session, the observer will enter the data into a PHSA/BCCA password-protected computer file and the paper-based spreadsheets will be kept in a locked cabinet within PHSA/BCCA facilities. You will not be identified in any published reports, as only aggregate results will be reported.

In addition, a pre-implementation (baseline) survey questionnaire will be used to capture BCCA clinicians' expectations about the potential effect of the iPad and VitalHub Chart application on their workflow and their relationship with BCCA patients and other healthcare providers, and to determine BCCA clinicians' level of prior experience using mobile technologies. The pre-implementation data collection will occur in the two-week period before the start of the iPad pilot project.

Two weeks after the start of the pilot project (after the iPad deployment), you will be observed for one clinic day to capture the time needed to access patient information. The observer will also capture the turnaround time between patient visits and any reported challenges related to the use of the iPad and VitalHub application. Similar to the baseline observation, the observer will explain the nature of the activities to be observed and the type of data collected. The post-implementation observation will take place in BCCA ambulatory clinics. You will be identified using an alphanumerical code and the codes will be kept in a locked cabinet, separate from the observation data. For the protection of patient confidentiality and privacy, the observer will not observe the iPad screen. You will be required to report to the observer any challenges you encounter while accessing patient data. The data will be collected using paper-based Excel spreadsheets. After the observation session, the observer will enter the data into a PHSA/BCCA password-protected computer file and the paper-based spreadsheets will be kept in a locked cabinet within PHSA/BCCA facilities.

During the pilot project period, semi-structured interviews will be used to ask open-ended and close-ended questions about the various effects of the iPad and VitalHub application on clinicians' workflow. The interview questions will address topics including clinicians' information needs, communication with patients and other healthcare providers, job satisfaction, and patient care quality and safety. Participants will be asked about the perceived benefits and challenges associated with use of the iPad and VitalHub application in the BCCA ambulatory care settings.

At the end of the pilot project, a post-implementation survey will be used to capture information about the overall effect of the iPad and VitalHub application on clinicians' workflow. The post implementation survey will include questions about the VitalHub application such as the information quality, system quality, service quality, usage patterns, and user satisfaction.

8. WHAT ARE MY RESPONSIBILITIES?

Surveys: Complete online survey within the timeframe provided.

Observations: Agree to be observed in the pre- and post-iPad implementation stages by the researcher/co-investigator. You will be required to report to the observer any challenges that you encounter while accessing patients' data during the baseline and post implementation observations.

Interview: The researcher/co-investigator will contact you to schedule a 30-minute appointment for the interview. You will be allowed to stop or re-schedule the interview at any time.

9. WHAT ARE THE POSSIBLE HARMS AND DISCOMFORTS?

There are no known harms or discomforts related to participating in this study, however there is a low probability that a participant might experience emotional or psychological harm. Participants do have the right to withdraw from the study or reschedule at any time if they feel embarrassed, uncomfortable, anxious, or upset during the observation or interview period. Furthermore, there is a minimum level of confidentiality risk related to the study.

The research team will use alphanumerical codes to identify the participants. Only the research team will have access to the alphanumerical codes, which will be kept in a locked filing cabinet, separate from the study data. The study results will be reported in an aggregated format without any identifying information.

10. WHAT ARE THE POTENTIAL BENEFITS FOR PARTICIPATING?

You may or may not receive any direct benefits from participating in this study; this study, however, will allow BCCA clinicians to express their opinions, expectations, benefits, and challenges related to the use of the VitalHub application. At the same time, these results will allow BCCA management to address clinicians' mobility needs while maintaining the security and quality of patient care. In addition, these results could help the system development, implementation, operations, and support teams to understand end-user needs and be able to better align the VitalHub application to meet those needs.

The study results will constitute another contribution to the literature available related to mobile computing technologies and applications in healthcare settings. The research findings will help establish the field of mobile health as a sub-discipline of health information science.

11. WHAT IF NEW INFORMATION BECOMES AVAILABLE THAT MAY AFFECT MY DECISION TO PARTICIPATE?

Participants will be advised of any new information that becomes available that may affect their willingness to remain in this study.

12. WHAT HAPPENS IF I DECIDE TO WITHDRAW MY CONSENT TO PARTICIPATE?

Participants may withdraw from this study at any time without providing any explanation.

13. CAN I BE ASKED TO LEAVE THE STUDY?

The study may be stopped if knowledge of any unexpected risks that affect participant safety and/or confidentiality becomes known.

14. WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?

Your confidentiality will be respected. However, research records and health or other source records identifying you may be inspected in the presence of the investigator or his or her designate by representatives of the BCCA Research Ethics Board for the purpose of monitoring the research. No information or records that disclose your identity will be published without your consent, nor will any information or records that disclose your identity be removed or released without your consent unless required by law.

As a participant in this study, you will be assigned a unique study number. Only this number will be used on any research-related information collected about you during the course of this study, so that your identity (i.e. your name or any other information that could identify you) as a participant in this study will be kept confidential. Information that contains your identity will remain only with the principal investigator and/or co-investigator. The list that matches your name to the unique study number that is used on your research-related information will not be removed or released without your consent unless required by law.

Your rights to privacy are legally protected by federal and provincial laws that require safeguards to ensure that your privacy is respected. This gives you the right of access to the information about you that has been provided to the sponsor and, if as well as, an opportunity to correct any errors in this information, if necessary. Further details about these laws are available upon request.

15. AFTER THE STUDY IS FINISHED

There are no restrictions that have been placed on publishing the study results. Participants will be able to access the study findings and report. The dissemination of the study results will be explained to the study participants in the process of obtaining their consent. The research team intends to publish the results in aggregated format. This study will also be a research thesis project for the co-investigator and the results will be discussed in an oral examination for this purpose.

