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MHEALTH FOR IMAGE-BASED DIAGNOSTICS OF ACUTE BURNS IN RESOURCE-POOR SETTINGS

STUDIES ON THE ROLE OF EXPERTS AND THE ACCURACY OF THEIR ASSESSMENTS

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mHealth for image-based diagnostics of acute burns in resource-poor settings

Studies on the role of experts and the accuracy of their assessments

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ABSTRACT

Background. The global burden of injuries could be reduced by the provision of adequate emergency care but this is impeded by barriers like poor access to specialised care. Accurate and timely diagnostics supported by mobile technology could enable more effective use of scarce resources. Acute burns are one type of injury amenable to image-based diagnostic consultation.

Aim. To increase the knowledge about how remote diagnostic assistance for burn injuries influences the role and work of clinicians. Focus is placed on medical experts and the context of resource-poor settings.

Methods. The thesis comprises one qualitative and three quantitative studies. In study I (I), on burn injury epidemiology, case reports of burns patients (n=1 915) treated in eight emergency centres during one year (baseline) were reviewed. Gender differences were examined using incidence rate ratios and a two-sample test of proportions. In study II (II), image quality on handheld devices was investigated via an online questionnaire including 18 clinical and non-clinical images viewed on a smartphone, tablet and computer by 27 medical experts. Perception of quality was rated on each image. Linear regression clustered by participant was applied, comparing the ratings for the tablet and smartphone with the ratings for the computer. In study III (III), diagnostic accuracy of assessments of acute burns made via smartphones and tablets was assessed using an online questionnaire with 51 burns images. Each image was assessed by 26 medical experts using their own device. Diagnostic accuracy and intra-rater reliability were assessed with a two-way mixed effect intraclass correlation coefficient (ICC) with 95% confidence interval. In study IV (IV), perceptions of medical experts of remote diagnostic assistance were explored using semi-structured interviews with 15 medical experts. Data were analysed with thematic analysis and positioning theory.

Results. Burns were most often caused by hot liquids (65.2%) and of minor and moderate severity (80.4%) with the majority of patients treated as outpatients (73.9%). Young children had the highest incidence rates (75.4 per 10 000) and gender differences were mainly observed in adults. A higher proportion of women were treated as outpatients and a higher proportion of men were transferred to higher levels of care (I). Clinicians rated the quality of images viewed on smartphones and tablets higher than when viewed on computer (II). Assessments of burn size by clinicians were accurate overall (ICC=0.82) while the accuracy of burn depth assessments was low (ICC=0.53) except for depth assessments made by South African burns specialists of child burns (III). Four positions of experts were described in current remote consultations: clinical specialist, gatekeeper, mentor and educator. Experts were already engaged in image-based consultation and were confident that images could improve the accuracy of consultation. Verbal communication was described as crucial for critical situations. The app is expected to improve security, information quality, access to experts, and learning (IV).

Conclusions. Altogether, the findings contribute important information for the implementation of an app for remote diagnostic consultation in resource-poor settings. The acute burns compare in many ways as those seen in other levels of care with only a few potentially challenging characteristics. Clinicians from the field are satisfied with the quality of images seen on smartphones and tablets and can accurately assess burn size by looking at images on their smartphones. Burn depth assessments may be improved by more additional information which can be requested in real clinical practice. The four positions described by the experts were all expected to change with the use of the new app. The current use of WhatsApp for remote burn consultation highlight the changing field in which experts work and can both facilitate and hinder implementation of the app.


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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AIS</td>
<td>Abbreviated injury scale</td>
</tr>
<tr>
<td>DALY</td>
<td>Disability adjusted life year</td>
</tr>
<tr>
<td>HIC</td>
<td>High-income countries</td>
</tr>
<tr>
<td>LMIC</td>
<td>Low- and middle-income countries</td>
</tr>
<tr>
<td>mHealth</td>
<td>Mobile health, i.e. the use of mobile devices for health purposes</td>
</tr>
<tr>
<td>MMS</td>
<td>Multimedia messaging service</td>
</tr>
<tr>
<td>POC</td>
<td>Point-of-care</td>
</tr>
<tr>
<td>SMS</td>
<td>Short message service</td>
</tr>
<tr>
<td>TBSA</td>
<td>Total body surface area</td>
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INTRODUCTION

Burn injuries have been referred to as the neglected epidemic of South Africa, with high incidence but low prioritisation in terms of funding, education and political will. I was first exposed to the cruel nature of burns when I had the opportunity to stay in South Africa to complete Master’s in Global Health thesis. During this time, I was involved in different studies on burns mortality including study visits, observations, data collections and analysis of register data. I tried to prepare myself emotionally as much as possible for the tough insights that were to come but still, eight years later, I am still taken aback by the many stories of burn-injured children, adults and entire families. Since then, I have been introduced to and seen the inequalities that are causing this heavy burden of burns striking the least well-off communities. I have also seen the severe consequences for individuals when their burns have not been managed adequately, causing life-long disabilities that could have been avoided if these individuals had benefited from the high-level knowledge that actually exists in this setting. Apart from the pain and the stigma these disabilities might cause, in an environment where almost half of the working age population is unemployed, any kind of disability exacerbates a person’s prospects of finding a job to make a living. Visiting the burns units, I was amazed by the great knowledge, skills and commitment that a small community of burns experts possess, trying to make the best of the resources available. Their enthusiasm and eagerness to expand and pass on the knowledge and skills to help ease the burden of this injury stimulated my interest and curiosity and laid the foundation for this thesis.
BACKGROUND

Diagnostic support as a means to reduce the global burden of injuries

Injuries – a global public health problem

Injuries are a major public health problem of increasing importance, causing every year close to 4.9 million deaths and 300 million disability adjusted life years (DALYs) [1,2]. There is a large variation in the incidence and morbidity of injuries both between and within countries [1–4] where children and adults from economically disadvantaged positions and areas are most affected [1–4]. These differences are seen for most causes of injuries including road traffic injuries, injuries due to self-inflicted and interpersonal violence, and even poisonings and burns although the latter two have been less studied in that respect [4]. Injuries are to a high degree related to the conditions surrounding how people reside, move around, work, and live their lives [3,4]. Although a source of health inequality and highly preventable [3,5], injuries continue to receive little attention and economic funds compared to other major health problems [3,6].

Burns, the type of injury that is the focus of this thesis, cause close to 153 000 deaths each year (about 418 a day) of which nearly a third occur in Africa [1]. As for other injury causes, there is a strong social gradient in their occurrence with economically disadvantaged individuals and geographical areas being at highest risk both between [1,2,7] and within [8,9] countries. In fact, many of the “distal” risk factors for burns such as dense living areas, poor housing conditions, unemployment, low education level and illiteracy are more common in settings with challenging economies [9].

A number of global processes like urbanisation and migration within and between countries [10–12] pose a threat to the establishment of well-conceived and built-in primary prevention measures that would help meet a number of the Sustainable Development Goals targeted to end poverty, improve health and well-being, reduce inequalities and make cities safe and sustainable (goals 1, 3, 10 and 11 respectively) [13]. Where primary prevention is lacking – or unsuccessful – the consequences of injuries to individuals can be minimised by quality emergency services [3,5–7,14,15]. This has also been established in the global agenda for burn prevention and care [15].

Improvements in emergency care in low- and middle-income countries (LMICs) have the potential to reduce substantially not only injury fatality and morbidity, but also the global burden of disease [14,16–20], in particular among young and productive ages of the population [17]. In fact, it has been estimated that as many as 24 million lives (accounting for 54% of deaths) are lost annually in conditions that could be addressed by the provision
of adequate emergency care systems in LMICs [14,20]. It has also been estimated that 3.6 million deaths each year are due to no access to care and 5 million additional ones are due to poor quality care [21]. Moreover, if the case fatality of injuries were the same in LMICs as in HICs, between 1 730 000-1 965 000 lives could be saved each year [19]. This is equivalent to more than a third of global injury deaths. Inequalities in access to emergency care are also found within HICs [3]. In Sweden, for example, waiting times at emergency centres differ geographically as well as with age [22] and outcomes of emergency conditions vary both socially and geographically [23]. Another case is the United States, where it is reported that 40% of trauma deaths could be avoided if everyone were given the same access [24].

A recent review of the burden and usage of emergency care from 40 countries around the world reports that the burden of emergency conditions has a reverse association with usage [16]: LICs have three times the burden compared to HICs while also having the lowest usage of emergency care, most likely due to poor access and availability. In that respect, Africa and South East Asia are identified as the most affected regions in terms of burden of emergency conditions [16]. A lack of data from emergency care in particular from LMICs prevents emergency care from being prioritised, resources from being appropriately allocated and the healthcare system from being efficiently planned [6,16,17,25]. Besides the capacity and readiness to provide timely and adequate care, studies point to a lack of research focusing on sex and gender disparities in the delivery of emergency care [26–28]. Less than a fifth of emergency care investigations report outcomes by gender and a slightly larger share do not report the gender composition of the participants at all [26]. Those results are poorer in terms of gender focus than research conducted in other specialities [26]. There is indicative evidence of gender differences in the access to trauma centre care where severely injured women are less likely to be transferred to a trauma centre than men with injuries of similar severity [29]. Calls to integrate sex and gender in research have been made by several international bodies, including the World Health Organization [30] and including a gender focus is identified as one of the top clinical research priorities within global emergency care research [27].

The early phases of the emergency care journey are the most effective ones to focus on, with most potential values to be gained for both patients and the healthcare system [31]. There are several factors related to the physical environment (e.g. infrastructure, equipment, infection control [32], transportation, referral systems and long distances [5,33,34]), as well as to human resources [6,17,25] and staff competence [17,32] that contribute to late initiation of patient care in resource-poor settings, in which the limited number of specialists plays an important role. The few specialists that exist are often based in urban areas leading to large geographic areas without specialised emergency care [6,35]. This has implications for triage and patient flow [17,36,37], communication and support to less experienced providers [17] where improvements can lead to reductions in in-hospital mortality. Specialised physicians have a key role to play for these improvements to take place [17].
Not surprisingly, many of the factors put forward above also apply for burns care in resource-poor settings; general hospitals often lack burn management capacity, first and foremost in terms of skills and knowledge of burns care, but also in terms of equipment [38–40]. Burns centres and experts are few, centres are under-resourced and often located in large cities with sub-optimal coordination between lower-level hospitals and burns centres and patients often have to travel long distances to receive care [38,41].

