Introduction


**Telemedicine**

Telemedicine is the delivery of healthcare and sharing of medical knowledge by use of information and communication technology (ICT), enabling caregivers and caretakers to work together independently of place and time for the purpose of consultation, examinations or medical procedures, and education.\(^1\) Telemedicine has been considered an organizational answer to keep healthcare accessible for the general population.\(^2\) It may become one of the solutions for the restructuring of healthcare systems in the developed world and the progression towards better healthcare in developing countries in the coming decades.

![Healthcare costs OECD countries per capita](image)

*Figure 1 - Healthcare costs OECD countries per capita*

Currently many member countries of the Organization for Economic Co-operation and Development (OECD) experience a marked increase in healthcare demand and costs (Figure 1).\(^3\) The OECD is an international economic organization of 34 countries with high-income economies, which are regarded as developed...
countries. Among the main reasons for the increased demand on healthcare are a rise in chronic diseases, medical and technological developments (when more is possible people seem to demand more), and the ageing of the population in most of the OECD countries. For example, about 27% of the Dutch population (16,782,300 inhabitants in Feb. 2013 on 37,354 sq. km of land) are estimated to be over 65 years old in 2037 and 48% of the population are estimated to be non-working, as compared to 39% in 2008. This latter group was already responsible for 50% of the total costs of care in 2007. The total amount spent on healthcare in The Netherlands of the GDP was 8% in 1972, in 2010 this had increased to 13%. Hence, the challenge lies in increasing care delivery productivity, with similar or higher quality of care, while keeping healthcare affordable and accessible for all.

With 25 referrals per year per 1000 patients from the GP to the dermatologist, dermatology is the specialism with the highest relative referral rate in The Netherlands. It is highly suitable for telemedicine due to its visual character. This thesis describes the results of several studies in the field of teledermatology (TD), the adaptation of telemedicine on the field of dermatology. This chapter will cover a brief history of teledermatology, summarize the available scientific knowledge and specify the research questions covered in this thesis.

**Teledermatology**

Teledermatology is the delivery of dermatologic care through information and communication technology. Since its introduction in 1995 it has evolved rapidly in the last two decades. MEDLINE has indexed 359 articles (search term: “teledermatology”, April 2013) presenting studies on TD in over 30 countries. Figure 2 illustrates its development as Pubmed (www.pubmed.gov) provides 12 suggestions of teledermatology sub fields in the search bar drop-down. Over the
years various actors, modes of delivery, capturing technologies and purposes have been developed and studied in TD research.²,³

Figure 2 – PUBMED search bar drop-down

Actors
There are various actors (e.g. patient, general practitioner (GP), dermatologist) who play a role in the TD process. A categorization of TD processes can be made dependent on the actors involved (Figure 3).²

Figure 3 – Teledermatology actors
Primary (or patient-initiated or patient-supplied or direct) TD encompasses communication between the patient and the GP or dermatologist. Primary TD has scarcely been researched thus far. No results on the diagnostic reliability (the ability to produce the same outcome in every occasion) of primary TD are published. Two studies reported a diagnostic accuracy (the degree of closeness of measurements to the actual true value (gold standard)) of primary TD, one of 51% agreement and the other 74% agreement.\(^\text{14-15}\) Image quality of primary TD is of “sufficient quality to adequately perform diagnosis”.\(^\text{16-17}\) Self-monitoring and patient empowerment are mentioned as important reasons for primary TD in acne or psoriasis patients.\(^\text{18-21}\) Primary TD may be used to improve outpatient clinic triage for patients that the GP has already referred to the dermatologist for a face-to-face consultation.\(^\text{15}\)

In secondary TD the GP or the homecare nurse communicates with the dermatologist. Secondary TD may be one of the most evolved telemedicine services so far, having been subject of research since 1995.\(^\text{22-23}\) Research has shown secondary TD to be diagnostically both accurate and reliable in many implementations.\(^\text{24-25}\) Secondary TD could be more efficient compared to conventional care and more cost-effective, but studies on large scale implementations of secondary TD to support this have long been lacking.\(^\text{26-29}\) This thesis will therefore focus on a large-scale secondary TD implementation evaluation on efficiency, quality and costs.

Tertiary TD facilitates communication amongst dermatologists. In tertiary TD cases with a more specialized character are presented to get an expert opinion from a specialized (often academic) dermatologist.\(^\text{30-31}\) Tertiary TD can also have an educational character.\(^\text{32}\) Diagnostic accuracy and reliability results are limited. One study reported accuracy rate of 78% and one study reported reliability rate of 96%.\(^\text{30-33}\) Overall, little scientific knowledge has been available on feasibility and
acceptance of tertiary teledermatology as a service. This thesis will evaluate the feasibility, the need for and the acceptance of tertiary teledermatology.

