Information and communication technology-based innovations for aging healthcare: a literature review

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Abstract: The paper presents a systematic literature review to identify the key application areas of innovations through the use of information and communication technologies (ICT) in providing healthcare information to elderly population. Out of the 210 articles published in various health informatics and information systems journals, 42 were identified to meet the requirements for inclusion in the particular review. Based on our analysis, ICT innovations offered for elderly population's healthcare are classified as: smart home-based; mobile-based; online-based; and personalised device and application-based innovations. However, most of the innovations focus only on user side demands and omit the service providers' dynamic demands for information delivery. A cloud computing-based innovation shows promise to develop an effective information delivery approach to provide benefits, both for service providers and the elderly population, needing to deliver and use relevant technologies.

Keywords: aging population; ICT solutions; cloud computing, healthcare informatics.

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1 Introduction

Information and communication technologies (ICT) generally offer connectivity and functions that take all data available to process into meaningful information. A good application of ICT should provide service tools specially in addressing the needs of communities. For aging community groups, previous studies have identified the importance of improving ICT services as a way of enhancing their daily living. In healthcare research, ICT has become an established way for aging community in the development of infrastructure, lifelines, communications and improvement of the richness of daily life. However, a limited number of studies identified the innovations of various ICT approaches that are applied to provide healthcare services to the particular community by addressing potential issues. The aim of the literature review is to identify key innovations of ICT applications and associated issues to deliver the healthcare information services for the elderly populations, in order to explore and develop an innovative information delivery approach.

A purely adoptive approach of implementing ICT-based applications for information service delivery towards 'active aging'[1] view is of paramount importance for the particular welfare of the elderly populations. The adoptive approach is not only for the end-user communities but also for the service providers. This need has received increased and holistic attention throughout national and local government initiatives. It has also become an emergent research topic in almost all developed and developing countries. A range of perspectives have been introduced to improve support services such as through e-health in elderly primary care (Flynn et al., 2009), through decision support systems for pressure ulcers (Fossuma et al., 2011) and through mobile-based applications for keeping elderly population more connected and improving awareness of their health issues. Researchers, policy makers, and funding bodies have attracted the attention of governments as the healthcare spending has rapidly escalated (Gaikwad and Warren, 2009). For instance, the growing burden of chronic diseases and overall increased awareness to improving quality of care (WHO, 2002) has increased demand in the context of reduced support of elderly healthcare and flawed funding models as well as public outcry about inadequate services for the elderly. The provision for delivering healthcare information increasingly looks toward the better use of ICT and possible cost effective ways to improve practices especially for handling long-term care challenges in an elderly society and to enable improved self-management though information sharing (Choi, 2011; Kluzer et al., 2010; Heart and Kalderon, 2013).

To remain independent and actively involved in exploring healthcare information, elderly populations have shown a growing interests in using different ICT applications, as evidenced in a number of studies in the field of health informatics (Capel et al., 2007; Piper and Hollan, 2013; Pulman, 2010). The elderly population (e.g., Capel et al., 2007 identified a elderly group who are less vulnerable and more active as taking a self-help view about their health) presumably perceive themselves as being healthier and happier when they become part of a strong social network (Pulman, 2010; Manthorpe et al., 2004; Wenger, 2001) and empowered through involvement in technology design (Capel et al., 2007) specially for exploring their own support needs. Therefore, in many instances elderly populations became the only target users of healthcare resources commercially,

due to improved options in intelligent devices, internet availability and rapid uptake of emergent technologies. At the same time, the requirement for increased attention, care and monitoring needs of the elderly population group have spearheaded advances in technology uptake among healthcare providers (Capel et al., 2007; Gaikwad and Warren, 2009).