16. WHAT HAPPENS IF SOMETHING GOES WRONG?

Signing this consent form in no way limits your legal rights against the investigators, or anyone else. Furthermore, you do not release the study team or participating institutions from their legal and professional responsibilities.

17. WHAT WILL THE STUDY COST ME?

There is neither cost associated with the study nor financial compensation paid for participating in this study.

18. WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY DURING MY PARTICIPATION?

If you have any questions or desire further information about this study before or during participation, or if you experience any adverse effects, you can contact *Shadi Bani Melhem* at 778 968 6685 *or* email *Shadi.melhem@phsa.ca.*

19. WHO DO I CONTACT IF I HAVE QUESTIONS OR CONCERNS ABOUT MY RIGHTS AS A PARTICIPANT?

If you have any concerns or complaints about your rights as a research subject and/or your experiences while participating in this study, please contact the Research Subject Information Line at the University of British Columbia Office of Research Services by e-mail at RSIL@ors.ubc.ca or by phone at 604-822-8598 (Toll Free: 1-877-822-8598).

An Evaluation of the Mobile Computing effect on the Workflow of Oncologists in Ambulatory Care Settings

20. SUBJECT CONSENT TO PARTICIPATE

My signature on this consent form means:

- I have read and understood the subject information and consent form.
- I have had sufficient time to consider the information provided and to ask for advice if necessary.
- I have had the opportunity to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the results will only be used for scientific objectives.
- I understand that my participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without any negative consequences.
- I understand that I am not waiving any of my legal rights as a result of signing this

consent form.

- I understand that there is no guarantee that this study will provide any benefits to me.

21. SIGNATURES

I will receive a signed copy of this consent form for my own records.

I consent to participate in this study.

Participant's signature	Printed name	Date

Signature of person obtaining consent	Printed name	Study role	Date

Appendix D: Ethics Approval

Approval from the following committees has been granted for the study:

•UBC BCCA Research Ethics Board approved the research on July 30, 2012 and assigned a protocol number H12-01964.

•Human Research Ethics, University of Victoria approved the research on August 27, 2012 and assigned Protocol Number 12-431.a

12-08-01 8:46 PM

BC Cancer Agency
CARE & RESEARCH

University of British Columbia - British Columbia Cancer Agency
Research Ethics Board (UBC BCCA REB)

UBC BCCA Research Ethics Board
Fairmont Medical Building
750 West Broadway, Suite 902
Vancouver, BC V5Z 1H5
Tel: (604) 877-6284 Fax: (604) 708-2132
E-mail: reb@bccancer.bc.ca
Website: http://www.bccancer.bc.ca > Research Ethics
RISe: http://rise.ubc.ca

Certificate of Expedited Approval

PRINCIPAL INVESTIGATOR:	INSTITUTION / DEPARTMENT:	REB NUMBER:
Jeff Barnett	Administration (BCCA)	H12-01964

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
BC Cancer Agency	Vancouver BCCA
BC Cancer Agency	Communities Oncology Network BCCA
BC Cancer Agency	Abbotsford Centre BCCA
BC Cancer Agency	Fraser Valley BCCA

Other locations where the research will be conducted:
N/A

PRINCIPAL INVESTIGATOR FOR EACH ADDITIONAL PARTICIPATING BCCA CENTRE:

Vancouver:	Jeff Barnett	**Vancouver Island:**	N/A
Fraser Valley:	Jeff Barnett	**Southern Interior:**	Jeff Barnett
Abbotsford Centre:	Jeff Barnett	**Centre for the North:**	N/A

SPONSORING AGENCIES AND COORDINATING GROUPS:
N/A

PROJECT TITLE:
An Evaluation of the Mobile Computing Impact on the Workflow of Oncologists in Ambulatory Care Settings

The UBC BCCA Research Ethics Board Chair, Vice-Chair or second Vice-Chair, has reviewed the above described research project, including associated documentation noted below, and finds the research project acceptable on ethical grounds for research involving human subjects and hereby grants approval.

This approval applies to research ethics issues only. The approval does not obligate an institution or any of its departments to proceed with activation of the study. The Principal Investigator for the study is responsible for identifying and ensuring that resource impacts from this study on any institution are properly negotiated, and that other institutional policies are followed. The REB assumes that investigators and the coordinating office of all trials continuously review new information for findings that indicate a change should be made to the protocol, consent documents or conduct of the trial and that such changes will be brought to the attention of the REB in a timely manner.

EXPIRY DATE OF THIS APPROVAL: July 30, 2013

DATE DOCUMENT(S) APPROVED: July 30, 2012

LIST OF DOCUMENTS APPROVED:

https://rise.ubc.ca/rise/Doc/0/COLJJMVC23G4L40N6H4P4T3NCF/fromString.html Page 1 of 2

