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Creating a continuum of care : smart technology in patients with cardiovascular disease

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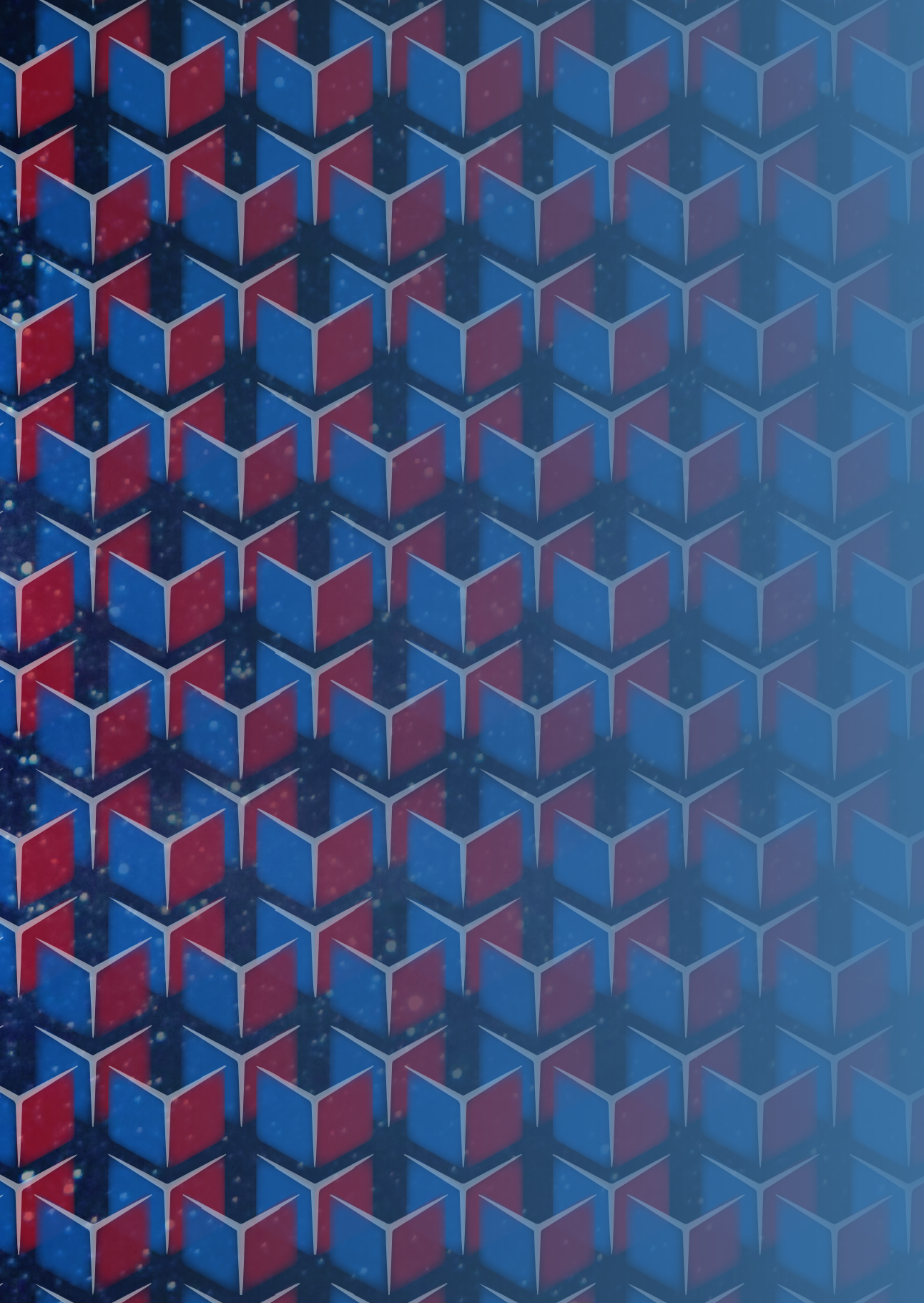