Previous studies have been established on various ICT innovations that provide a range of support services including information services to elderly community. Online-based services are one of the common ways of service innovations in that elderly populations have been offered healthcare information services and assistance for their independent living. Healthcare information providers (such as private and public healthcare institutes that works for community or public healthcare awareness) still suffer in choosing use of technologies for meeting the information needs of the population. Various ICT provisions became common as consistent systems of supporting the emerging information transferring (Thraen et al., 2012); web-based social networking (Pulman, 2010); personalised healthcare advice (Al-Busaidi et al., 2006) and security and monitoring (Hoof et al., 2011) along with other technology embedded solutions. However, most previous studies focus on the impact of ICT-based solutions only from end-user demands perspective highlighting the benefits and positive impacts on meeting particular demand such as for knowledge sharing (Pulman, 2010). In relation to the adoptive approach, fewer studies have been published on the benefits and impacts of new technology that can fulfil requirements from the perspective of healthcare service-providers to deliver the healthcare information for public use. One contemporary example is the application of adoptive technologies including – cloud computing, that is designed to enhance information management and delivery. Fitzgerald and Dennis (2010) described cloud-based design as a 'circuit-switched service architecture' that is easier to implement for organisations because they reduce the burden of managing the computing resources. This implies that end users can have service through the cloud without any technological burden. This type of ICT-based innovations provides a cost-effective and context-specific solution with reduced implementation burden (\ 2008). At the same time, cloud technologies ensure ready user demand oriented features to meet the needs of both end-user and information providers.

This paper presents a systematic literature review to identify issues in the key area of innovations of ICT used in healthcare services for elderly populations. To address the issues the study aims to propose a new information delivery approach that would support self-care and help elderly population for their independent living. The study used an inductive approach to capture about the existing innovations and issues that are identified through various ICT solutions development in improving the healthcare specially for delivering healthcare information.

The paper is organised as follows: First, we explore the problem context of elderly populations and broadly how ICT technology can assist in healthcare service provisions. Second, is described the research method adopted for this study. Then in subsequent section we present our analysis of the literature and emergent challenges, followed by omissions and opportunities. Finally, we conclude with the rationale and scope for further study in this important area.

2 Problem area

Health organisations have increasingly invested resources toward improving new technologies for healthcare service delivery. In some cases, organisations aim at developing ways to deliver timely and accurate health information to their target customer. Organisations also intend to provide effective access to most updated materials. In the particular area of information service delivery, previous studies suggested two main directions on developing technological innovations. First direction focuses on improving internal or in-house process to help various practitioners and stakeholders in relation to information management (Randell et al., 2009; Georgiou et al., 2011). Second direction focused on information delivery for public, e.g., within a non-clinical context for individual end-users or patients community who need healthcare support for their well-being and independent every-day living (Joe and Demiris, 2013; Capel et al., 2007; Pulman, 2010; Gaikwad and Warren, 2009; Andreassen et al., 2007). Extending the second direction, our study highlights the key problem area of ICT applications for supporting independent lifestyle of elderly populations in order to identify a new approach of information delivery that may be suitable both to service providers and end-users community groups.

The considerable demands of providing healthcare infrastructure have been influential towards developing innovative approaches. Studies reported that technology-based innovations are of paramount importance to improve public information services (e.g., Hardey, 2008) described the possibilities for targeted healthcare information need to be explored for public information support) to support care in their own home without delay and, therefore, reduce institutional admissions for receiving care or treatments (Soar et al., 2007). The realities are not only relevant to address the effects of the elderly demographic but also huge expectations of governments for effective use of their health resources. Government policy encourages investment and research in ICT within the national health service (NHS) to provide high-quality services to elderly populations (Pulman, 2010; Sammon et al., 2009). Along with the major risk factors for complications in healthcare, new technology considered only support for information services in the home environment to reduce costs associated with facility-based healthcare (Pulman, 2010). Soar et al. (2007) noticed that the information service issue demanded urgent attention for elderly population and anticipated its impacts on healthcare in many countries, including several European states, the USA and Japan (Plaza et al., 2011).

Researchers, subsequently, identified a new research area called 'aged care informatics' (Frean, 2004). A number of research organisations and associations around the world commenced research programmes on elderly population. In Australia, a relatively new research programme called 'SAIL' (smart aging and independent living) has developed a research pathway for effective adoption of intelligent technology for the elderly populations. The programme initiated by national and international collaborators to elevate the consumer-needs-based research with a focus on developing new and emerging technology, where the benefits are not limited to end-user groups but also for the care providers, communities and care funders (CAAIR, 2011). This comprehensive research strategy motivated us to conduct a literature survey in order to outline an effective approach for information delivery that would meet the dual requirements.