For burns, as for other conditions, diagnostic support in different forms is considered a precondition to improve global health [6,42,43]. Erroneous diagnoses can lead to several severe consequences of which the most obvious one is preventing optimal treatment [44–46]. An accurate and early diagnosis allows for timely initiation of treatment (or avoidance of treatment when not needed), improves patient’s journey and outcome, saves healthcare costs in any kind of setting and for any kind of condition or disease [46,47] and works to prevent development of resistance by appropriate use of medications [44,47,48]. More emphasis in research on diagnostics suitable for LMICs is called for [6,42,43] where innovative information communication technology has been highlighted as having an important role to play, for example via the development of rapid diagnostic testing, image-based diagnostics and other diagnostic tools adjusted to the specific infrastructure and available resources [6,45–51].

**mHealth as a support to the provision of injury care**

The telecommunication revolution is acknowledged as a potentially powerful driver to improve healthcare delivery to underserved areas [25,45,50,52–55]. In resource-poor and remote settings, wireless communication with mobile devices is becoming more and more widespread and is often a more suitable means of communication providing a less expensive and more accessible choice compared to traditional landlines [56]. Mobile health - mHealth - has thus been suggested as an especially appropriate tool to improve healthcare delivery in these kinds of settings and its potential has been emphasised by a Lancet commission [50] and in several mHealth reviews [54,56–58]. However, evidence as to whether the displays of these mobile devices provide sufficient quality for the purpose of image-based consultations is scarce [59]. There are a range of different applications for mHealth such as patient consultation, home health monitoring and decision support systems to name a few [60,61]. The type of mHealth which is the focus here – diagnosis and communication between healthcare providers located at different hospitals – only accounts for a small share of mHealth solutions [62,63]. The same is true for sub-Saharan Africa: of the numerous mHealth initiatives [53,55–57,64–72], few target communication between health workers [57], or are directed towards community health workers [55,56,70] and physicians [67]. Furthermore, injuries of any kind have received little attention despite the great potential for improvement that mHealth could offer trauma care [24,73,74]. In addition to these, there are many bottom-up initiatives of diagnosis and communication between physicians using
general applications for communication such as WhatsApp, referred to as “informal mHealth”, which will be described later on.

Images have a considerable role to play in the emergency department [75] and can support the diagnostic process and facilitate communication between healthcare providers [76,77]. A review of image-based teleconsultation in acute injury care found that transmitted images, in this case mostly radiological ones, were of sufficient quality to be assessed accurately by medical experts and that the practice could result in changes in patient management, including triage, referrals and management plans [74]. The studies included were almost exclusively from high-income countries with no representation from Africa and the need for more research from LMICs was highlighted [74]. Studies from the radiology field have shown good potential by demonstrating that different types of radiological images can be assessed accurately on tablets [78–86] and smartphones [87,88].

The growing number of informal mHealth initiatives that have emerged recently in different parts of the world (UK, Ireland, Turkey, Spain, Italy, India, Saudi Arabia, South Africa, Brazil) for physician-to-physician consultation and communication using mostly WhatsApp or MMS [62,89–104] clearly indicate a need and interest for solutions of this type. Those initiatives arise from a context of increasing access to and use of smartphones where sending, sharing and receiving images is becoming more and more affordable and part of the culture of communicating [91]. The major part of these systems include emergency consultations [90,92,93,95,98–101,104], are in surgical disciplines [89,90,92,94,95,97–101] and are mostly used for communication within units [89,90,92,94–98,102] although sometimes even between physicians in emergency care and specialists in other units [92,93,99–102]. Images of different kinds such as radiographs or photographs are commonly used in this communication [92,93,95–99,101,102,104]. Both positive and negative aspects and lessons can be drawn from these examples. The interest at point-of-care (POC) is demonstrated by their bottom-up perspective and show the positive attitude, curiosity and will that exist in healthcare to improve communication and management [105]. One of the downsides however, is security problems in terms of storage, data recording and patient confidentiality [106,107]. While some of these research articles directly or indirectly discuss security issues [90,92,96–98,101,102,104,108], few mention patient consent [92,97,101,104]. There is also a problem with reimbursements of the costs of the use of informal mHealth that are often left to the goodwill of healthcare workers [102,105]. In addition, apart from studies on the validity of diagnosis based on radiographs and CT scans [108–110], this kind of consultation has not been evaluated for the quality of the images provided and the accuracy of the diagnoses that are being made this way in other disciplines.

Specialists have a key role to play in many of these provider-to-provider systems and are often the drivers of both bottom-up and top-down mHealth initiatives. They have been approached mainly in relation to system performance [74] but less about how they perceive the consecutive changes in practices and their relations to other providers.
Implementation of mHealth for consultation between healthcare providers in Africa

Several African countries have developed national strategies for eHealth or mHealth [111–115]. Ethiopia is one of the African countries that have gone further in the execution of these strategies by aiming to employ 10 000 health information technicians by 2020 [116]. In South Africa (where the study is performed), a national telemedicine task team suggested telemedicine as a solution to the country’s efforts to provide quality healthcare to all South Africans as early as in 1998 [117]. Although the telemedicine system was cancelled after the initial phase in 2000, it planted a seed at the National Department of Health (NDoH) and a national strategy was developed in 2012 to support and spur the development of eHealth in the country [115]. In this report, the NDoH describes the suitability of mHealth in countries such as South Africa that have remote rural areas that need to be reached with healthcare in combination with a fast-developing telecommunications market [115]. An mHealth strategy for 2015-2019 was developed in 2015 [113] with the mission “to apply mHealth as an integral part of delivery of health care services in order to meet information communication, health education and data management needs of the health system in South Africa” [113].

New systems of communication impose new working methods and conditions [118–125]. Facilitating factors for successful implementation of mHealth projects in Africa include the use of simple low-cost technology that is widely available, appropriately adapted to the local context and needs, and with public-private partnerships and willingness and support from the government to integrate mHealth projects [57,126]. The flexibility of mobile technologies to adapt to local culture and replicate at a low cost facilitates the scaling-up of these projects, in particular in lower-resource settings [50,57]. Although the training within mHealth projects is normally straightforward, both training and incentives for users have been highlighted as additional important drivers of success [57,126,127]. From a healthcare provider perspective, interoperability with work processes and systems is one important factor to consider, as well as the availability of high-quality evidence showing the effectiveness of diagnosing this way [127–129]. Studies report a positive impact on communication, reduced transportation time and costs, and improved compliance to guidelines among health workers. But they also highlight problems related to a lack of evidence regarding effects on patients’ outcome [55], long-term results of mHealth and uncertainties of, for example, cost-effectiveness and external validity [57]. Indeed, a glance at the informal systems using WhatsApp or MMS suggest that the firm connection to the clinical needs, the perceived benefits for both patients and providers and the dedication among consultants are factors laying the foundations for successful integration into clinical routines [91]. Integration into local infrastructure was identified as the most important way to overcome implementation barriers in the clinical setting, and adding value to users was identified as the top enabler for front-line healthcare workers’ adoption in a round table event with stakeholders from different sectors on the topic of mHealth image-based diagnostic and treatment assistance [60].
Models to study change related to technological innovation

Introducing a change in a work practice through technological innovation requires an understanding of how this change may impact other aspects, both human and social, of the work tasks and the working environment at large. How this can be assessed and understood has been presented in a variety of models where technology receives particular attention [130]. Among the most commonly used and well known models of information systems success and acceptance are the Delone and McLean information systems success (ISS) model [131,132], the technology acceptance model (TAM) [133,134], the unified theory of acceptance and use of technology (UTAUT) [135,136], task-technology fit (TTF) theory [137] and innovation diffusion theory (IDT) [138,139]. Many of these models build on each other, have common components and can be applied to ongoing projects in which users can try out and give feedback on the specific technology used. For example, one of the dimensions in the Delone and McLean ISS model – system quality – is often measured by one of the variables in TAM – perceived ease of use [132]. Furthermore, the UTAUT model is developed by integrating eight existing theories and models, including TAM and IDT. In the UTAUT model, the TAM variables “perceived usefulness” and “perceived ease of use” are included in the dimensions “performance expectancy” and “effort expectancy” [135]. Another example may be that perceived usefulness could reflect the fit between the technology and the task in the TTF theory and perceived ease of use could reflect the fit between the skills and competencies of the users and the technology [140]. Another perspective is to look at it from an organisational point-of-view by using organisational models for change management [141]. Some examples of these are Leavitt’s Diamond model for organisational change [142], Nadler-Tushman’s Congruence model [143], McKinsey 7-S model [144] and Burke-Litwin’s causal model of organisational performance and change [145]. These models are useful to study the dynamics of organisations and to identify important aspects on which to focus with regard to a coming change [146]. A common feature with the four models is that the components within them are interdependent and a change in one affects all the other components [142–145]. The Nadler-Tushman’s congruence model builds on the Leavitt’s Diamond model [143] and offer overviews of factors affecting the performance of the organisation that are less detailed compared to those of McKinsey and Burke-Litwin. In contrast to the diamond model, the congruence model also includes the external environment by including input, throughputs and outputs and provides an overview of the process. It has previously been used to study organisational change from implementation in healthcare [147] and it is the model used in the thesis.

Although focusing on different aspects, both information systems success and organisational models point out that a change in technology does not occur in isolation to the surrounding environment and the importance of examining different factors and perspectives. To facilitate the introduction of innovative technology in healthcare, foreseeing barriers and facilitators by studying the target group of users is of paramount importance, in particular by understanding their expectations and perceptions on the change that is planned for. Additionally, keeping the
end-users in mind and involved in the design, choice of software and hardware and for motivation to use the system pave the way for sustainable implementations [126].