Appendix E: Studies Included in the Literature Review

(Author, year) design & methods, Participants & settings, Summary
Andersen et al (2009) **Settings:** 2 wards at a major teaching hospital in Sydney, Australia. **Design:** Mixed method study (observations, interview, heuristic evaluation), **Participants:** 27 nurses & 8 doctors Participants used variety of computer hardware (COW, Tablet, PC) to access a computerized provider order entry system (Cerner Power Chart). 2 observers observed all participants for a total of 80 hours using a checklist form & field notes over a three-week period.10 nurses & 2 doctors participated in brief interviews during the last week of data collection. Physical attribute assessments & heuristic evaluation was performed to identify factors that may impact on device selection with an emphasis on user-interface design issues. **Results:** **Nurses** indicated that they preferred the generic COW due to its availability, mobility, and design. Nurses' clinical tasks were completed in the patients' rooms and in the corridor. However, space limitations were an issue for COW use in the patient room. Lack of docking stations were a limitation for the Tablet compared to the COW that allowed more space for medications and other needed items for patient care. **Doctors:** used both COW and tablets but preferred the COW because of the trolley, with table and storage space, and the larger screen size which easily allowed more than one person to view the screen. The majority of doctors used the device in the corridors, with one-third occurring in the patients' rooms, and only a small proportion at the bedside. Mainly doctors on rounds used both COWs and Tablets. Usability problems (small screen size) of the tablet and lack of training was identified as main reasons for underutilization of the tablets. **Study limitations**: only 2 wards with convenience sample were selected for the study (cannot be sure of the representativeness generalizability to other settings. The study was conducted in hybrid environment (the acceptance of the COW was related to its trolley that supported carrying the paper chart and other items). **Conclusion:** The choice of device was related to clinical role, nature of the clinical task, degree of mobility required, including where task completion occurs, and device design.
Balen & Jewesson (2004) **Settings:** 1500-bed, acute-adult-tertiary care Canadian teaching hospital in Vancouver, British Columbia. **Design:** an 84-question written survey was distributed by mail **Participant**s: 106 practicing hospital pharmacists The study was conducted to gain a better understanding of pharmacists' computer skills and needs immediately before the implementation of an applied informatics program. Only 28% of pharmacists were using PDAs on a daily basis, most respondents were happy with their computers kills but recognized the importance of upgrading their computer search skills. **Limitations:** self reported skills & needs (does not provide in-depth understanding of how the handheld device has been used). Small non-randomized local sample of hospital pharmacists from two sites of a single health-care organization. Validated survey was available according to the Author at the time of the study.
Fischer et al. 2003 **Design:** Systematic review The authors reviewed relevant articles regarding the use of handheld devices in medicine and the current literature was summarized. The authors concluded that only a small number of articles have evaluated the use of PDAs in medicine. It showed that handheld computers were being used widely in medicine, and various medical applications were discussed. Most publications consisted of reports of clinical experience with the use

of PDAs or innovative uses without significant substantiating data. More uses of PDAs and further evaluation of PDA applications are encouraged.
Baumgart (2005) **Design:** Literature review Review of PDA use in health care, the operating systems, basic functionality, security and safety, limitations, and future implications of PDAs introduction to medical PDA applications, software, guidelines, and programs for health-care professionals. The author is a physician and describes how his PDA is an indispensible tool for his personal and professional life.
Berner et al (2006) **Settings:** USA, primary care **Objective:** Evaluate the effectiveness of a personal digital assistant (PDA)-based clinical decision support system (CDSS) on non-steroidal anti-inflammatory drug (NSAID) prescribing safety in the outpatient setting intervention **Design:** Randomized controlled study using pre-intervention and post-intervention assessments of safe and unsafe prescribing. Unannounced standardized patients (SPs) trained to portray musculoskeletal symptoms presented to study physicians. Safety outcomes were assessed from the prescriptions given to the SPs. A committee of clinicians blinded to participant, intervention group assignment, and baseline or follow-up status reviewed each prescription. **Participants:** 68 internal medicine residents **Results:** Unsafe prescribing in intervention group reduced from 27% to 23%; control group increased from 29% to 45% ($p < 0.05$). With the CDSS, intervention participants documented more complete assessment of patient gastrointestinal risk from NSAIDs. Participants provided with a PDA-based CDSS for NSAID prescribing made fewer unsafe treatment decisions than participants without the CDSS. **Limitations:** study was conducted in a single clinic with participants within the same specialty and a small number of cases may limit generalizability. Also, lack of reliable data on how the participants actually used the CDSS during the SP visits is another limitation as well.
Chen et al (2004) With the goal of improving patient safety, The authors describe the design, development, and evaluation of PalmCIS: an application that provides access to needed patient information via a wireless personal digital assistant (PDA). **Setting: USA-New York Presbyterian Hospital (NYPH)** **Design:** Survey and Log analysis **Participants:** not reported. **Results:** user evaluation survey showed that the application had speed issues (cumbersome sign on function, connection speed) that limited its use. The author believed could be mitigated with the use of more advanced PDA technology. **Conclusion:** Security and usability features of mobile EHR system are important factors for success. **Limitations**: limited information on participants, how the technology was used, and how it impacted work processes.
Dala-Ali et al (2011) **Journal article** Describe and review the available iPhone resources and apps for surgeons: OsiriX, Pubsearch, Epocrates, I-surgery notebook, Surgical textbooks. Also, the authors called for integration with HER, and the potential benefits of using smartphone applications in surgery practice.

Dasari et al (2011) **Participants and settings:** 918 anaesthetists in England responded to a national online survey Questionnaire **Design**: online survey Questionnaire: **Results:** 59% of British anaesthetists owned an iPhone. Of those who owned an iPhone, 60% actively used medical apps for clinical activities, and 47% for educational purpose. Medical Calculators were the most used apps. The author called for more development of mobile apps by anaesthetists and regulatory bodies to exploit the full potential of this new technology. **Limitations:** the number of respondents represent only 8% of the anaesthetist in the UK (low response rate)
Davies et al (2012) **Objective:** Study about the role of mobile technology in supporting undergraduate medical students. **Settings:** UK, Brighton and Sussex Medical School, **Participants**: 387 medical students were provided with a personal digital assistant (PDA) loaded with medical resources for the duration of their clinical studies. **Designs:** Mixed-methods surveys, focus groups and usage tracking data. **Results:** The PDA was an important addition to the learning ecology rather than a replacement. The authors developed a model for mobile learning in the clinical setting. Contextual factors impacted on use both positively and negatively. Barriers included concerns of interrupting the clinical interaction and of negative responses from teachers and patients. Students preferred a future involving smartphone platforms.
Edson et al (2010) **Objective:** Internal medicine residents from multiple hospitals were surveyed about their reading habits and preferences **Survey:** web-based survey that was developed based on literature review & iterative discussion. **Setting & participants**: 189 internal medicine residents at five United States training programs. **Results:** The overall response rate was 45.8% (189/413 eligible Residents). The majority of residents reported reading less than 7 h a week, preferred the electronic format, and read in response to patient care encounters. UpToDate was cited as the most useful resource, which can be accessed at the point of care using mobile devices.
Embi, 2001 **Descriptive Journal article** **Objective**: The author reviewed the use of handheld computers in medicine, emphasizing how they might help the practicing physician. **Key Notes:** Handheld computers can be used to access reference information, make medical calculations, improve coding and billing, and track patient data, all at the point of care. Handheld computers currently have various limitations, including small screen size, slow data entry, limited memory, and few security features for protecting sensitive data.
Engum, 2003 **Design:** Randomized controlled study **Participants:** randomly selected 25 third-year medical students who were surveyed at the end of the study. **Settings:** USA, Indiana University School of Medicine – affiliated hospitals. **Results:** Students logged their skill encounters for 9 months and then electronically transferred the database by e-mail. Student information was analyzed to identify gaps in medical student basic clinical skills, which indicated significant gaps in basic clinical skills. **Conclusion:** medical students in this pilot study viewed the hand-held devices as useful tool to track their educational needs and offered time savings in construction, electronic transfer, and educator evaluation of the student's procedure/skill database as well as the curricular exposure and offers the ability to provide clerkship directors and faculty feedback on skills education and opportunities. The PDA also provides many other