Many academic journals in the field of health informatics identified useful aging healthcare themes in their special issue (for example, Sammon et al., 2009) for the purposes of:

1   investigating methods that are used to inform decisions through ICT technology adoption

2   developing ICT solutions for use with patients groups

3   investigating the results of using such IS/ICT innovations in practice to assist both elderly patients and clinicians.

Importantly, some journals focused on the special issue of the aspects of information service delivery on recipients. It therefore creates opportunity for a combined view of service delivery innovations considering the public role to yield an integrated approach in practice. The problem domain within the context shows the clear opportunities noted above. The study aims to conduct a review on the current ICT innovations in order to establish an approach of healthcare information delivery, particularly for elderly populations. We anticipate that the work will create a foundation for a cloud-based information delivery framework in order to advance approaches to healthcare technologies.

3   Used method

To identify the key ICT application used for elderly population's healthcare information globally, the study initially conducts searching relevant articles published in the well-known health informatics journals. We used search engines of the University Library, Google Scholar and National Center for Biotechnology Information (NCBI) Portal, using the terms such as: 'aging population' AND 'technology', 'elderly' and 'technology' and 'older people' and 'ICT technology'. We also used OR instead of and in three cases. Similarly, the terms 'aging population', 'older people' and 'retiree needs' also used separately to identify which journals publish on aging healthcare needs. Firstly, we found that nine health informatics journals represented the highest presence in the search output. We decided to contain our enquiry to nine journals that published the majority of the papers, and in Table 1, the list of the journals identified are presented. In our meta search, we identified 186 articles on aging populations and drawing on the of the six (out of the nine listed) most frequently used journals for such output, we then select 42 (29 primary and 13 secondary) articles for further analysis in our study.

Articles that outlined impact, benefit and implementation of ICT applications were identified manually. Articles related to disease specific innovations and medical issues for older people were excluded. Following a searching guideline described by Gaikwad and Warren (2009), we retrieved each article that passed the inclusion criteria with respect to:

1   innovations/technological relations to objective

2   country in which research was performed

3   study design and method

4   study results and outcomes as a means to the older people's benefits

5   conclusions drawn from the study.

Table 1 shows the title of the journals in health informatics, relevant publishers and numbers of associated articles that were primarily considered for our analysis. The key issues and relevant technologies are identified from a range of the selected studies. The results, outcomes, conclusions, and whether the innovation worked in the included studies are summarised in the section below.

Table 1   Names of the health informatics journals and numbers of articles

Name of the journals	Publishers	Numbers of papers
Health Informatics Journal	Sage Publications	8
Electronic Journal of Health Informatics	Australian College of Health Informatics	5
International Journal of Medical Informatics	Elsevier	4
Journal of Medical Internet Research	JMIR Publications	4
Health Information on the Internet	RSM Publishing	3
British Medical Journal	BMJ	2
Procedia Technology	Elsevier	1
Journal of Biomedical Informatics	Elsevier	1
IEEE Transactions on Information Technology in Biomedicine	IEEE	1

4   Findings and analysis

Based on the findings, innovations of ICT applications for elderly populations can be classified as: smart home applications, mobile-based applications, online-based applications and personal devices and application-based innovations. The following sub-sections provide the details of the four innovations of ICT technologies.

4.1   Smart home applications

Smart home-based innovation for elderly populations enables various assistive technologies for the everyday activities inside and outside of home, using electronic peripherals such as remote sensors, embedded systems, robotics and wireless mobile networks. The aim of such innovation is to enhance elderly group's comfort and the efficiency of healthcare and illness prevention (Axisa et al., 2005). These types of support are mainly hardware dependent, but most of them are embedded with ICT applications. For example, electrically controlled door opening, remote control of furniture and home electronics such as TV, digital reminders that offer health advice or support programmed for individual patients (Essén and Conrick, 2007). Axisa et al. (2005) described smart home technologies for smart clothing and home healthcare and disease prevention. ICT

applications are also embedded with portable devices for healthcare applications, and alarm installations that can detect and alert health emergencies in the home environment. However, the relatively expansive smart home-based applications are useful for independent living (e.g., for particular support) of elderly populations. The usage are limited to target groups with special needs rather than providing useful public provisions such as for delivering healthcare information. The technologies such as artificial intelligence (AI) provide inflexible options to tailoring requirements to also meet the end users demands.