**Mode of delivery**

Two main technologies are used for the delivery of information and care in TD. The most common is store-and-forward (SAF), asynchronous data transfer in which photos and videos are created, sent and assessed at the actors’ time of convenience independent of the actors’ location. Another, less popular mode, is real-time (RT) or live-interactive, synchronous data transfer in which video streams are created, sent and assessed at a time all actors are available independent of the actors’ location. Lastly there is a hybrid mode where SAF and RT are used simultaneously. As SAF has become the most prevalent mode of delivery and is the current standard used in The Netherlands, this thesis will focus on teledermatology using the SAF technology.

**Capturing technology**

Teledermatology has been made possible through the introduction of consumer digital cameras. As store-and-forward is the main delivery mode, video camera equipment is not discussed in this chapter and is also not subject of investigation in this thesis. In the late 90’s and early 00’s the costs of digital camera equipment posed a barrier for the use of TD and the quality of different cameras continued to be a critical topic of discussion in literature. With the current hardware, these issues have become obsolete. Practically any off-the-shelf digital camera can produce an image of more than sufficient quality for TD. The quality of the image is not only dependent on the camera, but also largely on the skills of the photographer. It is therefore recommended to take an introductory course in taking (clinical) photographs when practicing TD.
The development of digital cameras in mobile phones brought a new capturing device to TD. Pilot studies show mobile phone TD to be feasible\textsuperscript{14;37-40} and to contribute to mobility and self-management\textsuperscript{18;41} Recently, mobile phone TD used as a skin cancer screening tool has shown promising results using mobile phones as capturing devices in a small number of pilot studies.\textsuperscript{42-45}

**Purpose**

The most common purpose for TD is consultation: to get an advice from an expert on diagnosis, management or both in order to prevent a physical referral, or to obtain a second opinion. Patients are currently selected for teleconsultation based on the assessment of the referring actor (e.g. GP). The principal goal is to improve the provided care on either quality, efficiency or both.

Triage is the second use of TD and overlaps with teleconsultation, as the result of a teleconsultation improves a patient’s triage by either avoiding physical referral or accelerating referral. Main difference with consultation is that all patients are included, who are for example referred to a specialist or screened. When used to prevent a physical referral, studies report TD can reduce physical referrals by 18.5\% to 58\% depending on the setting.\textsuperscript{46-54} TD is also used as a triage tool in skin cancer screening\textsuperscript{55;56} and a pilot study has been performed in outpatient clinic triage based on patient-supplied TD.\textsuperscript{15}

Monitoring, a third purpose of TD is used for and by patients with chronic disorders such as psoriasis patients on systemic treatment and patients with chronic ulcers. Pilot studies show that monitoring can optimize treatment, improve compliance and improve empowerment of the patient’s responsibility.\textsuperscript{16;21;57} Monitoring patients with chronic wounds via TD may improve quality of life and cost effectiveness of long term woundcare.\textsuperscript{58;59}

Teledermatology is also used in education programs. Online discussion groups and Internet Fora are used as a stage to present interesting cases as continuing
medical education for colleagues. \textsuperscript{60-63} Resident training programs have been developed that incorporate TD in their courses. \textsuperscript{33} In this thesis the possibility of a passive learning experience in GPs who have performed TD for a longer period and thus gaining knowledge from the answers provided by the dermatologists is evaluated.

Finally, there is the purpose of cost reduction that has so far been more difficult to prove, compared to the aforementioned purposes. Nevertheless, cost reduction is a very important motivator of many telemedicine implementations. Under the assumption of providing equal or better quality of care and only after cost-effectiveness has been proven, TD can grow into a fully implemented practice of care delivery. Due to the many variables and different perspectives, it has proven difficult to design complete cost analyses in telemedicine, both short term and long term. Major limitations in economic analyses of telemedicine are the scarcity of clinical outcome data, the rapidly evolving technology resulting in changing market prices, and difficulties with availability, accuracy and transparency of cost elements in the healthcare financial systems. \textsuperscript{29} Still, some costs studies in SAF teledermatology have been performed. A Dutch study indicates that teledermatology can be cost saving from a societal perspective when over 37% referrals can be prevented through teledermatology or travel distance to dermatologist is over 75 km. \textsuperscript{27} Another societal perspective study showed teledermatology cost was 79.78 Euros per patient compared to 129.37 Euros per conventional care patient. \textsuperscript{64} Finally, a study by Pak et al. found teledermatology also cost saving (340 U.S. dollars per patient for teledermatology versus 372 U.S. dollars per patient for conventional care). \textsuperscript{65}

**Satisfaction and acceptance**

Although reliable validated methods to assess satisfaction of patients and referring and consulting clinicians do not yet exist in telemedicine research, there is some
related work. The mainly positive results on patient satisfaction display high rates of acceptance, confidence and favouritism of TD (76 - 93%) with faster treatment and not having to travel as perceived benefits.\textsuperscript{46,66,70} Difficulties in acceptance of TD were mainly expressed as “not seeing a dermatologist in-person”, but were expressed by a small percentage of the study populations (30 - 40%).\textsuperscript{46,66,70} Clinicians are generally satisfied with TD and acceptance is high, but they express concerns on time consumption, low quality of dermatologic photographs and complex or faulty software.\textsuperscript{46,68,71} As one would expect, most clinicians who are using teledermatology are frontrunners who embrace innovative techniques and tend to be more positive than the average user. On the other hand, studies by Collins et al. and Bowns, et al. in which participation for dermatologists was not voluntary, showed satisfaction rates as low as 20%.\textsuperscript{46,71} These results are all based on secondary teledermatology implementations. In this thesis the satisfaction and acceptance of clinicians concerning tertiary teledermatology will be evaluated.

