Abstract

As a society we have to reimagine our health and social care models to meet the challenge of an ageing population with greater levels of chronic disease. The digital revolution offers us the potential to leverage technological innovations to develop proactive ‘connected’ health and social care models that are built around the patient’s needs to facilitate efficient management of wellness and health throughout their lifespan. However, efforts to utilise technological innovations for this purpose have not been universally successful to date, indicating that technology itself is only part of the solution. To achieve a truly connected, technology enabled, health and social care model we need to overcome some key challenges; Firstly we need to optimise the process of sensing data from end users in the home and community such that monitoring protocols are built around the person and designed with respect to their needs to provide for accurate and reliable harvesting of target data. We then need to gather and mine large datasets from the home and community in order to analyse the complex relationships between home and community acquired data and health status. Only then can we begin to design, implement and evaluate new models of care that leverage technology platforms. In meeting this challenge we can leverage technology to transform the way in which we promote and manage wellness and health throughout the lifespan.


Background

Society is currently being faced with a massive health and social care challenge. Apart from the demographic changes that will see the proportion of the population over 60 rise by almost a factor of 3 by the year 2050, we are also having to face unmanageable costs associated with increasingly prevalent chronic diseases such as cardiovascular, respiratory and metabolic disorders, and deal with a global shortage of suitably qualified healthcare professionals. It is clear that we need to find new ways of managing health and social care throughout the lifespan.

Poon and Zhang have described a paradigm shift in healthcare, one that suggests that preventive, pre-emptive and predictive healthcare decisions should be made in a pervasive, participatory and personalised manner. It is widely accepted that such a paradigm shift is not possible using the traditional tools and processes that have been used in healthcare to date. Thankfully, we are now living in a digital age where technological innovation is occurring at an exponential rate. Increased availability of technology, allied to the need to reimage healthcare, is driving a move towards leveraging technology to deliver more effective and cost efficient health and social care models.

The Connected Health Model

The term ‘Connected Health’ has been increasingly used in recent years to describe this new technology enabled model of healthcare delivery. A standard definition for Connected Health has not been proposed to date so we now propose the following: Connected Health encompasses terms such as wireless, digital, electronic, mobile, and tele-health and refers to a conceptual model for health management where devices, services or interventions are designed around the patient’s needs, and health related data is shared, in such a way that the patient can receive care in the most proactive and efficient manner possible. All stakeholders in the process are ‘connected’ by means of timely sharing and presentation of
accurate and pertinent information regarding patient status through smarter use of data, devices, communication platforms and people. This approach enables us to shift from a reactive episodic healthcare model to a more proactive model that connects stakeholders across the spectrum from the home to the acute care setting throughout the lifespan and puts the patient at the centre of the process (Figure 1). In doing so, a Connected Health approach has the potential to empower patients, clinicians and healthcare planners alike by means of delivery of pertinent information at key touchpoints.

**Figure 1. The Connected Health Management Model**

The driving element of the Connected Health cycle is the acquisition of health related data from the patient in the appropriate context, the data itself being the fuel for the process...
(Figure 2). This data may take the form of results from standard biomedical tests or investigations, subjective reports of symptoms or feelings, or ongoing monitoring of health-related behaviours in the home and community using body worn or ambient sensor networks. This data is subsequently aggregated, stored, shared and analysed (often in concert with that from other patients) in order to derive actionable information that can trigger appropriate interventions and feedback in a proactive manner. This is an ongoing process that takes place throughout the life span. A key feature of connected health is the potential to bring the patient into the management of their own health by means of provision of persuasive feedback regarding their health status or lifestyle.

Figure 2. The Connected Health Cycle

Evidence Base.
Though there is a widespread belief that technology enabled connected care pathways can transform how we manage health, adoption on a large scale will not occur unless there is an adequate evidence base. Despite the exponential increase in research in this field in recent years, there has been minimal translation into real change in how healthcare is delivered on the ground. This is due to a lack of clear understanding as to how technologies can be used to provide the relevant information that can drive better and more efficient healthcare. There remains a disconnect between our ability to use technological innovations such as mobile and ambient sensing platforms to harvest vast amounts of data from the home and community, and understanding how this data can drive new care models. Recent reports have demonstrated that the use of technology to monitor patients at home can be have a positive effect on care.\textsuperscript{6,7} However, the general consensus from the literature is that the evidence for the effectiveness of technology enabled care models in terms of clinical outcomes and cost savings is limited at best.\textsuperscript{5,8,9,10} This may be partly due to a lack of understanding as to how to harness the value in data that can be acquired from patients by monitoring them in the home and community, and combine it with other biopsychosocial data to derive accurate information as to the patient’s rate of progress or deterioration and need for interventions, and the contexts and care pathways within which remote monitoring might be advantageous. It is also a reflection of the fact that development of connected health systems and devices has traditionally been driven by technical possibilities rather than by the real needs of the end users or their caregivers.\textsuperscript{11} Another dimension to the problem is the lack of a truly connected end to end system being in place and the persistence of a siloed approach to management and storage of health related data.