4.2   Mobile-based applications

The innovation of mobile-based healthcare provisions is one of the well-recognised areas defined for elderly populations globally. In many parts of the world, mobile phone technologies are used to deliver healthcare information and other medical services at remote area, not only for the target end users communities, but also to meet the management need of governments and healthcare providers. In the literature, studies describe various mobile-based applications and other portable platforms to ensure remote access to various healthcare services related to the elderly independent living and support, one of the latest applications is 'the Guardian Angel application' (Panou et al., 2013). This innovation is based on the practical needs of formal and informal care-givers, healthcare and emergency support service providers, elderly associations, representatives of the scientific community to meet defined requirements for the particular elderly population with chronic conditions, stroke, asthma and hypertension. For Japanese elderly community, Obi (2013) introduced smartphone applications for the ageing and disabled communities for their well-being and independent living. Blake (2008) reviewed the role of mobile devices and applications and defined that both the text message and the voice response functions of the mobile phone are used in monitoring wandering in dementia, monitoring blood glucose in diabetes or promoting health information for safeguard.

The innovations in the particular area have been coined with the concepts such as telehealth, tele-care and tele-rehabilitation and e-health. Tele-care and tele-rehabilitation provide services directly to the end-users while e-health performs the combined role of electronic communication and information technology in the healthcare sector, the use of digital data in the healthcare sector – data transmitted, stored and retrieved electronically for clinical, educational and administrative purposes, both at the local site and remotely (Melander et al., 2007). Mobile-based applications offer a more personalised model of healthcare to meet individuals demand and in most of the cases the nature of the applications are intelligent agent-based (Plaza et al., 2013). This type of innovation has promise to enhance independent living for the elderly.

4.3   Online-based applications

Online technologies such as social media and networking sites and blogs have become the platform for cutting edge practices, not just for the communication-specific functions, but also in terms of engagement and participation in larger communities of practice. Baker et al. (2013) described Facebook, LinkedIn, and other online communities represent an important opportunity to reframe the operation of disability and elderly

community, especially those in which distributed networks and communities substitute for geographic proximity. Nyman and Yardley (2009) described usability and acceptability of a website that could provide tailored advice service on prevention activities. A tailorable website is used as a technique that could lend itself to innovations delivered online (Nyman and Yardley, 2009). Tailorable web enables a technique that makes information more personally relevant to the individuals by taking the individual's answers to questions and using them to match the advice to the individual's needs and preferences (Treweek et al., 2000, Nyman and Yardley, 2009). Sillence et al. (2005) suggested personalised web options for elderly groups for their information and advice. Nyman and Yardley (2009) explained the tailoring technique as interventions to current web-based healthcare solution. The benefits and impact focused studies on web-based technology identify methods and service verity for patients' specific conditions for example, with long term conditions (Pulman, 2010), patient with asthma (Shegog et al., 2006). Pulman (2010) described Web 2.0 technologies for improving healthcare services for people with long-term conditions. These provisions enable supporting personalised choice and provide resources for end-user or target community to self-care and self-manage. These studies show limited discussion of overall impacts of such technology use across elderly populations and benefits that are offered for the relevant service providers.

4.4 Personal device and application-based innovations

A range of assistive devices (laptops, tablet PCs, mobile phones, smartphones, alarm systems) have been implemented, trialled and promoted for the elderly that have been developed to improve the well-being and safe care of older citizen. These are intelligent walkers, which increase patient mobility, monitor blood pressure, and detect falls. Singh et al. (2009) evaluated the need to understand factors that determine elderly patients' enthusiasm to use e-mail to communicate with their physicians. These studies contributed to personal care delivery and enhance care facility capacity to service the health requirements for specialised groups. The other group of studies identified device-based solutions that show various applications through special computing devices that are used to support ageing populations' wellbeing and healthcare support needs. Piper and Hollan (2013) introduced shared touch-screen computer in use for elderly patients and how it may suit the needs of elderly patients in facilitating the doctor-patient interview process. Hoof et al. (2011) described a prototype of a surveillance system for monitoring by providing alarm in an emergency situation. On the other hand, Wu et al. (2011) mentioned the needs and preferences of elderly population towards employing an assistive robot in the home as a means of supporting these groups in the home taking in to account possible cognitive impairment.