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CHAPTER 1

General introduction and outline of the thesis

Setting the scene

Telemedicine has been part of healthcare in Leiden for a long time. The famous Willem Einthoven, Nobel prize laureate in 1924, already transferred his ECGs from his laboratory to the ward via telephone lines.(1) In 1996, ironically, the paper of the Academic Hospital Leiden “Cicero” already showed the hazards of the current health care system (especially the fully packed parking garage) and the solution: the world wide web and the possibility of teleconsultations.(2) After 1996, personal computers, pocket sized agenda’s, internet enabled mobile phones and smartphones were consecutively introduced. After the introduction of the iPhone in 2007 and the subsequent inclusion of numerous healthcare apps in the App Store, the potential of e-Health was recognized. First, e-Health has the potential to defrag the current healthcare system. The current healthcare system has become fragmented and patients with chronic conditions often have to switch between multiple doctors, departments and hospitals. As a consequence, information has to be transferred between multiple doctors and no continuous monitoring of patients is currently possible. With e-Health devices, information can be digitally stored and transferred. Furthermore, patients can apply the devices themselves without assistance of staff, enabling more frequent monitoring. Smartphone devices which enable self-measurement of ECG, blood pressure, weight and saturation are already available.(3, 4)

Second, e-Health might help patients with prevention. A recent report of the Centers for Disease Control and Prevention (CDC) showed that approximately 33% of cardiovascular deaths are preventable with lifestyle adjustments.(5) In terms of secondary prevention, regular exercise is as effective as medication in coronary heart disease patients.(6) Mobile apps allow patients to track their lifestyle (body mass index, dietary intake, exercise) and even coach them based on the acquired data. Various apps give hints to exercise more, lose weight or improve dietary intake. It can be expected that these apps will play an important role in primary and secondary prevention of cardiovascular disease in the near future.

Third, mobile apps might help to improve the way patients are informed. Studies have shown that better informed patients (i.e. patients that know cognitively more about the pathophysiology, treatment and prognosis of their disease) have better outcomes.(7) This may be due to various reasons, which include better medication adherence and better lifestyle. Mobile apps can give patients insight in their own data. Furthermore, apps can give information about the pathophysiology of the disease.

Fourth, mostly due to the advantages mentioned above, mobile apps may contribute to higher patient satisfaction.

Fifth, the advantage of mobile health is that it is built on an already existing infrastructure. Data from the Dutch Statistics Bureau (in Dutch: Centraal Bureau voor de Statistiek) show that in 2017, 97.1% of the entire Dutch population had internet and 89% of all Dutch citizens had a smartphone. Of the elderly population (aged 65 years or older), 88.3% had internet access and 62.2% had a smartphone. It is worth noticing that the last percentage was 9.8% in 2012, marking an increase of 535% in five years.(8)

Sixth, mobile health is said to lower costs of healthcare delivery. Costs of healthcare in The Netherlands have increased from 46 billion euros in 2001 up to 96 billion euros in 2016.(9) This amount is expected to increase the upcoming years.(9) Healthcare expenditures are growing faster than the economy, making the system unsustainable for the future. As treatment options are increasing, population size is increasing and life expectancy is increasing, prevalence of cardiovascular disease and subsequent demand for cardiovascular care is estimated to rise in the upcoming 10 years.(10) Mobile health might be an important tool to contain costs of care.

However, scientific evidence published in peer reviewed journals for all promises above is mostly lacking. In telemonitoring for heart failure, for example, two major trials were unable to demonstrate a difference in all-cause mortality or hospital readmissions.(11, 12) Also, scientific evidence for cost-reductions is rare. Although studies have shown that e-Health is cost-effective, most studies show an increase in costs (as well as an increase in clinical effectiveness), but do not show a cost reduction.(13)

Lastly, there is the issue of data safety. There have been examples of apps claimed to measure blood pressure or prevent pregnancy. The blood pressure apps claimed to measure blood pressure with the smartphone camera only. Kumar et al.(14) reviewed the 107 most downloaded apps after searching for “hypertension” in the Apple App Store and Google Play Store. Of all apps, 6.5% claimed to be able to measure blood pressure. None of these apps were validated.(14) Another recent example (though not in cardiovascular disease) is the Natural Cycles app, which claims to predict fertility in women by daily temperature measurements.(15) Nevertheless, 37 women visited a hospital in Sweden for abortion because they became pregnant despite using the app.(16)

In practice, so far, development and implementation of mobile health is mostly money driven. Over the past five years, the number of start-ups in smart technology has grown exponentially, as well as the investment in these start-ups. In 2012, total size of the mHealth market was 6.7 billion US dollars. In 2018, this market is projected to 33.6 billion (an increase of 401%).(17) This has resulted in an exponential increase in apps, smartphone compatible wearables and platforms that collect and represent these data. Of course, these investments have to pay off and therefore it has been suggested that these healthcare technologies might increase supplier induced demand, thereby increasing volumes and costs.