\textit{Future Development Needs in Connected Health Research.}
To address these issues the clinical and technology research communities need to work closely to unlock the clear potential that exists. There are some key challenges that need to be addressed to advance the case for a new connected approach to management of health. It is critical that these challenges are addressed with input from the end-user groups and with the leadership of the clinical research community in order to ensure that the unmet clinical need can be addressed.

1. **Optimising Sensing Strategies.** Significant advances in wearable, mobile and ambient sensor technologies over recent years now mean that we have the capability to harvest large volumes of biomechanical and physiological data in an unconstrained environment. Furthermore, we can now realistically hope to capture target biomedical variables within appropriate contexts over extended periods of time. However, we still need to make further progress on optimal strategies for acquiring such target data in the most unobtrusive manner possible and on ensuring that data is both accurate and reliable with respect to the target clinical variables of interest. We also need to better understand how we can combine different sensing modalities for best clinical advantage and inform the context within which the target data was acquired. Otherwise we run the risk of harvesting large volumes of data that cannot be analysed and interpreted with respect to clinical need.

2. **Making Sense of Sensed Data.** The next challenge is to turn data into information. Though we have made significant progress on optimising the sensing process, we have not yet developed a strong understanding as to how this data can be used, either in isolation or in combination with other biopsychosocial data from the acute or primary care setting, to predict disease progression and inform the clinical decision making process. For example, we can monitor lung function, daily activity levels, subjective report of symptoms, nocturnal respiratory rate, and oxygen
saturation on an ongoing basis in the home setting. This opens up a completely new longitudinal measurement and monitoring paradigm as opposed to the existing episodic model. However, we have not yet developed the robust algorithms that can process this data as it is acquired and use it to predict the occurrence of an impending exacerbation in a patient with COPD. Doing so requires the acquisition of large datasets from the home and community and modelling it against health outcomes. Only then can we say that we have the capability to turn data into clinically relevant information. This challenge is being addressed in a number of prospective modelling studies and predictive models that leverage home monitored data for conditions such as COPD and Heart Failure are beginning to emerge from ongoing Irish research programmes.

3. **Developing New Care Pathways.** Once we have established the relationships between the sensed data and health progression or outcomes we then have to build and evaluate new models and pathways of care that are based on this new knowledge. These new care models must then be subject to robust evaluation in prospective RCTs that focus on clinical and cost effectiveness before we can expect widespread adoption in the clinical community or reimbursement from payors.

4. **Optimising Feedback Strategies.** A fundamental element of the connected health value proposition is its capability of providing feedback to the patient and engaging them in management of their own health and wellness throughout the lifespan. Feedback can take many forms in terms of modality and delivery strategy. However, we have yet to systematically study the relative benefits that different feedback strategies have in specific populations and develop an understanding of the effect
that factors such as life stage and cultural context have on the effectiveness of feedback.

5. Business Modelling. It is imperative that connected health care models are underpinned by sound business models or they will not achieve widespread adoption. A number of recent market reports have forecast rapid growth in the health technology sector. However, all refer to the significant challenge in understanding how the business model for this emerging sector will operate at steady state. The multidimensional nature of the connected health ecosystem (requiring input from sectors such as devices, clinical services, communications, and cloud services) is likely to need a truly collaborative business model before different stakeholders can understand how to unlock the value in the system.

Conclusion.

Society is being forced to radically re-imagine how we can leverage technology supports to deliver a new model for connected healthcare. The clinical research community is making rapid progress in understanding how we can apply technology to deliver patient centric models of care. Though we still have to address some significant research challenges, this area can transform health and social care in the coming period.

References:

2 Bodenheimer T, Chen E, Bennett HD. Confronting the growing burden of chronic disease: can the U.S. health care workforce do the job? Health Aff (Millwood). 2009 Jan-Feb;28(1):64-74. PMID: 19124856