healthcare related tools to help make the physician or physician-in-training more efficient and potentially safer. **Limitations:** limited number of participants**.** Did not investigate the security of the electronic device in case it was stolen or lost and whether patient information was recorded or not.
Fisher & Koren (2007) **Objective:** The authors explored nursing students' perceptions in relation to the use of PDA loaded with clinical reference software **Participants & settings:** USA, 28 nursing students from different clinical setting (pediatrics, maternity, medical/surgical, & psychiatric) had assigned access for PDAs with licensed medical resources during their 7-week clinical practicums. **Design and methods:** A descriptive and exploratory qualitative design was employed (4 focus groups). Students **Results**: Most participants found the PDA to be useful in the clinical setting. Perceived benefits: enhanced clinical decision-making, developing critical thinking, professional image, communication and quality of care. The author called for future studies to examine learning outcomes with the use of PDA's in a nursing curriculum, examine what it brings into daily patient care related to time management, and how this tool is effective at the point of care to provide safety to patients in the clinical area. **Limitations:** not generalizable to other populations having utilized a purposive convenient sampling.
Franko (2011) **Participants & settings:** USA-based orthopaedic surgeons, fellows, and residents. **Design:** 1. The five most popular smartphone app stores were searched for orthopedic-related apps: Blackberry, iPhone, Android, Palm, and Windows. 2. An Internet survey was sent to ACGME-accredited orthopedic surgery departments to assess the level of smartphone use, app use, and desire for orthopedic-related apps. **Results:** The database search revealed that iPhone and Android platforms had apps specifically created for orthopedic surgery with a total of 61 and 13 apps, respectively. However, only one had greater than 100 reviews (mean, 27), and the majority of apps had very few reviews. The national survey revealed that The use of smartphone apps is prevalent among the orthopedic residents, fellows, and attending surgeons surveyed (84%, n= 476), and most with smartphones use apps in their medical practice. However, few highly ranked apps are available for orthopaedic caregivers, despite a strong need and desire. The four most requested categories of apps were textbook/reference, techniques/guides, OITE/board review, and billing/coding.
Garritty, & EI Emmam (2006) **Systematic review of PDA published surveys** **Objective**: To estimate current and future PDA use among health care providers and to discuss possible implications of that use on choice of technology in clinical practice and research. **Methods:** eight databases (Medline, Current Contents, Inspec, BA/RRM, Biotechnology, Biological Abstracts, EI Compendex, and EMBASE) were screened against distinct eligibility criteria for PDA survey studies between 1993 and 2006. Inclusion criteria: surveys related to an application in human health care and involved the use of a PDA device; contained original data; written in English (not including abstract or conference proceedings); published after 1993; and specifically reported handheld usage rates (prevalence of PDA use as a metric) in populations of health care professionals who were surveyed about the extent of their PDA use. **Results** 1. 23 relevant surveys were identified, 15 of which were derived from peer-reviewed journals 2. There was clear evidence of an increasing trend in PDA use that ranges between 45% and 85% (high but variable), primarily among physicians. Early adopters include young physicians and residents, and those working in large and hospital-based practices. 3. The fast development of mobile technology and applications pose a challenge for evaluating systems

before they are released.

4. Professional PDA use in health care settings involves more administrative and organizational tasks than clinical tasks. However, there is an urgent need to evaluate the effectiveness and efficiency of specific tasks using handheld technology to inform those developing and those using PDA applications.

Limitations: the quality of the included surveys could not be determined given the absence of validated quality assessment instruments, and, therefore, there was no adequate way to assess the influence of bias. A related issue is that some of the included surveys did not go through a rigorous peer-review process. Because of the heterogeneous Methodologies used in the included surveys it cannot be compared easily.

Hammond & Sweeney (2000)
Participants & settings: UK, District General hospital (9 Senior House Officers & 13 Specialist Registrars)
Methods: Database analysis
This paper describes a pilot project to use PDA-based logbook in general district hospital in the united Kingdome. The author described their experience and the benefits for trainee learning experience and how it enabled them to carefully analyze individual workload of each trainee in the department.
Limitations: in addition to being small-scale pilot project, it did not describe the view of the end-users themselves to using the handheld device.

Hauser et al (2007)
Objective:

1. To evaluate the effectiveness of wireless handheld computers for online information retrieval in clinical settings.
2. The role of MEDLINE in answering clinical questions raised at the point of care.