**Why image-based remote diagnostic of burns in resource-poor settings?**

There are several reasons for why burns are a relevant area of application for diagnostics with support of mHealth: 1) burns make a substantial contribution to the burden of disease and mortality and morbidity in resource-poor settings connected to the unequal distribution of resources and possibilities; 2) burns diagnosis and care are a challenge to physicians working in emergency care; 3) the visual nature of burns make them suitable for image-based remote assistance; 4) there is a strong commitment among burns experts to improve the care and knowledge regarding burns. In the following section, each of these reasons will be explained more in detail with a special focus on why the South African setting is well suited for this kind of application.

1. **Morbidity and mortality from burns is high and affects girls and boys, women and men**

The risk of burns varies throughout life and the age distribution of burns in sub-Saharan Africa is similar to the global one. In childhood, not only living conditions and life style habits but also developmental aspects come into play. Children [148–155], in particular young children, are a high-risk group for sustaining burns with the majority of injured children under the age of five [149–152,154,156–160], exploring their close environments completely dependent on parents and caregivers possibilities to protect them [8,161]. Among adult patients, most burns are seen among the working-age population and particularly among 20-44 year-olds [150–152,156,162,163]. Adults around that age [164] or aged 55 years and older [165] are also at highest risk for fatal burns, their vulnerability being much related to the higher fatality associated with higher age. Age is one of the three (burn surface area and inhalation injury being the other two) important predictors of outcome [8]. There is a tendency for burns in adults to be deeper [148], larger [148,150] and more often caused by flames [148–150,153,156] compared to burns in children, which are more commonly caused by scalds [148–150,153,156,157,160,166–169].

Globally, slightly more than half of all burn deaths are among women (54.9%) [1] and burn injuries are rather unique in relation to other injuries in the sense that several Asian studies [170–174] show a preponderance of women. In the sub-Saharan setting, all studies except one [175] point to an excess risk among men [150,153,155,162–165] or a relatively similar gender distribution [176]. Similar results are found for children in sub-Saharan Africa, where some studies have presented a preponderance of boys [157,158,160,164,177,178] and others a similar distribution among boys and girls [155,159,167,175,179]. Gender differences in burn severity and mechanism have also been reported in studies from different parts of the world. Women have both a higher total body surface area (TBSA) and are overrepresented among flame burns in studies from South East Asia and the eastern Mediterranean.
Contrasting results are seen in studies from Australia and North America where men have higher percentages of flame burns than women [181,182]. In sub-Saharan Africa, gender differences have not been observed in mechanism [153,158,176,177] but in circumstances [183,184], management [175,185] and consequences where more women die despite similar severity [163]. Age and gender differences in burn injuries can be attributed to either differences in exposures (which vary of course across settings and regions) or differences in susceptibility whereby children and adults, men and women sustain different consequences for similar burns [163]. It is also possible that children and adults, and men and women receive different care or attention when they present to some healthcare facilities [163,186].

2. Burns challenge physicians working in emergency care

For a burn, an accurate diagnosis and related triage together pave the way for adequate management and treatment outcomes. Research shows that inexperienced physicians without burns or emergency specific training often assess burns incorrectly [187–189]. In South Africa, the pressure on the healthcare system is high and physicians working in emergency care have a quadruple burden of disease to deal with, including both high levels of HIV/AIDS and TB, maternal and childhood illnesses, intentional and non-intentional injuries and non-communicable diseases [190,191]. One third of the admissions to emergency departments are trauma-related and burns account for 2.5% of them [190]. Poorly equipped emergency facilities and a lack of expertise in burns care leading to faulty initial diagnosis and management are common problems in the setting [192]. An incorrect diagnosis leads to under- or over-triaging that might cause errors in management, for example fluid calculations and airway management [193,194] which could have severe consequences for the patient and lead to excessive use of resources [195].

Including innovative technology in the assessments of burns patients is suggested as a means to improve their accuracy [196]. Furthermore, perceived usefulness and ease of use of mHealth interventions are associated with the perception among healthcare providers of the burden of the specific disease and condition as well as their capacity and skills to provide adequate care for it [127].

3. Burns are to a large extent of a visual nature

The visual nature of burns makes them well suited for teleconsultation. This has the potential to improve the use of resources in making triage and referrals more appropriate and allow the expertise of burns centres to expand and benefit healthcare facilities in more rural and remotely located areas [41]. In fact, assessments done remotely by burns specialists are more accurate than those of general physicians at POC [195] and are similar to expert assessments made bedside when made via videoconference [195] or by viewing images on computer screens [197]. Similar results have been presented in other specialties like dermatology [198,199], radiology [200,201] and pathology [202]. In an environment like the emergency setting, where every minute counts, valuable time could be saved by allowing experts to
review the cases on their own mobile devices instead of on a computer screen. The accuracy of diagnosing this way has not been established in specialties where diagnosis is reliant on conventional photographs, such as in the case of burn injuries.

4. Strong forces of commitment from the burns community in South Africa

There is a strong commitment among the few burns experts in South Africa to improve the care and the knowledge regarding burns. Initiatives of using smartphones for image-based remote consultation have been initiated by several burns units in the province and elsewhere in South Africa using WhatsApp or MMS [92,203,204]. This could be seen as an indication of the need of such systems and appreciation of their usefulness. Indicative evidence from the burns units shows that communication via WhatsApp resulted in fewer admissions [92,204] and changes in management plans [92]. However, there are still a lack of assessments on the accuracy of consulting this way. Furthermore, many users acknowledge the problems with patient confidentiality and other security issues but say the benefits outweigh these risks.

Development of burns apps

Burns apps globally

A number of different smartphone applications for burns have been developed in recent years. A review from 2015 [205] divides these into four categories: apps developed for calculating burn size, fluid requirements and severity; information apps with guidelines on first-aid and treatment of burns; books on burns for medical professionals; and games aimed at stimulating the learning of first-aid and burns treatment. The vast majority of the apps fall into the first two categories and are developed for medical professionals [205]. Only three of the 32 apps allow the transfer of any kind of patient data and two of them include information about the closest burns centre [205]. The app described in the following section was not available at app stores at the time of the review.

The app being implemented in the Western Cape, South Africa

The studies are all linked to the introduction of a mHealth system for emergency burns care in Western Cape Province, South Africa (Figure 1). The system uses a mobile phone-based app to transmit visual and textual information between emergency staff (i.e. nurses and physicians within emergency care) and a network of burns experts [107,206]. The aim is to facilitate timely and equitable access to high-quality care of acute burns patients, to the particular benefit of poor and marginalized men, women and children. The long-term objective is to improve the management of, and outcomes from, burn injuries in resource-poor settings, and reduce social inequalities in the access to specialised care.
The system has gone through several phases of development with different generations of the app. Local stakeholders from burns and emergency medicine have been involved during all phases as members of a recurrent panel of experts. The app was first provided in a dedicated phone to the healthcare facility but after some input from the intended users, the app could be downloaded to providers’ own smartphones. Originally, the app was planned to be piloted in eight emergency centres located in both rural and urban areas but due to delays in the development of the app and to highlighted problems when tested in real-practice setting, the pilot was never completed. Since 2016, the app has been integrated into the Vula platform (www.vulamobile.com) and has been developed further in collaboration with the Vula Mobile team [107]. The Vula app was originally outlined within the speciality of ophthalmology and has subsequently included other specialities such as cardiology, orthopaedics and burns, all to be used in emergency care at public healthcare facilities between frontline users and experts. The app can be downloaded free of charge by registered healthcare providers in South Africa to both Android and iOS devices.

Currently, the use of the app at the emergency centre is voluntary, based on the perceived need of frontline users (nurses and physicians). The procedure of the remote consultation is planned to take place more or less in the following manner: in the case of a burns patient, a nurse or a physician fills in patient data and uploads images together with a clinical question. This is all sent to a burns specialist based at any of the two dedicated burns units in the province (one for paediatric patients 0-12 years and one for patients 13 years and older). The burns specialist reviews the case on either a smartphone, tablet or PC and returns with advice on diagnostics, treatment and need for referral. The frontline clinician considers the advice, manages the patient and if in doubt or has further questions, uses the chat function (added following requests from users) to contact the burns specialist again.
AIM AND RESEARCH QUESTIONS

The overarching aim of the thesis is to increase the knowledge about how remote diagnostic assistance for burn injuries can influence the role and work of clinicians. Focus is placed on medical experts and the context of resource-poor settings. The following research questions are addressed:

- What are the distribution and circumstances of burn injuries treated in emergency services in resource-poor areas? Are there gender-related differences? (Study I)

- How do medical experts assess the image quality of clinical images viewed through handheld devices (smartphones and tablets) compared to when viewed on a laptop monitor? Is the assessment influenced by the clinical background of the participants? (Study II)

- How accurate is the image-based remote diagnosis of burns commonly presenting to emergency services in the Western Cape? Are remote assessments of comparable accuracy when made on handheld devices compared to on a computer? (Study III)

- How do experts perceive the opportunities in, and challenges of, the diagnostic and decision support system about to be implemented? What does it imply for their role in the management of burn injuries? (Study IV)
The four studies of the thesis take place before or in the very early phase of the mHealth project in a phase that could be classified as the pre- or initial use phase [207] of the implementation of the app and therefore do not investigate the performance of the specific technology. Therefore, a model that could support the understanding of a coming change in healthcare and that includes both social, structural and technical dimensions was sought. The point of departure of the chosen model is therefore not in health informatics but rather in organisational theory. The congruence model (Figure 2) by Nadler and Tushman [143,208] describes the organisation as a system with both social and technical dimensions consisting of four key components: task, people, and formal and informal organisation. The vertical axis comprising the informal organisation and the people could be seen as the social dimension of the organisation while the horizontal axis provides the structural and technical dimension with the work and formal organisation components.

The four studies are related to different aspects that need to be considered when introducing a change in how experts work in healthcare and the studies fall into different components of the model. Many more aspects might be relevant to consider, although here, the focus lies on those that are related to the specific role of images in the change that is about to take place. The organisation is not limited to one organisation or hospital, but rather to the organisation

![Figure 2. The congruence model [143,208] in relation to the context of emergency burns care](image)
around burns care in the province. The text in red describes the application of the different components in the context of the thesis.