**Teledermoscopy**

Dermoscopy is the examination of skin lesions with a dermoscope. High quality dermoscopic images can be acquired when a dermoscope is attached to a digital camera. The assessment of dermoscopic images through TD is called teledermoscopy (or teledermatoscopy) and is used for screening and management of skin cancer. Its advantages and risks are described and studied in this thesis.

The concept of teledermoscopy had already been developed as early as 1999.\textsuperscript{72} A major concern with teledermoscopy has always been the diagnostic accuracy and reliability, even more than with regular teledermatology. The main reason is the high mortality risk found in patients with melanoma skin cancer. As dermoscopes are mainly used to exclude and diagnose skin cancers, the adaptation in teledermatology provides the possibility to diagnose skin cancers via
telemedicine. This is a group of skin disorders that has not been present in regular teledermatology. The use of dermoscopy by trained dermoscopists increases diagnostic accuracy for pigmented and non-pigmented skin lesions, especially in melanoma.\textsuperscript{73,74} Many articles have been published reporting on the diagnostic accuracy\textsuperscript{42,43,55,56,72,75-81} and diagnostic reliability\textsuperscript{56,82-85} of teledermoscopy for (non-)pigmented skin lesions. Several recent studies have reported high diagnostic accuracy of teledermoscopy (Cohen’s Kappa 0.74 – 0.95), comparable with diagnostic accuracy found in face-to-face dermoscopic examination. Diagnostic reliability studies reported moderate to good concordance between observers (Cohen’s Kappa 0.44 – 0.93). The diagnostic accuracy of teledermoscopy is mostly dependent on the observer’s level of experience\textsuperscript{80} and the quality of the provided images. In this thesis the quality of dermoscopic images acquired in a real world clinical GP setting is evaluated.

From pilot to practice
Teledermatology services have started up all over the world, in almost all cases as part of a research program. Results are positive in general, but TD services have predominantly remained in the pilot setting.\textsuperscript{26} A review performed in 2009 stated that ‘until now, there is no country which has implemented TD within their national health system’.\textsuperscript{12} This holds true when evaluating publications in the scientific press. However, TD has been successfully integrated in the Dutch healthcare system on a large scale. In the Netherlands TD is practiced by the majority of Dutch GPs and dermatologists.\textsuperscript{86} The teleconsultation volume is increasing yearly, with 4,337 teleconsultations performed in 2006 and 13,737 in 2009 by approximately 2000 GPs and its reimbursement is integrated in the national health insurance plan.
Aims of the Thesis

This thesis is divided into two parts: Secondary and Tertiary Teledermatology. It will answer the following research questions that will be addressed in 5 chapters:

1. What is the effect of a large-scale implementation of secondary teledermatology on efficiency, quality and costs of care when integrated in daily practice and applied following patient selection by the GP?
2. Can secondary care teledermatology be combined with dermoscopy images in a real world clinical setting?
3. Can the model of secondary teledermatology be applied to tertiary care models and what would be the effects on efficiency?

Outline of the Thesis

Part A - Secondary Teledermatology (Chapters II & III)

II. As efficacy of secondary teledermatology concerning diagnostic and treatment outcomes has been demonstrated under controlled conditions in other studies, the aim of the study in Chapter 2 was to evaluate the effects of secondary teledermatology on efficiency, quality and costs of care when integrated in daily practice and applied following patient selection by the GP.

III. In teledermoscopy research, most studies on accuracy and reliability took place in a lab setting with a clinical photographer or a highly skilled dermoscopist with experience in taking dermoscopic images. As high quality measurements are an important factor in the success of any teleconsultation service, the aim of the study in Chapter 3 was to assess the
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accuracy and reliability of teledermoscopy with images taken by GPs applied during regular practice.

Part B - Tertiary Teledermatology (Chapters IV, V & VI)

IV. The aim of the systematic review in Chapter 4 is to give an overview of studies on tertiary teledermatology (TTD) with emphasis on the categories of use. In other words, it addresses the question for what purposes tertiary teledermatology is applied. Second, it describes the modality, technology, setting, outcome measures and results of the current studies on TTD. Third, we were interested in the question whether TTD shows differences compared to secondary teledermatology on modality, technology and outcome measures.

V. The aim of the pilot study in Chapter 5 was to evaluate the feasibility and acceptance of TTD in a three-month project setting in a dermatology department of a Dutch university hospital with emphasis on reduced physical referrals between general and academic dermatologists, and usability and acceptance of the TTD system.

VI. The primary aim of the study in Chapter 6 was to determine reasons for success or failure of tertiary teledermatology and to determine the effect of prolonged use of the tertiary teledermatology system on referrals to tertiary centres.
Reference List


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