Participants and settings: five internal medicine residents accompanying teaching rounds in hospitals associated with the University Of Hawaii's John A. Burns School of Medicine

Design: (Single-Cohort study) while accompanying medical teams on teaching rounds for about four consecutive weeks, five internal medicine residents used and evaluated MD on Tap, an application for handheld computers, to seek answers in real time to clinical questions arising at the point of care. An intermediate server stored all transactions. Evaluators recorded clinical scenarios and questions, identified MEDLINE citations that answered the questions, and submitted daily and summative reports of their experience. A senior medical librarian corroborated the relevance of the selected citation to each scenario and question. All transactions stored in the applications Databases were analyzed and combined with the evaluator reports, statistical analysis, were used to test for significant differences.

Results
Clinicians were able to answer 68% of the clinical questions during clinical rounds. Handheld computers with Internet access are useful tools for healthcare providers to answer specific clinical questions when several medical terms are used to form a query. The MD on Tap application is an effective interface to MEDLINE in clinical settings, allowing clinicians to quickly find relevant citations. Feedback from the study participants indicate that wide adoption of handheld technology for online information retrieval depend on the affordability of a fast wireless Internet connection at the point of care as well as the ergonomics of the used applications and devices to facilitate data entry. Also, contextual and environmental factors are important (e.g. not practical in fast paced environments with lots of distractions such as the ICU).

Limitations: The small number of evaluators limits the power of the study. The teaching rounds were artificial situations to create as many questions as possible.

Househ et al (2012)

Literature review
The authors discussed the opportunities within mHealh field (chronic disease management, patient education, healthcare providers education) and challenges of mobile technology (human rather than technical limitations).

Usability issues, lack of integration with electronic health records, limited evaluation studies. The authors believed that harnessing the full benefits of mobile computing technologies & apps depend on integrating the current standalone apps with more complex HIS.
Hsu et al (2005) **Objective:** evaluate the impact of introducing health information technology (HIT) on physician-patient interactions during outpatient visits. **Settings**: USA, Medical office building of Kaiser Permanente. **Participants:** 313 patients & 8 Primary care physicians. **Design and methods:** a longitudinal pre-post study: two months before and one and seven months after introduction of examination room computers. Pre/post Survey questionnaire were used to measure patients satisfaction. **Results:** Patients reported that physicians used computers in 82.3% of visits and that these activities appeared to have positive effects on several aspects of physician-patient interactions including overall visit satisfaction, satisfaction with the physician's level of familiarity, communication about medical decisions, and patient understanding of the medical decisions. **Limitations:** a convenience sample of physicians and patients & lack of control group. There is the potential for selection bias, e.g., early adopters or individuals more predisposed to favor computers in the examination room may be more likely to participate. Also, Small number of physicians who practiced in a single clinic limits the result generalizability. Also relied on patient perceptions and did not attempt to directly assess areas such as patient comprehension of self-care practices.
Johnston et al (2004) **Participants & settings:** 169 Year 4 undergraduate medical students at the University of Hong Kong. **Designs & methods: Survey and focus group:** All participants completed a survey about CDSS/PDA usefulness, satisfaction, functionality and utilization after a randomized controlled study. Focus groups were conducted to derive complementary qualitative data about students' experience and attitudes. **Results:** Overall, the students found the CDSS/PDA useful. However, They were less satisfied with the functional features of the CDSS and the PDA. Therefore, Utilization was low, with the average frequency of use less than once per week. Multivariable regression showed that higher perceived CDSS/PDA usefulness was associated with more supportive faculty attitudes, greater knowledge of evidence based medicine, better computer literacy skills and increased use in a clinical setting. Greater satisfaction with the CDSS/PDA was associated with increased use in a clinical setting and higher successful search rates. Qualitative results were consistent with these quantitative findings. **Limitations**: while participants were consented, there is no clear indication if participation was voluntary especially with 100% response rate for the survey.
Kho (2006) **Objective:** To describe medical trainees' use of PDAs for education or patient care, identify popular software applications, and evaluate the impact of PDA use on patient care. **Systematic review:** the authors searched OVID MEDLINE (1993 to September 2004). Reports presenting a qualitative or quantitative evaluation were included. **Results:** Based on the published literature, Approximately 60% to 70% of medical students and residents use PDAs for educational purposes or patient care. Satisfaction was generally high and correlated with the level of handheld computer experience. However, certain barriers still exist, such as lack of technical experience, a preference for

pen and paper, difficulty handling the small device, and concerns about data loss and security. Studies described PDA use for patient tracking and documentation. Medical textbooks, medication references, and medical calculators are the most useful applications. Only 1 randomized trial with educational outcomes was found, demonstrating improved learning and application of evidence-based medicine with use of PDA-based decision support software. No articles reported the impact of PDA use on patient outcomes. Most medical trainees find handhelds useful in their medical education and patient care. Further studies are needed to evaluate how PDAs impact learning and clinical outcomes. **Conclusion:** The authors found that most of the studies are descriptive and identified the most important areas that need further research in terms of handheld technology impact on educational processes, educational outcomes, patient care processes, and patient outcomes. **Limitations:** the review was limited to the medical literature and did not include human factors or computer engineering research, the quality of the included studies limits the ability to draw firm conclusion.
Koeniger-Donohue (2008) **Objective**: to learn how to use a PDA as a personal organizer and to determine the value of PDAs as an alternative to traditional model of textbook use for NP students and clinical faculty **Participants and Settings:** 6 graduate Nurse Practitioners form USA-based Nursing School. **Design and methods:** focus groups were conducted at the end of 9-month clinical practicum. **Results**: Nurse Practitioners were able to learn how to use the PDA instead of traditional textbooks in clinical setting. Participants found that The PDAs enhanced nursing clinical education and an effective student learning resource. However, success rely on availability of ongoing support and training **Limitations:** The sample size was small, and the focus group results may be confounded because the author conducted the focus group and was also a co-participant in the project.
Krauskopf & Farrell, (2011) **Objective:** Evaluate the accuracy and efficiency of novice nurse practitioner (NPs) clinical decision using either PDA-based Griffith's Five-Minute Clinical Consult application or the traditional textbook to answer specific clinical scenarios **Participants & settings:** USA-based 40 Nurse Practitioners students & recent graduates. **Design:** Experimental with a repeated measures design, participants were assigned to either the PDA group or the textbook group. **Results:** Accuracy of the PDA-group was equal to the textbook group when making decisions regarding laboratory values, diagnosis, and treatment. In terms of efficiency, PDA users required significantly less time to determine an answer in three of six clinical decision-making areas with equivalent accuracy to the textbook group. The authors emphasized the need for developing and employing scientific methods to evaluate the quality of mobile health applications **Limitations:** limited number of participants and convenient sampling may have introduced Bias. Also, the Hawthorne effect may have impacted the results of the study. Artificial situation does not reflect how students will use the PDA and its effect in real clinical settings.
Kushniruk et al (2005) **Objective:** evaluate the relation between interface usability problems and technology-induced errors. **Participants and settings:** 10 Internal Medicine physicians working in an outpatient ambulatory clinic **Methods:** Usability engineering - The study procedure involved the collection of data consisting of transcripts of the subjects who were asked to "think aloud" while interacting with the prescription writing program to enter medications. User interactions with the device were video and audio recorded. **Results:** There were a variety of usability problems, with most related to interface design issues. Certain types of usability problems were closely associated with the occurrence of specific types of errors in prescription of