The input component consists of different elements in both the external and internal environment that influence the specific organisation and the conditions in which the organisation works. Here, the input is the healthcare system or, more specifically, the emergency care system around burns care and entails for example the resources available and the distribution of burns that are all affected by the larger environment, regulations and historical context. Knowing the extent and the distribution of burns is important to have an idea of the kind of injuries that potentially will be up for consultation. It is of note that the input can change with time and is not a static condition. For example, at the start of the thesis work, remote diagnostic support for burns care and other conditions was not practised neither informally nor formally, so it was not part of the emergency care for burns and the input. With time, smartphones started to be introduced in the healthcare, both formally and informally, and increasingly became part of regular practice. If the starting point of the study had been today, remote diagnostic support could have been considered for inclusion in the input. Here, it is considered the strategy – the trigger of change – that comes in to create a transformation process in the four components of the organisation. The first study of the thesis relates to the input and focuses on the distribution of injuries. This is an important aspect since burns are the main focus of the work of many of the experts and the knowledge at hand regarding distribution of burns from the sub-Saharan region is focused on fatal [164,165] or severe burns [148–151,153–155,157–159,162,163,177,209] while studies including outpatients [152,156,160,210] remain few. Different parts of the healthcare system have different perspectives on the caseload treated and the types of injuries that are presented to emergency care, often the first point of contact of care, vary from those seen in other levels of care. Hence, there is a gap in knowledge as regards the injuries presenting to e.g. emergency care services, injuries for which there could be age and gender differences that have not been highlighted in earlier studies [25,26]. Studies of this kind are very limited in the sub-Saharan region.

The task component could be explained as the basic activities that are to be done by the organisation. This can be studied for example by focusing on what skills are needed for the work and the nature of the tasks including specific constraints like time or costs. The two following studies focus on image quality and diagnostic accuracy and examine the specific action of assessing burns using handheld devices. Evidence around this kind of assessment is, as mentioned earlier, available in other specialties using radiological and echocardiological images [78–88,108–110,211] but there is a lack of research on burns and other specialties that depend on conventional photographs for assessment.

The people component is made up of those who perform the tasks and could be studied by examining their knowledge, skills, needs and expectations. In this case, the people involved are experts and frontline users working in emergency care. All users should be included in the monitoring and evaluation of these systems, focusing both on satisfaction and acceptance
with the mHealth technology in itself and on the technology’s effect on, and compatibility with, working practices [57,106]. Changes in professional relations and roles among clinical staff (i.e. nurses, physicians, residents, allied health personnel, to name but a few) have been reported in regard to the use of different types of media in healthcare such as video [212–214], text messages [124], verbal telephonic [215], and image-based teleconsultation [122,216] but the specific role of the experts is relatively unexplored [212]. The fourth and last study focuses on the experts’ perspectives on remote diagnostics. Experts have a key role in image-based teleconsultation but have mainly been approached for evaluating diagnostic validity [74]. Less is known about how they relate to these practices and their influence on working practices and relations to others. As key stakeholders in many mHealth projects, their views are an important part of preparedness as well as of the evaluation process.

The formal organisation component could be described as the formal structures that are in place to support individuals to perform tasks. In emergency burns care, this could be, for example, the formal coordination of the interaction between different units or facilities, referral criteria and prehospital care and transport.

The fourth component of the organisation is the informal organisation, which relates to the arrangements created by the people themselves, separate from the formal organisation, such as relationships and interaction patterns.

The performance of the organisation, the output, is related to the congruence between the four components of the organisation – high performance comes with high congruence [143,208]. The output, which here is considered to be accurate diagnostics and changes in patient management and referral patterns, could subsequently lead to different outcomes for patients and the healthcare system and society. The formal and the informal organisation are not studied in this thesis. The output and the outcomes will be evaluated later on in the process when the app has been used for long enough to enable those assessments.
METHODS

Overview

The thesis builds on four articles related to the congruence model as illustrated in Figure 3. The first article feeds into the input, the second and third into the tasks of the organisation and the fourth one into the people.

Figure 3. The four studies included in the thesis in light of the congruence model [143,208]

Population indicators and healthcare in Western Cape, South Africa

South Africa is a large and populous country situated on the southernmost tip of Africa (Figure 4). It is classified as an upper-middle-income country [217] and has one of the highest income inequality levels in the world with a gini coefficient of 0.69 [218]. In the South African setting, as in other countries with high inequality, the unequal share of resources within the population prevents those living in the most disadvantaged areas from benefiting from most primary prevention strategies.
The mHealth project takes place in Western Cape Province, the fourth largest of nine provinces and the third most populous [219]. Two thirds of the population live in the metropolitan area of Cape Town [220]. Most indicators of the Western Cape population and their health suggest they are slightly better off than the South African population at large (Table 1); a higher share of the population uses electricity for cooking, are members of medical aid schemes (for use in private healthcare), life expectancy is higher, and a smaller share of the population is unemployed and on social benefits. However, the province also has a higher share of the population living in informal settlements than in the country as a whole (Table 1). In these areas, unemployment can in many places reach 45% [221,222] and paraffin is a dominant source of energy used, in particular for heating [221–223] but also locally also for cooking [224]. It is in these areas where the risk of burns is particularly high [162,168,225,226] due to the strong association of burns with living conditions and economic deprivation.

South Africa has a two-tiered system of healthcare with both private and public providers that serves 16% and 84% of the population respectively [227]. In 2007, the ruling party African National Congress (ANC) initiated the implementation of a National Health Insurance (NHI) with income-based payment in an effort to make healthcare more equitable and accessible to
Table 1. Population and health indicators in Western Cape Province and South Africa

<table>
<thead>
<tr>
<th>Population and health indicators</th>
<th>Western Cape</th>
<th>South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population in 2018 [219]</td>
<td>6.6 million</td>
<td>57.7 million</td>
</tr>
<tr>
<td>% of population below 5 years in 2018 [219]</td>
<td>9.2</td>
<td>10.3</td>
</tr>
<tr>
<td>% of population below 15 years in 2018 [219]</td>
<td>26.1</td>
<td>29.5</td>
</tr>
<tr>
<td>% of population living in informal settlements in 2017 [228]</td>
<td>19.0</td>
<td>13.6</td>
</tr>
<tr>
<td>% of households using electricity for cooking in 2017 [228]</td>
<td>79.8</td>
<td>75.9</td>
</tr>
<tr>
<td>% of individuals being members of medical aid schemes in 2017 [228]</td>
<td>24.8</td>
<td>16.9</td>
</tr>
<tr>
<td>% of individuals 15-64 years unemployed in 1st quarter 2017 [229]</td>
<td>21.5</td>
<td>27.7</td>
</tr>
<tr>
<td>% of individuals on social benefits in 2017 [228]</td>
<td>22.5</td>
<td>30.8</td>
</tr>
<tr>
<td>Average life expectancy at birth 2016-2021 [219]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>72.1</td>
<td>67.3</td>
</tr>
<tr>
<td>Male</td>
<td>66.2</td>
<td>61.1</td>
</tr>
<tr>
<td>% adults 20 years and older being literate 2017 [228]</td>
<td>98.1</td>
<td>94.3</td>
</tr>
<tr>
<td>% of households owning a computer in 2017 [228]</td>
<td>37.0</td>
<td>21.9</td>
</tr>
<tr>
<td>% of households with internet access on mobile devices in 2017 [228]</td>
<td>61.5</td>
<td>56.9</td>
</tr>
<tr>
<td>% of households with mobile phones in 2017 [228]</td>
<td>95.5</td>
<td>96.4</td>
</tr>
</tbody>
</table>

all South Africans [227,230]. In terms of healthcare organisation and burns care, Western Cape province has 450 primary healthcare facilities, 34 district hospitals and 8 regional hospitals [220]. Minor burns should be treated at any of the primary facilities or district hospitals while the regional hospitals are expected to take care of minor and moderate burns. As mentioned above, there are two dedicated burns units in Western Cape – one for children 0-12 years and the other for adults 13 years and older – where major and complex burns meeting the Western Cape provincial referral criteria (Figure 5) [231] should be referred [192], receiving patients from the whole of South Africa.

- Age: under 2 and over 60 years
- TBSA: All partial thickness burns >15% TBSA in children, >25% TBSA in adults. All full thickness burns >15% TBSA
- Anatomical site: Face, hands, feet, genitalia, perineum, major joints, circumferential burns (these burns could also be dealt with at level 1 or 2 but discretion must be used)
- Inhalation injury requiring ventilation for more than 48 hours
- Mechanism of injury: Exposure to ionizing radiation injury, high pressure steam injury, high tension electrical injury (>1000 Volts), hydrofluoric acid injury >1% TBSA, suspicion of non-accidental burn injury: paediatrics and adults
- Existing co-morbidity: Cardiac limitation and/or MI within 5 years, respiratory limitation of exercise, uncontrolled type 1 diabetes, pregnancy, medically or disease induced immune-suppression for any reason, existing psychiatric or suicidal tendencies, suspected drug/alcohol abuse
- Severe associated injuries e.g. polytrauma and crush syndrome

Figure 5. Western Cape provincial entry criteria for level 3 burns centre [231]
Study participants, data collection and data analysis

Study I. Injury characteristics

What are the distribution and circumstances of burn injuries treated in emergency services in resource-poor areas? Are there gender-related differences?

This cross-sectional study is based on case reports of patients who sought care for a burn injury at eight emergency centres between June 1st 2012 and May 31st 2013.

The emergency centres are open 24 hours a day, seven days a week and located in six hospitals and two community health centres. Five of the hospitals are situated in predominantly rural areas situated between 113 and 185 km from Cape Town. The other three facilities, of which one is a district hospital and the other two community health centres, are situated in the metropolitan area of Cape Town in suburbs predominated by informal settlements.