Apart from web-based solutions, many studies proposed personal software applications for productive healthcare delivery and support. For example, decision support systems for controlling pressure ulcers (Fossuma et al., 2011); telehealth system (Lai et al., 2009), e-mail and SMS-based reminder system for appointments and medication management (Hughes et al., 2011), and electronic mail-based care communication (Singh et al., 2009), where end users or relevant user utilise such technologies.

Table 2   Main technologies and key purposes identified in previous studies

Main innovations	*Technological components with the key purposes*
Smart home-based innovations	• Assistive technologies for the everyday activities inside and outside of home – Axisa et al. (2005)
	• Electrically controlled door opening, remote control of furniture and home electronics such as TV, digital reminders for individual patients – Essén and Conrick (2007)
Online-based ICT innovations	• Public website for helping achieve and maintain patient's healthy life – Capel and Farrugia (2005)
	• Social networking through Web 2.0 for improving long term conditions quality of life – Pulman (2010)
	• Personalising web information for patients' healthcare information – Al-Busaidi et al. (2006)
	• Communities of participation for elderly groups – Baker et al. (2013)
	• Evaluating usability and acceptability of a website – Nyman and Yardley (2009)
Mobile-based applications	• Mobile healthcare application for the elder caregiver monitoring – Ferreira et al. (2013)
	• Mobile applications in an elderly society – Plaza et al. (2011)
	• Smartphones application for elderly people with disabilities in Japan – Obi (2013)
Personal devices and applications-based innovations (e.g., personalised system)	• Home-based information and communications technology enabled interventions for chronic disease management – Gaikwad and Warren (2009)
	• Computerised decision support system on pressure ulcers and malnutrition in nursing homes for the elderly – Fossuma et al. (2011)
	• Computer-based decision support for paediatric asthma management – Shegog et al. (2006)
	• E-mail and SMS text message healthcare reminders – Hughes et al. (2011)
	• Telehealth system – Lai et al. (2009)
	• Touch-screen computer technologies – Piper and Hollan (2013)
	• Intelligence surveillance system for monitoring ageing in home – Hoof et al. (2010)
	• Robotic agents for supporting community-dwelling elderly people – Wu et al. (2011)

Table 2 illustrates technological details with key purposes of the four classes of ICT innovations below. There are associative issues to use these ICT innovations discussed in the literature over the past. It is also defined how internet options associated with other digital technologies provide easy methods to access health information to make choices about older people's healthcare needs and services. Nonetheless, Capel et al. (2007) argued that internet does not fulfil their needs of information seeking behaviour. Moreover, there are major barriers to use the internet for elderly population due to issues associated with experience, technological knowledge, cognitive capacity and physical

capacity, such the demand on the visual cortex and optical functions that decline with age (Capel et al., 2007; Becker, 2004). Hindmarch et al. (2006) argued that internet usage for aging groups in respect to finding health information is problematic because of the 'digital divide' and lack of balance between ICT, medical and social research. Specifically, though technological solutions are viable and potentially valuable, the capabilities, motivation, needs and requirements for aged groups to benefit from technology has not been adequately considered all of the human factors in the particular case. On the one hand, the technology providers consider simply ICT solution-based interventions for their target information management. However, in many cases they fail to accurately consider relevant social and business implications in their automation. As a result, ICT implementations and adoptions result lack in contextual and user uptake although many contemporary studies suggest approaches for enhancing user uptake in healthcare decision-making (Miah, 2014).