medications. Usability evaluation could be used to identify and predict technology-induced error and improving the safety of Mobile applications.
Leung et al (2003) **Objective:** To assess the educational effectiveness on learning evidence based medicine of a handheld computer clinical decision support tool compared with a pocket card containing guidelines. **Setting & participants:** 169 fourth year medical students, University of Hong Kong. **Design:** Randomized controlled trial, students were assigned randomly into 3 groups and then each group was assigned to specific clinical rotation. 3 intervention arms were created (one with handheld decision-support, one with Pocket card guidelines, and one control group). A validated questionnaire was used to measure five key self reported measures: personal application and current use of evidence based medicine; future use of evidence based medicine; use of evidence during and after clerking patients; frequency of discussing the role of evidence during teaching rounds; and self perceived confidence in clinical decision making. The questionnaire was administered at baseline and after rotations and the results were statistically analyzed using SPSS version 10. **Results:** Significant improvements were observed in the handheld group compared to modest improvement in the pocket card group and no significant change in the control group in any of the outcome measures. No significant deterioration occurred after the withdrawal of the handheld computer during the washout period, suggesting a short-term sustainability of effect. **Conclusion:** The use of PDA-based CDSS can improve learning evidence-based medicine, increase current and future use of evidence, and boost students' confidence in clinical decision making. **Limitations:** The standard questionnaire measures contained self reported behaviour and future intentions and not objective or evaluative outcome measures. Complicated crossover design and the duration of intervention was relatively brief due to the fact that medical students in their clinical years rotate through a series of teaching blocks rapidly preventing measurement over long time.
Lu et al. (2005) **Objective:** to describe mobile computing adoption among healthcare providers, benefits, and challenges **Systematic Review**: the authors searched Medline database and the published proceedings of one primary conference (Proceedings of Healthcare Information and Management Systems Society [HIMSS]) to identify related publications; In addition, the authors conducted Internet search engines (Google and Yahoo) and several electronic resources to assess the types of application available for different platforms. **Results** 95 articles were considered for review. High adoption rate among healthcare providers was reported in many studies. From clinician's perspective, most useful PDA applications: the apps that support documentation, clinical reference, and access to patient data. Challenges are related to usability, security concerns, and lack of technical and organizational support. Better designed PDA hardware and software applications, more institutional support, seamless integration of PDA technology with HIS, and enhanced security measures are necessary to increase acceptance and wide use of PDAs in healthcare. More evaluation studies are needed to explore expanding roles and clinical impacts of the technology in health care.
Martin (2003) **Objective:** describe PDA adoption among physicians in Canada. The article reports the results of the CMA's 2003 Physician Resource Questionnaire (PRQ). **Reported Results:** In 2003, one third of Canadian physicians were using personal digital assistant (PDA), a 73% increase from the level of 19% recorded in 2001.
Mosa & Sheets (2012) **Systematic Review** **Methods:** MEDLINE was searched to identify articles that discussed the design, development, evaluation, or use of smartphone-based software for healthcare professionals, medical or nursing students, or patients. A total of 55 articles discussing 83 applications were selected for review. **Results**