Data collection took place between October 2012 and August 2013 at each participating healthcare facility through a series of visits from members of the research team. There were a minimum of two trained data collectors at each visit. The visits started with a review of the patient register at the emergency centre to note down all patients who had sought care for a burn injury since the last visit. Any type of burns, i.e. scalds, fire, contact, electric, chemical burns etc. were included. The patient records of the burn-injured patients were thereafter searched for either electronically by the research team (at one of the hospitals) or manually by the reception, sometimes with support of the research team, at the remaining seven hospitals. Data were captured from each patient record using a standardised case report form based on WHO guidelines [232] (Appendix 1).

There were 2 172 patients that were formerly included from the data collection. Twenty-six of those were removed due to double entries (nine due to double entries from one and the same hospital and seventeen were referral patients that had been recorded at several hospitals). In cases where a patient had been referred and recorded at two hospitals in the study for the same burn injury, the information from the hospital where the patient first sought care was used. Crosschecking was performed by comparing double entries for the same case.

In total, 2 146 patients with a burn injury sought care at the eight healthcare facilities from June 2012 to May 2013. Of those, there were 230 patients (10.7%) for whom we could not find the patient records and those were therefore excluded from the analysis. Another patient with missing information about sex was also excluded, resulting in a total of 1 915 patient cases.
The data were analysed in the following two ways:

a) **Gender differences.** Age-specific incidence rates were compiled for men and women respectively in urban and rural areas. Gender differences in incidence were examined using incidence rate ratios between men and women. Gender differences in burns aetiology, Abbreviated Injury Scale (AIS), length of stay and disposition of the patients were examined using a two-sample test of proportions.

b) **Typical injury cases at emergency centres.** To start with, the data were split into children (0-12 years; n=1 013) and adults (13 years and older; n=900) and women (n=904) and men (n=1 011). Thereafter the body parts burned in these four groups separately were reviewed and ranked in order of most commonly burned body parts. It was also taken into account if the burn had affected a single body part or multiple, hence excluding multiple body part burns when assessing single body parts and combining body parts when two or several body parts were involved. This means that the percentages of the cases presented in Table 3 in the results section are when the lower extremities, trunk, upper extremities, hands and head were presented as single body part burns to the emergency centre. Similarly, the percentage of the case “upper extremities and trunk” is when those two body parts were presented in one and the same patient.

**Study II. Image quality**

How do medical experts assess image quality of clinical images viewed through handheld devices (smartphones and tablets) compared to when viewed on a laptop monitor? Is the comparison influenced by the clinical background of the participants?

This study is based on the results of an online questionnaire including 18 images viewed on three different devices (smartphone, tablet and computer) by 27 medical experts.

Images were selected to cover both clinical and non-clinical subject and were gathered from two previous studies conducted within the research group [197,233] and an open access medical database found online [234]. The online software SurveyMonkey was used to develop the questionnaire where each image was accompanied by a 7-point Likert scale (from 1=terrible to 7=excellent). The participants were instructed to use this scale to indicate their perception of the quality. At the end of each survey, a few additional questions were asked related to perception, experience and comfortableness along with some demographic data at the end of the final survey (Appendix 2).

Participants were selected purposively to include physicians that are likely to be contacted in their work to consult on acute burns. They were also required to have normal visual acuity and colour vision (by self-report). The participants (n=27) were recruited in April 2015.
during one local and one international expert meeting in Cape Town and included four burn surgeons from South Africa and 23 emergency medicine specialists from sub-Saharan Africa and the United States. The participants conducted the survey individually on one device at a time in an order that was predetermined by six possible permutations. The participants were seated in the same spot during the whole procedure with consistent surrounding lighting. All three devices were covered in a black custom-designed box to hide the brand and model but it was obvious for the participants which type of device s/he currently used due to the different sizes and shapes of smartphones, tablets and laptops.

The data were analysed with linear regression clustered by participant. The ratings of quality for the tablet and smartphone were compared with the ratings for the computer. Interaction between type of device and image and medical specialty was tested separately using a Wald-type test. Only the interaction between device and image type was significant, which is why the investigation continued with regression analyses stratified by image type.

**Study III. Diagnostic accuracy**

How accurate is the image-based remote diagnosis of burns commonly presenting to emergency services in the Western Cape? Are remote assessments of comparable accuracy when made on handheld devices compared to on a computer?

The third study is based on the results of an online questionnaire including 51 images of burns assessed by 26 burns and emergency medicine experts using their own smartphone or tablet.

The study was prepared by using images reflecting the typical cases of burns in children and adults that were seen at emergency centres in the province (Table 3). Each image had to reflect only the body part/s in that specific case with one image, and the images were selected to reflect a variety of burns in terms of size, depth and mechanism. A physician from one of the emergency centres was thereafter consulted to confirm representativeness of the images and their suitability for inclusion for image-based assessment of burns. A total of 5-6 images for each case were selected, which resulted in the 51 images that were included in the questionnaire.

Similar to study II, the questionnaire for study III was built in SurveyMonkey. It started with a few background questions (Appendix 3), followed by the 51 images to assess. Each image came with a short description of age and sex of the patient and burn mechanism. Participants were asked to estimate burn depth and size for each image. The final questions of the questionnaire focused on their perceptions around the use of images in telemedicine systems for burns (Appendix 3).
Participants were selected purposively to have burns diagnosing skills, by training or by clinical practice. Recruitment took place via the following three channels: 1) emergency medicine specialists (n=11) and burns specialists (n=2) involved as tele-experts in the mHealth project for burns; 2) burns specialists from Sweden (n=7) involved in similar studies; 3) burns specialists from South Africa (n=6) from the network of burns specialists from group 1. Sorted by specialty and country of practice, a total of eleven emergency medicine specialists from South Africa and eight and seven burns specialist from South Africa and Sweden respectively were recruited.

The participants were contacted via email with a link to the questionnaire and instructed to use their own smartphone or tablet for completing it. Participants reviewed the images (presented in a random order) and could pause the questionnaire and resume working on it using the same link. Eight of the participants were also asked if they were willing to meet up at a later occasion (at least two weeks after having conducted the first survey) to repeat the same questionnaire on a dedicated laptop computer.

A two-way mixed effect intraclass correlation coefficient (ICC) with 95% confidence interval (CI) was used to assess diagnostic accuracy of burn size (versus bedside diagnosis) for handheld devices and computer respectively and as an equivalent for weighted kappa for burn depth. ICC was also used to estimate intra-rater reliability. The data were analysed including all images aggregated and stratified by children and adults. For diagnostic accuracy, data were also stratified by specialty and country of participants (three categories). To interpret the ICC, the following interpretation of de Vet et al. [235], used previously for photographic assessment of burns [236], was employed:

- $<0.70 =$ low
- $0.70-0.80 =$ acceptable
- $>0.80 =$ high

**Study IV. Expert interviews**

How do experts perceive the opportunities in, and challenges of, the diagnostic and decision support system about to be implemented? What does it imply for their role in the management of burn injuries?

This was a qualitative study using semi-structured interviews [237] with medical experts. The study was originally inspired by the information ecology framework developed by Nardi and O’Day that describes information ecology as “*a system of people, practices, values, and technologies in a particular local environment*” [238]. This framework focuses on the activities surrounding the technology rather than the technology itself, where all parts of the
information ecology are interrelated and co-evolve [238]. The process of developing the interview guide (Appendix 4) was iterative between this framework, contextual local knowledge of the healthcare system and the results of a literature search focused on user perspectives of telemedicine solutions. The interview guide underwent sequential piloting, firstly with a physician in Sweden with experience from the area of telemedicine to confirm comprehensibility, flow of the questions and length of the interview, and secondly, with an emergency physician practicing in the Western Cape with knowledge of the mHealth project in order to safeguard that both content and language suited the local context. The pilots led to some minor changes where some probes for example about informal practices of WhatsApp were added, but the overall structure remained.

Participants were selected by purposive sampling [237] to include a broad range of potential tele-experts for burns. They were selected from the following three groups: 1) the burns and emergency medicine experts enrolled in the mHealth project; 2) senior level registrars in burns and emergency medicine specialty for a next-generation perspective; 3) one burns expert from another province for an outsider perspective. In total, the specialties were represented with seven and eight burns and emergency medicine experts respectively and a gender representation of seven females and eight males. Ten of the participants had knowledge about the app prior to the interview.

Two interviewers were present and took turns in leading each interview which lasted between 44 and 95 minutes. Notes taken after each interview were kept in mind when going through the transcripts to find themes that required further clarifications. These concerned their experiences of WhatsApp, the expert role, and views on disadvantages and advantages of having experts based at a tertiary centre or elsewhere. Member checks [237] were conducted via phone with notes taken. Several visits were also made to burns units and emergency departments in the province to get more acquainted with the working environment that the interviewees discuss and experience every day. Descriptive and reflective notes were taken during and after these visits.

To analyse the material, a two-staged approach was used. The first consisted of a data-driven thematic analysis that allowed the development of themes from the material. This thematic analysis [239] started with open coding of seven full-length transcripts using in vivo codes [237] for example “I need to see” and “it’s not just the burn” and developing other codes such as “Responsibility of the patient and the care”. The codes were discussed within the research team and categories of types of interactions were created. When all transcripts had been coded, the different backgrounds of the participants were compared to examine if their different perspectives varied.

After primary analysis, it was found that both clinical assessments and social circumstances were important in the interactions between experts and staff at POC. The literature on frameworks was re-examined with this finding in mind and a theory that could frame the many tasks and positions was looked for [240]. The information ecologies framework was judged to be too broad and too far from the data. Roles of medical experts have been studied
earlier and WHO launched the concept of “five-start doctor” in the early 1990s to expand the roles of general physicians [241]. The perception of medical roles is that they are relatively stable over time despite the changing environment in which physicians work [242]. It was from this discussion that the idea of applying the positioning theory [243], developed by Harré and Van Langenhove, emerged. This theory has been applied earlier in healthcare research [244–247], although not on medical experts, and provides a dynamic and interchangeable alternative to describe how individuals position themselves in interaction with others. The theory facilitated highlighting the changes in interaction that would come up from implementation. Furthermore, it supported the understanding of the results of the thematic analyses and made it possible to understand experts’ account of various approaches they used during consultations. When reviewing the material again with the theoretical frame of positioning, positions were compared and contrasted with each other until four positions were developed.