Furthermore, big technology companies (e.g. Apple, Google and Microsoft) are investing in healthcare. They have all resources to become big players in healthcare. They have the money (all companies net incomes are estimated to be 48 billion, 16 billion and 21 billion US dollars in respectively) and the data.(18-20) Apple has launched the Apple Health App, which tracks sensitive health information (such as BMI, temperature and physical activity) and is now launching a service that allows iPhone users to view their electronic medical record on their smartphone. (21) Microsoft has started a similar project, "HealthVault", (22) which allows users to store their medical records on Microsoft owned servers (the cloud). These companies, and especially Google, have the knowledge to transform these data into clinical meaningful information. Google, famously, was able to predict flu epidemics based on search data.(23)

In order for cardiologists to be in the lead in an era where computers are integrated in healthcare delivery, it is important to generate scientific evidence on the effects of e-Health in healthcare delivery.

Defining e-Health

The first step might be to be conclusive on the definition. One of the interesting aspects of e-Health, is the confusion about its definition.(24-30) Searching various dictionaries, it was found that the Oxford Dictionary(24), the Dutch "Van Dale dictionary"(25), Dorland's Medical Dictionary(26) and Stedham's Medical Dictionary(27) do not provide a definition of e-Health. The Dutch medical dictionary "Pinkhof Geneeskundig Woordenboek" defines e-Health as "the use of information and communication technology, especially internet technology and ICT appliance to support health care".(28)

Furthermore, searching the literature in Pubmed using the search term "(("ehealth"[ti] OR "e-health"[ti] OR "electronic health"[ti]) AND ("definition"[ti] OR "define"[ti] OR "definitions"[ti]))", two eligible reviews were found. The first one by Oh and colleagues, published in 2005, encompasses a thorough search of various scientific

databases including MEDLINE and Web of Science, as well as a search of Google Scholar and Google. A total of 51 unique definitions were found and discussed.(29) In 2012, Showell and al. reviewed the literature for publications about the definition of e-Health. No other eligible articles than Oh et al. were found.(30)

Even when picking one definition of e-Health, the term remains an umbrella term. When following the definition of the RVZ, e-Health can vary from a physician e-mailing his patient to an implantable chip that transfers live blood glucose levels. Therefore, the RVZ subdivides e-Health into: general information, wellness, monitoring of vital signs, establish a diagnosis, therapeutic advices, communication or a combination of the previous.(31) In this thesis, e-Health is predominantly seen as monitoring of vital signs. This is often referred to as telemonitoring.

General outline of the thesis

It is the purpose of this thesis to investigate if telemonitoring in patients with cardiovascular disease can improve clinical and cost-effectiveness.

In **chapter 2**, an overview is given of different telemonitoring strategies that are available for patients with cardiovascular disease. In **chapter 3**, it is discussed how data derived from these telemonitoring devices need to be integrated into the electronic medical record in such a way that clinicians are not hampered by information overload. In **chapter 4**, a randomized controlled trial investigating the clinical-, and cost-effectiveness telemonitoring intervention in post myocardial infarction patients is discussed. In **chapter 5**, an RCT investigating the diagnostic detection rate of a mobile ECG device in patients with cryptogenic stroke is presented. The diagnostic accuracy of the blood pressure monitors used in the trial described in chapter 4 are discussed in **chapter 6**, comparing four smartphone compatible blood pressure monitors with an oscillometric device and the gold standard. In **chapter 7**, an overview of tools that are used to improve medication adherence are summarized. A possibility of detection of acute ischemia using serial ECG analysis is proposed in **chapter 8**. In **chapter 9**, a new telemonitoring strategy in patients with congenital heart disease, based on healthcare consumption data, is proposed. **Chapter 10** describes a new method of detecting central sleep apnea in heart failure patients using overnight oximetry. In **chapter 11**, conclusions of the different chapters are summarized.

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