83 applications were identified and classified according to intended users**. Healthcare professionals:** 57 applications focusing on disease diagnosis, drug reference, medical calculators, literature search, clinical communication, Hospital Information System (HIS) client applications, medical training and general healthcare applications. **Medical or nursing students:** 11 applications focusing on medical education. **Patients:** 15 applications focusing on disease management with chronic illness**.** The majority were standalone apps and only 4 applications were Hospital Information System (HIS) client applications. Disease diagnosis, drug reference, and medical calculator applications were reported as most useful by healthcare professionals, medical & nursing students. Medical applications make smartphones useful tools in the practice of evidence-based medicine at the point of care, in addition to their use in mobile clinical communication. **Limitations:** the study identified only smartphones apps that have been reported in the literature, which excludes a vast amount of available apps in commercial app stores.
Murphy 2007 **Objective:** to evaluate the ease of use & usefulness of a convertible tablet in comparison to desktop computers. **Participants & settings**: 10 oncologists & 3 nurses, Fraser Valley BC Cancer Agency Centre (outpatient clinic)**.** **Methods:** 68 items Survey Questionnaire developed based on Davis technology acceptance model and in collaboration with participants. **Results:** Convertible tablet was not able to replace fixed desktop computers, but provided better support for other user activities including: reviewing images and lab results with the patient, providing more up-to-date information than the paper chart, accessing Intranet portals to review management guidelines, printing prescriptions, test requisitions, and patient educational material. Issues were related to lack of reliable wireless infrastructure, and cognitive overhead with technical issues. **Limitations:** small number of participants, which limit the generalizability of the study results.
Murphy et al (2009) **Objective:** to evaluate the impact centre-wide implementation of wireless tablets on clinicians' productivity in relation to time spent on chart filing & print. **Participants & settings:** 14 oncologists at the BCCA. **Methods:** the IMPROVE project collected data on chart activities before and after the implementation of the tablet. Clinicians' were asked to complete 73-item survey questionnaire that was based on the previous questionnaire study. **Results:** Improved productivity: Centre wide tablet implementation resulted in 1.14-minutes/chart reduction in printing and filing information already available through the Cancer Agency Information system. **Limitations:** No specific data bout when the tablet was used.
Payne et al (2012) **Objective:** examine smartphone acceptance and patterns of medical app usage within the Student and junior doctor populations. **Participants & setting:** UK, 257 medical students and 131 junior doctors **Methods: using an** online survey, participants were asked whether they owned a Smartphone and if they used apps on their Smartphones to support their education and practice activities. Frequency of use and type of app used was also investigated. Open response questions explored participants' views on apps that were desired or recommended and the characteristics of apps that were useful. **Results:** response rate of 15.0% and 21.8% respectively. High adoption of smartphones among medical students and junior doctors (79.0%, 74% respectively), the iPhone is the most adopted mobile device, The majority of students and doctors owned 1-5 medical apps. Both

students and junior doctors have used mobile apps several times a day for duration of 1-30 minutes. Students were more interested in disease diagnosis/management and drug reference apps, while doctors used more clinical score/calculator apps. **Conclusion:** while there is high adoption rate, there is a need to evaluate the organizational effect for using mobile technology in clinical settings, and end users perceptions of the benefits & challenges for their successful use. **Limitations:** Low response rate.
Prgomet et al (2009) **Objective:** The authors conducted a systematic review to examine evidence regarding the impact of mobile handheld technology on hospital physicians' work practices and patient care **Methods: Systematic Review**: the authors conducted the literature search using multiple search engines to overcome the problem of inadequate indexing. Of the 88 articles identified, 13 met the criteria for inclusion (only quantitative studies were included). The largest number of the included studies originated from the United States (n = 6) and the remaining (n = 7) from the UK, Australia, Canada, Denmark, Finland, Germany, and Hong Kong. The handheld devices used within the studies were all identified as PDAs. The majority were observational studies (n=11) and only 2 RCT. The majority were pilot studies (n=5) and only one of the studies stated specifically where within the study site the handheld device was used, and four concluded that the mobility of the device had an impact on the study outcomes. **Results:** The authors found personal digital assistants (PDAs) positively impact three major areas: rapid response, error prevention, and data management and accessibility. However, the authors found limited evidence to support that these benefits are due to the device mobility. Future research needs to explicitly demonstrate how the mobility of devices impact clinicians' practices and outcomes. The authors sought to include tablet computers in the review but found no studies investigating this mobile handheld technology that met the review criteria, further demonstrating the dearth of research on this topic **Limitations:** only quantitative studies were included which limited the number of studies to be included in the review. **Conclusion:** Prior to widespread adoption of mobile technologies in hospitals, implementers and adopters should address explicit questions about why and how the mobility of these devices is expected to improve care delivery. Pilot observational studies should test assumptions about how mobile technologies will be used in practice to support the work of physicians.
Rao et al (2012) **Objective:** to understand the factors, which promoted the demand for iPads by physicians in two Emergency departments (ED) prior to a system wide implementation of an electronic medical record (EMR). **Participants & settings: USA, 14 EDs Physicians** **Design & Methods:** a pre- and post-qualitative design to compare physician perceptions of the value of using an iPad for implementing an EMR in two Emergency Departments within one health system. Physicians' perceptions about iPads were gathered through a series of semi-structured interviews. The interview instrument was derived from other published articles on the implementation of EMR's utilizing handheld technologies and relevant research instruments that gathered perception and belief data. This article addressed the pre-implementation part of the study. All interviews were audio recorded and transcribed for analysis. **Results:** three major themes emerged from the analysis of the interview scripts**:** 1. Participants perceived that iPads would enhance patient-physician interactions by enhancing patient communication, improving patient education and increasing patient satisfaction. 2. They also felt iPads would improve their workflow by improving access to vital information, reducing redundancy, enabling physician mobility and helping to speed up work processes within the ED. 3. Based on their positive personal experience using iPads, physicians were able to discern structural benefits of iPads over desktops and laptops like the touch screen functionality and ability for