Ethical considerations

There are several ethical considerations to reflect upon regarding the thesis project. One has to do with patients in two different aspects (study I); gathering patient data from patients who are already injured and describing the characteristics found. Others have to do with the participating experts; for example, keeping the anonymity of the participants (study II, III and IV), and asking them to diagnose based on images (study III), the latter implying a judgement on their capacity as physicians. All participants in studies II, III and IV consented to participate in the research and it was made clear to them that their choice to participate or not would not affect their working conditions or their potential future involvement in the mHealth project. For study III, the online questionnaire was selected to provide the participants with the anonymity required and the participants were assured that their ability to diagnose would not be judged. The participants were therefore coded before the analysis of their responses so that not even the researchers would be able to identify individual responses. All electronic data have been password-protected from the very start and only members of the research team have had access to the data. No names or other information that might identify the participants have been disclosed in the presentation of the results during either oral or written presentations.

All of the studies were granted ethical approval from Stellenbosch University HREC prior to the start of data collection (HREC numbers N15/01/008, N15/03/018, N12/08/049 and N16/09/107).
RESULTS

What kind of injuries are seen at the emergency centres?

![Injury characteristics diagram](image)

**Main results**
- 6/10 patients were 19 years and younger and 2/3 of them were younger than 5 years
- 2/3 of the burns were due to hot liquids
- 1/10 were related to interpersonal violence
- 4/5 were minor to moderate burns
- Young children had the highest incidence but gender differences in incidence, circumstances and management were mainly observed among adults.
- Adult men were transferred to higher levels of care more often while a higher percentage of women were treated and discharged despite similar severity in men and women
- Lower extremities, trunk and upper extremities were the most commonly burnt body parts in children and adults and women and men.

![Figure 6. Summary of the results of the study on injury characteristics and the congruence model](image)

The main results of study I are presented in Figure 6. The number of burns patients presenting during the study period at the emergency centres varied between from 81 and 492 (unpublished results). Almost 60% of the patients seeking care were 19 years and younger, of which two thirds were under the age of five. Hot liquid was the most common mechanism (65.2%), followed by fire (11.3%) and contact burns (9.3%). Almost one in ten burns (9.3%) were reported to be related to interpersonal violence. Looking further into detail, the data show that hot liquid was the most common mechanism in both children (69.4%) and adults (60.3%), followed by contact burns in children (12.6%) and fire burns in adults (17.6%) (unpublished results).

Most burns patients came in with minor or moderate burns (80.4%), stayed shorter than 5 hours at the hospital (65.1%) and were treated as outpatients (73.9%) although it should be noted that a considerable amount of data are missing for AIS (17.0%), length of stay (21.3%) and patient disposition (3.5%). Of the patients that stayed longer than 5 hours at the
emergency centres, nine in ten (88.8%)\(^1\) met at least one of the criteria (Figure 5) [231] for referral to a burns centre (unpublished results).

**a) Gender differences**

The gender differences presented in this section are all significant. Young children had the highest incidence rates (75.4 per 10 000) and it was particularly high among children from the urban areas (91.9 per 10 000) with the highest rates from hot liquids (69.7 per 10 000). With the exception of boys 0-4 years in urban areas who were more affected by fire burns (M/W RR 3.29; CI 1.03-13.73), no gender differences were found among children. The highest rates among adults are found in the ages 20-39 (15.2 per 10 000) with the same rates in urban and rural areas. It was in this age group and among the over-55s that the incidence of men surpassed that of women in fire burns (M/W RR 1.55; CI 1.00-2.42) and hot liquids burns (M/W RR 3.38; CI 1.59-7.82) respectively. A higher proportion of burn-injured men sought care during weekends (53.4% vs 44.4%) and more often with suspected use of alcohol involved (7.6% vs 3.0%). A higher proportion of the burns in men were also reported to be related to interpersonal violence (22.5% vs 15.6%). Men and women had burns with similar severity and length of stay but a higher proportion of women were treated and discharged (82.8% vs 73.4%) while a larger share of the men were transferred to higher levels of care (9.8% vs 5.2%). This pattern can be seen in both hot liquid and fire burns but only reached significance on the mechanism level among those treated and discharged.

**b) Typical injury cases at emergency centres**

Table 2 shows the five most common body parts burned across gender and age groups. The lower extremities, trunk and upper extremities were the three most common single body parts burned in children and adults as well as women and men. A combination of burns on upper extremities and trunk was the fourth most common burn among adults seeking care at emergency centres, followed by burns on the head. Hand or head burns were the fourth or fifth most common burns among children, women and men.

Table 2. Five most common body parts burned among children and adults and women and men presenting to emergency centres in the Western Cape

<table>
<thead>
<tr>
<th>Body part</th>
<th>Children (n=1013)</th>
<th>Adults (n=900)</th>
<th>Women (n=904)</th>
<th>Men (n=1011)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Lower extremities</td>
<td>13.1</td>
<td>13.9</td>
<td>15.8</td>
<td>11.4</td>
</tr>
<tr>
<td>Trunk including buttocks</td>
<td>12.1</td>
<td>11.3</td>
<td>12.1</td>
<td>11.6</td>
</tr>
<tr>
<td>Upper extremities excluding hands</td>
<td>9.6</td>
<td>9.9</td>
<td>10.1</td>
<td>9.4</td>
</tr>
<tr>
<td>Hands</td>
<td>8.6</td>
<td></td>
<td>7.0</td>
<td>7.5</td>
</tr>
<tr>
<td>Upper extremities and trunk</td>
<td></td>
<td>7.7</td>
<td>8.1</td>
<td>7.1</td>
</tr>
<tr>
<td>Head</td>
<td>7.9</td>
<td>7.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Compiled by first removing all patients with missing data on length of stay or who stayed between 0-5 hours. Thereafter a step-wise analysis of fulfilling any entry criteria among the remaining patients was performed.
Are the images of satisfactory quality and are the assessments made on handheld devices by medical experts accurate?

**Figure 7. Summary of the results of the two studies related to image quality and diagnostic accuracy in the congruence model** [143,208]

The main results of study II and III in relation to the congruence model are presented in Figure 7. Images viewed on smartphone and tablet were rated significantly higher in terms of quality than when viewed on computer. These ratings hold true when testing for all types of images separately, except in the case of burns and other clinical images, where the differences between tablet and computer for burns images and between smartphone and computer for other clinical images were not significant. The medical specialty of the participants did not influence the ratings substantially. The type of device used to provide image-based advice did not seem to matter much among the participants since most of them stated that they would feel comfortable or very comfortable with providing image-based advice through any of the three devices (25, 26 and 22 on smartphone, tablet and computer respectively).

Using images representing the five most common cases of burns seen at the emergency centres in children and adults (Table 2), the assessments of burn size made on handheld devices resulted in high accuracy for both child (0.81; 95% CI 0.78-0.83) and adult (0.81; 95% CI 0.78-0.84) cases (Table 3). The assessments were accurate among all participants although slightly more among burns specialists from either South Africa or Sweden than emergency medicine specialists. South African burns specialists were slightly more accurate.
in their assessments of child cases than the emergency medicine experts while the participants in the three groups assessed adult cases with similar accuracy.

For burn depth, the assessments of child cases (0.61; 95% CI 0.55-0.65) were slightly more accurate than those of adult cases (0.46; 95% CI 0.40-0.52) although low overall (Table 3). Similarly as for burn size, the assessments made of child cases by South African burns specialists were slightly higher than those of emergency medicine specialists, and no differences were seen between the three participant groups in their assessments of adult cases.

Table 3. Diagnostic accuracy of burn size and depth assessments made on handheld devices by all participants and by participant group

<table>
<thead>
<tr>
<th>Cases</th>
<th>Participants</th>
<th>Size ICC (95% CI)</th>
<th>Depth ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>All</td>
<td>0.82 (0.81-0.84)</td>
<td>0.53 (0.49-0.57)</td>
</tr>
<tr>
<td></td>
<td>South African EM specialists</td>
<td>0.80 (0.77-0.83)</td>
<td>0.49 (0.43-0.55)</td>
</tr>
<tr>
<td></td>
<td>South African burns specialists</td>
<td>0.87 (0.85-0.89)</td>
<td>0.64 (0.58-0.69)</td>
</tr>
<tr>
<td></td>
<td>Swedish burns specialists</td>
<td>0.87 (0.84-0.89)</td>
<td>0.51 (0.43-0.59)</td>
</tr>
<tr>
<td>Children</td>
<td>All</td>
<td>0.81 (0.78-0.83)</td>
<td>0.61 (0.55-0.65)</td>
</tr>
<tr>
<td></td>
<td>South African EM specialists</td>
<td>0.77 (0.72-0.81)</td>
<td>0.54 (0.45-0.62)</td>
</tr>
<tr>
<td></td>
<td>South African burns specialists</td>
<td>0.90 (0.87-0.92)</td>
<td>0.75 (0.68-0.80)</td>
</tr>
<tr>
<td></td>
<td>Swedish burns specialists</td>
<td>0.83 (0.78-0.87)</td>
<td>0.59 (0.48-0.68)</td>
</tr>
<tr>
<td>Adults</td>
<td>All</td>
<td>0.81 (0.78-0.84)</td>
<td>0.46 (0.40-0.52)</td>
</tr>
<tr>
<td></td>
<td>South African EM specialists</td>
<td>0.79 (0.75-0.83)</td>
<td>0.44 (0.35-0.53)</td>
</tr>
<tr>
<td></td>
<td>South African burns specialists</td>
<td>0.85 (0.81-0.89)</td>
<td>0.54 (0.43-0.63)</td>
</tr>
<tr>
<td></td>
<td>Swedish burns specialists</td>
<td>0.87 (0.83-0.90)</td>
<td>0.45 (0.33-0.56)</td>
</tr>
</tbody>
</table>

Similar to those assessments made on handheld devices, the assessments made on computer of TBSA were high while those of burn depth were low (Table 4).