However, consideration for the most fundamental aspects of design for the optimum healthcare solution needs to take into account of the important requirements that can add value to healthcare community. Service providers' issues in relation to how to reduce cost of health information delivery through the use of technologies are ignored in most of the instances. Each identified intervention offer benefits to address the relevant targeted issues. However, it is found that the impacts of most of these solutions focus only on user side demands but in general exclude the service providers' side demands in the purpose of technology design and implementation to meet requirements. Taking a systematic perspective of information users and practitioners who work with the aged as well as those of service provider facilities is an important as initiative to offer foundation understanding of comprehensive and quality applications with information resources for elderly population. Such an approach will add value to shaping a more effective information delivery model that will benefits the group and healthcare information providers to achieve positive outcomes.

To address the gaps in previous studies, the cloud computing, as adoptive approach, can possibly offer improvement for:

a   information usage

b   healthcare services

c   end user uptake – client and service provider (Miah, 2014; Marston et al. 2011).

These improvements can add value over the four above mentioned innovations. The technological improvement through cloud computing can provide end user community with simplified access and service providers with having control over to web information (Miah, 2014). Many recent studies have described advantages of cloud computing-based services over other approaches. In improving healthcare service providers' options Lin et al. (2014) recommended that cloud computing can empower healthcare practitioners and service providers as it offers scalability, online delivery of software and virtual collaboration storage services which enable organisations who engaged in healthcare delivery (Sultan, 2014). The analysis of Lin et al. (2014) showed that the approach supports the healthcare information delivery at all levels of the healthcare system, including the work in the rural areas of China. Sultan (2014) described advantages of cloud computing-based applications in contributing to the advancement of healthcare information delivery. Although the study by Sultan (2014) identified cloud computing options to meet general expectations of health providers such as more innovative and

cost-effective solutions and easy and quick solutions, no solution framework has been proposed to implement the solution. There are cloud-based healthcare solutions that have emerged recently such as GE healthcare (GE Healthcare, 2010). The solution is based on the patient self-service portal which enables patients to remotely communicate with their healthcare providers, request appointments and easily access their clinical information. Cloud-based EMR systems are likely to attract many US health delivery organsations (Sultan, 2014; Kolakowski, 2010). de Assunção et al. (2010) conducted a cost-benefit analysis of cloud-based services over the capability of cluster-based solution. The study found effective performance and response times with lower usage cost when using cloud-based operations.

5   Discussion and conclusions

The study identified the key areas of ICT innovations in the domain of aging healthcare and the associated issues that were discussed specially for delivering healthcare information. The outcome of the study helped create an initial basis to develop a new adoptive approach to support implementation of healthcare interventions for the wellbeing of the target population. For a wide-scale implementation, the benefits for the providers are important to consider such as for cutting cost of information delivering and service implementations. We have illustrated the arguments through our analysis on previous innovations in use and to address their issues.

The aim of the ground work presented a preliminary idea of cloud-based information delivery for the benefit of healthcare information providers and elderly population for their healthcare needs. Fitzgerald and Dennis (2010) described cloud-based design as a 'circuit-switched service architecture' that is easier to implement for organisations because 'they move the burden of network design and management inside the cloud' (p.297). This implies that both, user such as elderly population and information service providers, and health research organisations can use the cloud without any technological burden especially for a wide-scale implementation.

This study adopted a comprehensive approach to identify the growing requirements. With respect to the related works, author acknowledges the approach using a systematic literature review conducted by Gaikwad and Warren (2009) which evaluated the feasibility and benefits of home-based ICT enabled interventions for chronic disease management. Using similar approach, Barlow et al. (2007) conducted a literature review of home tele-care related to the frail elderly and chronically ill. The study of Barlow et al. (2007) reported about the effective Tele-care interventions to reducing health service use and improving clinical indicators and reducing health service use. However, a particular shortfall of the current study is a cost-benefit analysis related to specific technological implementations which could add value to its further evaluation. Such information is so far, limited in the target literature area that describe benefits realisation from such technology investments. Our study mainly articulated the user-side options and benefits in order to identify requirements and importance of service providers provisions in healthcare information delivery, that may not be a suitable scale of measure to which adoptive approach can help gain greater benefit both for end-user and service provider communities.

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Notes

1   According to WHO (2002) the 'active ageing' is the process of optimising opportunities for health, participation and security in order to enhance quality of life as people age.