instinctive learning.
Reddy (2005) **Objective:** To analyze the effects that new wireless notification system tool on both healthcare professionals work practices and the information flow in the ICU unit. **Participants**: 4 Surgical residents, 2 Surgical fellows, 4 Surgical attending physicians, 3 SICU nurses, and 1 SICU pharmacist **Methods:** Semi-structured interviews and observations: interviews were used to identify physicians' perceptions of a new wireless alerts pager. Also, participants were shadowed during morning rounds over a three-month period. Grounded theory was used for the collected data. **Results:** while the introduction of a wireless pager notification system into the ICU provided physicians healthcare professionals real-time notification of critical events, it changed the flow of information in the ICU. It also disrupted the work practices within the institution. For example, notifications were sent to multiple providers who are involved in the patient care (Residents, attending, fellows) without mechanism to provide feedback of who is addressing the patient issue. Therefore, there is a need to understand end-users established practices and hierarchies when intruding new technologies.
Rothschild et al (2006) **Objective:** To assess the role of Handheld-based clinical reference software in medical practice by conducting a survey and assessing actual usage behavior. **Participants:** 1501 physicians who were using a software package (pharmacopeia, a medical diagnostic and therapeutic reference, and an infectious disease reference). **Design & methods:** users of a Handheld-based clinical reference application were asked by e-mail to complete a survey and permit analysis of their usage patterns. Software usage data were captured during handheld device synchronization for the 4 weeks prior to survey completion. **Results: 1500 users completed the survey and 1249 allowed analysis of their usage pattern.** Physicians reported using the clinical reference software for a mean of 4 years and 39% reported using the software during more than half of patient encounters. The Drug reference applications was the most frequently used app (mean=6.3 times/day) .the majority (61%) believed that the use of the clinical reference package prevented adverse drug events or medication errors three or more times during the study period. realizing the full benefits of mobile clinical reference applications depended on healthcare organizations' support to provide mobile access to patients' electronic healthcare record (EHR). Also, integrating clinical reference applications with health information systems (e.g. EHR, CPOE), and providing financial and training support
Rothschild et al (2002) **Objective:** To evaluate the clinical contribution of a drug database (ePocrates Rx) developed for the handheld computer. **Participants & methods:** A seven-day online survey of 3,000 randomly selected ePocrates Rx users was conducted. The survey measured user technology experience, product evaluation and usage patterns, and the effects of the drug reference database on information-seeking behavior, practice efficiency, decision-making, and patient care. **Results**: the survey response rate was 32 percent (n=946). The authors found that improved access to drug information through handheld technology was associated with improved practice efficiency (Clinicians needed 1 to 5 min to find drug information when using traditional search methods compared to less than 20 sec when using Rx). Benefits associated with the use of ePocrates Rx included: time saving during information retrieval, easily incorporated into clinicians' workflow, and enhanced drug-related decision-making. **Limitations**: users and respondents represented a group of early adopters who may have been biased toward

favorably reviewing newer technologies. Also, the study was limited to the respondents' retrospective perceptions of their mean times to look up information with and without the handheld drug information database.
Sintchenko et al (2005) **Objective**: to assess the impact of information accessible via a handheld device on patient management. **Participants & Settings:** 12 physicians and one resident trainee in the ICU of, an 800-bed, university-affiliated tertiary center in Sydney, Australia. **Design**: 6 month prospective study during which participants received PDAs loaded with locally developed guidelines and site-specific laboratory data. The rate of antibiotic use and outcomes of patients in ICUs during the intervention period were compared with 6 months of historical data, during which no computerized DSS was available. **Results:** On average the DSS was used four times per day during the study period, primarily to access laboratory data. A significant decrease of antibiotics used occurred. The pre-intervention consumption rate was 1,925 defined daily doses per 1,000 patient days, and decreased to 1,606 in the intervention period ($p = 0.04$). The average patient length of stay decreased significantly during DSS use [6.22 bed days compared with 7.15 bed days ($p = 0.02$)]. Registrars had higher levels of DSS use compared with consultants. **Limitations**: the study was conducted in a relatively short period of time, in a single critical care unit, and with limited number of participants. There is a potential for a Hawthorne effect, temporary increase in the quality of work due to the stimulus of being singled out and observed. Historical control group limit the accuracy of the results.
Stroud et al (2009) **Objective:** To describe the prevalence and patterns of use of personal digital assistants (PDAs) among active nurse practitioners (NPs) **Participants & settings:** USA, 126 randomly selected members of the American Academy of Nurse Practitioners **Methods:** A descriptive correlational survey. **Results:** 64% of participants used PDAs. Pharmacopeias were found to be the most useful and frequently used app. Benefits include: enhanced clinical decision-making, enhanced patient safety, and increased productivity. There is a critical need to evaluate the effectiveness of PDA use in clinical settings and develop an evidence base to guide use of the PDA in solving clinical problems. **Limitation**: the sample size (126) was not representative of the 10435 NPs at the time of the study (desired sample size is 240–370 within plus or minus 5 percentage points at the 95% confidence level).
Wallace et al (2012) **Objective:** To examine how medical teachers and learners are using mobile computing devices such as the iPhone in medical education and practice, and how they envision them being used in the future? Design: **Mixed methods (Interviews & online Survey)** **Settings:** a large Canadian medical school. **Participants:** Interviews: 18 participants (10 students, 7 residents and 1 faculty member) **Survey**: 213 participants responded to the online survey (93 medical students, 72 residents and 48 faculty members) **Results:** High Adoption among respondents (85%). mobile devices were mainly used for information management,

communication and time management. Benefits: portability, flexibility, access to multimedia and the ability to look up information quickly. Barriers: superficial learning, difficulty finding good learning resources, distraction, and privacy related concerns. While there are potential benefits, it is important to for educational program leaders & healthcare organizations to have clear strategy that enhance benefits and reduce risks to medical education and practice **Limitations:** response rates to the online survey were relatively low, about 15% for students, 10% for residents and 7% for faculty. Potential for response bias as non-users of the technology would be anticipated to be less likely to respond to a survey about mobile computing devices.
Wittmann-Price et al., 2012 **Objective:** to evaluate nursing students and staff nurses perception about allowing students to use medical smartphone apps (nursing diagnosis, pharmacology, and laboratory information; an encyclopaedia; and the MEDLINE database) during a 10-week clinical rotation. **Settings**: a medical-surgical unit **Participants**: 7 nursing Student & 5 Staff nurses **Design:** mixed-method, descriptive pilot study. **Students**: Usage log analysis and Focus group. **Unit Staff Nurses**: Survey. Both the focus group transcript and staff surveys were evaluated and the themes summarized by content analysis. **Results:** Smartphones apps were perceived as powerful information resources that enhanced students' confidence and their clinical decision-making. The medical-surgical unit staff believed that students should be allowed to use their smartphones for clinical purposes. They saw that its usage made students more prepared and confident when providing patient care However, other factors need to be considered before incorporating smartphones use in nursing education such as the student financial situation and computer skills. And the impact on nurse-patient relationship. .