Table 4. Diagnostic accuracy and intra-rater reliability (handheld vs computer) of TBSA and depth assessments made on computer

<table>
<thead>
<tr>
<th>Cases</th>
<th>Accuracy ICC (95% CI)</th>
<th>Intra-rater reliability ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TBSA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.85 (0.82-0.88)</td>
<td>0.88 (0.85-0.90)</td>
</tr>
<tr>
<td>Children</td>
<td>0.90 (0.87-0.92)</td>
<td>0.85 (0.80-0.88)</td>
</tr>
<tr>
<td>Adults</td>
<td>0.82 (0.77-0.86)</td>
<td>0.87 (0.84-0.90)</td>
</tr>
<tr>
<td>Depth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>0.48 (0.41-0.55)</td>
<td>0.63 (0.57-0.69)</td>
</tr>
<tr>
<td>Children</td>
<td>0.50 (0.39-0.60)</td>
<td>0.65 (0.56-0.72)</td>
</tr>
<tr>
<td>Adults</td>
<td>0.46 (0.35-0.56)</td>
<td>0.62 (0.52-0.69)</td>
</tr>
</tbody>
</table>
**Additional observations**

Data from study II and III indicate the extent to which handheld devices are used in current medical practice. In study II, it was found that smartphone was the most popular device among the three to use for professional purposes (23 of the 27 participants). It was also the device most used for providing image-based advice, where 19 out of the 27 used it a few times a month for this purpose. In study III, conducted almost two years after study II, as many as 15 out of 26 participants used handheld devices a few times a week or more for image-based assessments. This was more common among the South African than Swedish participants with only 2 out of 15 being Swedish. Despite this, all participants bar two answered that they would feel comfortable using a teleconsultation system including analogous information and images as presented to them in the questionnaire, and all of them perceived images as a useful aid to diagnosing and giving advice about burns.

**What do the experts foresee?**

![Main results](image)

- Experts described several different positions with regard to their work; two concerned the diagnosis and their clinical competence – clinical specialist and gatekeeper – and two others, the relations with other clinicians – mentor and educator.
- Experts are already engaged in remote image-based consultation and trust that images could improve the accuracy of remote consultation, with implications above all for the clinical specialist, the gatekeeper and the mentor positions.
- They emphasise the importance of verbal communication for certain situations, in particular for the mentor position.
- Compared to using WhatsApp, the app is expected to promote learning (educator), make the experts more approachable (clinical specialist) and safeguard that the most relevant information is transferred (gatekeeper).

**Figure 8. Summary of the results of the interview study with the experts in the congruence model [143,208]**

The main results of study IV are presented in Figure 8. At the time of the interviews, it should be noted that consultation practices for remote advice were already changing since the interviewees had informally started to use images for this purpose, mostly by using WhatsApp. Four main positions that the experts move in-between in their work practice emanated from the material; two concerned the practice of diagnosing and their clinical
competence – clinical specialist and gatekeeper – and two others, the relations with other clinicians – mentor and educator.

**Clinical specialist.** The clinical specialist position involves clinical expertise in diagnosing and managing patients and consequently comes with both authority and responsibility. In remote diagnostic practices, images are perceived to improve the trustworthiness of the information that they receive from staff at POC and to facilitate making a diagnosis:

“It’s eyes on. I’m a surgeon, I need to see, even better, I need to feel, I need to be there, but if I can’t actually physically, I need to see because if you are not experiencing burns, what you are telling me, I can’t be sure that what I understand you to mean is actually what you mean.” (BS.7)

Even with the use of WhatsApp, certain additional information supporting the diagnosis, like for example how the injury occurred, is still transferred verbally and the experts envision that verbal communication will be important even with the use of the new app. The app is expected to modify the power dynamics and to make experts more approachable compared to current practices taking place via the hospital switchboard or WhatsApp, as there would be a dedicated system in place to link POC staff with experts. The quality of remote advice with the use of images, disregarding whether it is via WhatsApp or the app, is perceived to approach the quality of a bedside diagnosis. This has made the division of patient responsibility between POC and remote consultant more ambiguous and the app is not expected to clear up those ambiguities.

**Gatekeeper.** The gatekeeper position entails the monitoring of the patient flow so that patients are managed at the right place according to their needs. This position overlaps with the clinical specialist since an accurate diagnosis supports the decision on where patients should be managed and the start of the use of images has changed also the gatekeeper position. The usefulness of including images in the referral process is expressed by the experts, in particular for those patients where there are uncertainties about the need of referral. Images are perceived to increase confidence in the information that staff at POC provide to them and to make the referral process faster and more efficient:

“We’ll use WhatsApp, saying “This is what I’ve got, what do you think?” and we’ll make a decision on transfer from those pictures. And they can also e-mail us; then ultimately we use a formal e-mail reference. But for that initial decision it’s all made on cell phone images.” (BS.4)

When comparing with WhatsApp, the experts express that the app would provide a safer way to transfer images between staff at POC and experts. The app is also expected to formalise the WhatsApp practice and ensure that relevant information is transferred:

“To have an app, it just makes it more structured. The app asks you the right questions, so you give the right answers.....That’s really helpful because like I said, people don’t always know what’s important” (BS.7)
A problem highlighted by the experts that could reduce the willingness among POC staff to use the app is if expert advice cannot be followed due to lack of resources and patient beds. Some information supporting the decision to transfer a patient or not, like for example social circumstances of the patient or capacity of staff at POC, is often communicated verbally. The experts posit that this kind of information could be lost by using the app.

**Mentor.** Supporting junior doctors and staff at POC is described as an important task for experts. The perception among experts is that burns patients are regarded as emotionally challenging by staff at POC due to the extreme pain and the seriousness of the situation. The most extreme situations where the support of experts is needed are when patient survival is uncertain:

“Being overwhelmed by this really bad burn and knowing that it’s wrong for them to take up a bed in some way and having to make that decision, particularly for a junior provider to say well, I’m not going to do anything for this patient, I’m going to leave them here to die, or I’m going to let their family come in and then I’m going to intubate them and its...that actually needs quite a lot of support.” (EM.8)

The experts describe images helpful in this situation to set an accurate diagnosis and to allow experts to shift between the mentor and the specialist position more easily for diagnosing and taking responsibility:

“I will usually ask them to send me a photo so I can just see what they are seeing, to just see if they are giving me an accurate description of the burn depth, because the worst thing is that you don’t want to make an error when it comes to withdrawal of therapy...” (BS.3)

According to the experts, the app could provide some additional benefits for improving the accuracy of diagnosis and also include some basic advice on palliative care, but they also accentuate the importance of verbal communication in these situations, which is why this position is expected to change the least with the implementation of the app.

**Educator.** The experts perceive education and empowerment of staff at POC as a key mission in their work. Using WhatsApp images in remote consultation allows this expertise to expand beyond the staff within the unit. The structured way of filling in information that the app offers is expected to promote learning and could provide a benefit compared to WhatsApp:

“So I think the app will offer a more structured approach and the doctor also will learn about the information he needs to gain. Because the app will guide you: How was the patient burnt? How old is the patient? The structured approach....helps the junior doctor to form processes.” (BS.6)

It is also hypothesised that this could in some way take over the role of experts to educate staff at POC but at the same time, they do stress the advantage of a pleasant voice making verbal communication difficult to replace fully.
DISCUSSION

Main findings

The four studies of the thesis have contributed knowledge on the aspects of input, task and people in the congruence model. The main findings will be discussed in light of these aspects considering four broader themes. Thereafter, methodological considerations of the studies will be discussed.

Attributes of the acute burns cases seen in emergency centres

The input relates, in this application of the congruence model, to the kind of injuries seen in emergency care. By looking at the injuries, their distribution and management, a few suppositions could be made regarding the suitability of image-based consultation with regard to burns. To start with, burns are a common injury with new patients presenting between once or twice a week and once or twice a day depending on facility. The caseload of burns presenting at emergency compares in many ways to that seen in previous studies in resource-poor settings, like, for instance, the overrepresentation of young paediatric patients among non-fatal burns, seen previously in the sub-Saharan region [148–160] and in LMICs in other parts of the world [161], or even the rather minor and moderate severity of the injuries sustained, observed previously in studies from the region [148,156,157,160,166], with a few exceptions where children [167] and adults [148] had more severe burns. The preponderance of hot liquid burns in children is also consistent with the bulk of earlier studies [148–150,153,156,157,160,166–169] but the preponderance among adults comes a bit more as a surprise as flame burns often outnumber hot liquid ones [148–150,153,162,163]. Therefore, the kind of injuries seen in emergency care, the input, does not indicate specific challenges for the tasks that should be completed related to remote diagnostic assistance of emergency care patients. One hesitation might be the larger burden of hot liquid burns among adults since remote assessments of scald burns were reported to be slightly less accurate than those of flame burns in a prior study [248] and it is possible that those burns are more complicated to assess this way. The need for the practice of remote consultation is highlighted by the high number of patients seen in emergency care that are in need of a referral discussion regarding the necessity of transfer to specialised care. These findings altogether indicate that there is good potential for this kind of consultation in this clinical practice. There were, however, certain structural problems related to the input that were expected to remain with the app in place, like for example that the system is undersized. The app cannot create more beds but
could support appropriate patient flow where burns patients are treated at the right place according to their needs.

Questions around potential gender differences among burns patients in sub-Saharan Africa have been raised in earlier studies [163,175]. Studying these issues could be a way to lift the potential problem of gender-based differential treatment and prevent it from happening when using the app. The findings around differences in referral between men and women are not easy to explain and deserve special attention. A recent study on paediatric burns from the same area present similar results [185]. Whether these differences are related to severity factors that could not be captured in the material or reflect actual gender differences in healthcare such as the views of healthcare staff on female and male patients or from requests from individual patients or circumstances around the injury is unclear.

**Performance of experts when assessing**

The task is studied by looking at the specific moment of assessing the burns using handheld devices and the findings with regard to the accuracy of the assessments both support and contradict each other. The experts appreciate the quality of images viewed on smartphones and tablets, similar to findings reported about radiological images viewed on tablets [59], and are familiar with using handheld devices for viewing clinical images, a practice that has been reported also from other areas and regions [89,92,93,95–99,101,102,104]. Experts’ assessments showed that, at least, burn size could be accurately assessed based on images viewed on handheld devices. This finding is in line with previous studies [236,248,249] and has considerable implications for the initial management of a burn [250] and lays the foundations for more appropriate management and referrals of patients. The findings in relation to burn depth were of a more troublesome nature with lower accuracy in general. The results are in-between those of previous research showing more [248] and less [236] accurate remote assessments of burn depth. Burn depth assessments challenge experienced providers even at bedside [251] but it is possible that the results of study 3 are on the conservative side since the assessments were made based on limited information complementary to the photographs which would be different in real practice where more information could be requested. This might be particularly important for supporting the assessments of burn depth.

The differences seen between the two South African specialties are likely to be related to varying experience and training in burns care. Indeed, it was discussed in the free text comments by some participants that emergency medicine specialists are more used to assessing burn size than burn depth since they use it for calculating fluid resuscitation for initial management while depth assessments are more a task involving burns experts to assess the need for surgery. This finding implies the potential for improvement by training image-based diagnosis.
Interactions among clinicians using smartphone messaging apps

The people in the organisation are the ones who perform the tasks and have been studied focusing on the perspective of the experts. Experts’ current use of WhatsApp and other smartphone messaging apps for image-based consultation indicates their interest in a digital solution and is reported in three of the studies. Their use also points to there being a place for this kind of consultation in the organisation around burns care in the setting and that experts are open to changing their work practices. The advent of using images and WhatsApp have affected all four positions of the experts by facilitating accurate diagnosis (clinical specialist), speeding up decisions regarding referral (gatekeeper), taking responsibility for decisions (mentor) and expanding expertise (educator). However, the satisfaction that many of the experts expressed regarding WhatsApp in comparison to how consultation used to occur (by telephone without the use of images) may interfere with their acceptance of the proposed app. It is clear that the people in the organisation – experts and frontline staff – are creating informal ways around the formal organisation of burns care. Although the app is expected to contribute additional benefits compared to using WhatsApp by making the experts more approachable (clinical specialist), providing a safer way to transfer patient information and safeguarding that the most relevant information is transferred (gatekeeper) and promoting learning (educator), it could have difficulties integrating with certain parts of this informal organisation. One such difficulty is the WhatsApp’s networking feature, in the form of a group chat function and profile pictures where there is a thin line between the clinical and social dimension. While this is an appreciated characteristic among users [103] that could promote better relations between providers, it raises concerns when social and personal conversations occur in-between discussions around for example patients’ medical issues [94,252–254]. Furthermore, it was clear that the perceptions around WhatsApp came with mixed feelings and some experts communicated discomfort around the informal consultations taking place. They were still using it since it was a functioning system that came with substantial benefits compared to the conventional telephone consultations but expressed a need of a formal system for burns, mostly because of issues around patient confidentiality and data security.

The value of verbal communication

Interacting verbally is a crucial element for certain collegial interaction and this was of particular importance for the mentor position: verbal conversation has been emphasised for critical issues in earlier studies [97,255], which is in line with the findings from this research. Texting via SMS on complex medical matters [124] has been reported to lead to misunderstandings from loss of context and loss of personal contact. In addition to these critical situations described by the experts, verbal communication was also used for contextual information of importance for management and referral decisions of a more informal character. By the use of WhatsApp, verbal communication is an expected part of the interaction between experts and POC. A chat function in the app may be a partial substitute.
for verbal communication by providing a link between the informal and formal organisation albeit the humane dimension of communicating verbally might still be needed for certain situations. Unlike WhatsApp, this is not currently an available feature in the app and this could lower the acceptance of, and interest, in using it.

**Methodological considerations**

The studies of the thesis are based on data collected with different methods, both quantitative and qualitative, and provide various perspectives on burns diagnostics. There are several methodological considerations and these will be discussed for each of the three different approaches used. The first one is related to collection of hospital data (study I), the second one deals with questionnaire data via online surveys in different ways (studies II & III) and the third and last one with interview-based studies (study IV).

**Collection of hospital data**

The study is based on hospital data routinely collected for other purposes and reviewed retrospectively for the specific purpose of this study. A few strengths should be mentioned to start with. First of all, data collection was performed systematically and there were a minimum of two trained data collectors present at each facility. Moreover, considerable volumes of data were captured during an extensive time period and the data were cross-checked to control consistency. The many and repeated visits to each facility contributed to an understanding of the healthcare setting and the procedure around patient register and records.

As is often the case with data of this kind, some data were missing. There are no reasons to expect systematic biases for most of the variables under study but it can be underlined that, in one of the participating hospitals, the records of some of the patients coming after hours could not be found. This has influenced the compilation of the burn incidence rates and it may also have introduced an underestimation of gender differences if, as it seems, male patients are more likely to present in the evening or at night.

Another problem in line with that is the fact that there was some information missing from the patients (in the files). This problem is related to factors surrounding the attending physician and nurse and the hospital environment with varying patient load and staff culture. There is no reason to suspect this would affect women or men differently.

Since there are other healthcare facilities in the uptake areas where individuals could seek care, the burn incidence rates presented underestimate the burden of burns but severe burns would all be referred to any of the facilities included. The rates are also affected by the choice of catchment areas and the population data used as denominators. The same catchment areas used for healthcare planning were used in this research which should be a close estimate of
the population to be served. Concerns about overestimation of the provincial population in general as well as overestimation of the age group 0-4 years have been raised in relation to the census data used. This would imply that the burn incidence rates are underestimated in particular in the youngest age group. Any potential gender bias in the census data has not been reported. Underestimation of involvement of violence and alcohol in burns is common and could be the case in the material used here but whether this would affect the reports of women and men differently is unknown.

**Online questionnaires**

There are several methodological strengths related to the design of the two studies. Both were conducted in life-like lighting conditions to simulate clinical practice. The images were also presented to participants in random order to avoid any effect of response fatigue. Furthermore, all participants assessed all images and the number of missing answers was negligible for both studies.

Some common considerations with the two studies should be mentioned. A random sample of experts could have strengthened the potential for generalisation but this was not possible due to the few number of burns experts. It is uncertain, however, whether a random sample would have yielded different results. Furthermore, for both studies, the images were compiled from different sources, which is why we could not control for different resolutions. This could have influenced experts’ abilities to make an accurate diagnosis although there is no standard resolution in the images used in clinical practice.

In relation to the study on image quality, differences in pixel density between the different screens could affect participants’ perception of the quality. Indeed, the computer screen has a lower spatial resolution than the smartphone and tablet. It is also possible that participants had a preference for one of the handheld devices from the start and that this could have affected the results since size differences made complete disguise impossible. To further prevent any possible effect on the results deriving from response fatigue, the order in which the devices were presented to participants was predetermined. Furthermore, the brands of the devices were hidden to avoid preference for any specific brand. It is of note that the devices used in the study were selected to reflect the devices used in low- and middle-income settings, hence the computer used as reference was a recent model to warrant optimal screen quality and the two handheld devices were of slightly older models. It is therefore likely that similar or even better results could come from using more recent models.

In relation to the study on diagnostic accuracy, participants could choose which device they wanted to use for replying, reflecting reality in clinical practice. The time between the handheld device- and the computer-based questionnaires was enough to limit the effect of recall bias given the high number of images to assess. The number of images was decided bearing in mind sample size recommendations for validation studies [235] and the limited
time available for experts. Lastly, participants were given the possibility to interrupt and resume working on the questionnaire as a measure to limit the effect of response fatigue and to take into account their limited time. Participants were given little information about the burn and the patient which is different from clinical practice where the expert has the possibility to ask for more information. Another consideration that could contribute to the lower accuracy of the assessments of depth is that, although few, images with several burn depths were included. This has in the past been reported to lower the concordance of assessments of depth [248].

**Expert perspectives**

This interview study has several methodological strengths. A first one is the sample of participants that includes various perspectives with experts from different levels of care and specialties, with a broad range of years of experience, and both women and men of different ages. Being two interviewers present allowed for different perspectives in approaching the interviews and the two different backgrounds and experiences complemented each other well. The member checks helped to clarify any identified doubts about what the participants meant to convey. By spending time and become more familiar with the work environments of the participants, some of the practices described by participants could be compared to what was observed in the facilities.

While every effort was made to make the study more robust and trustworthy, some potential sources of bias should be discussed. One is the fact that some of the interviewees knew about the app from having seen or heard about it prior to the interview. How much this affected the interviews is not easy to estimate. This was presented as a limitation in the published article but it could also be considered a strength since it contributes variability among the participants and could increase the transferability of the findings. Irrespective of whether they had prior knowledge of the app or not, they all shared good and bad experiences and expectations and came up with recommendations for improvements. Another potential source of bias is that the number of eligible participants is small which could lead to concerns about privacy among the participants. However, the response rate was high and the interviewees were all generous in sharing examples of their experiences from their day-to-day practice and their expectations of potential changes that could come from the implementation of the new app. Furthermore, being two interviewers present could create a power dynamic that would leave the person being interviewed feeling intimidated although no sign of discomfort was noted among the interviewees.

The interviews were planned knowing that WhatsApp was already used for sending images in remote consultations but without knowing the extent of this use. Participants were therefore less hypothetical in their answers than expected and both the scope of the use and their willingness to share their experiences about it came as a surprise.
The researcher is never neutral in qualitative research processes [256] and my role in the project affected both how the participants viewed me and my understanding of their responses. Indeed, some of the interviewees were known to me and I was known to them from meetings during early phases of the project. Even though I had been disconnected from the project for a long while, some of the interviewees could still have regarded me as representative for the project. To deal with this, after each interview, we interviewers took time to discuss and reflect on our understandings of the interview, not only between ourselves but also with the others in the research team to air out any potential emotions that could affect the process. Being multiple researchers involved at all stages, from the planning phase to analysis and presentation of the findings, enabled us to share and reflect on preconceptions and new understandings throughout the process.

**The use of the congruence model**

Using the congruence model as a conceptual framework for the studies of the thesis helped to link the four studies to the change that was about to take place. It supported the understanding of a few of the aspects that would challenge the implementation, acceptance and use of the new app. Formal and informal organisation were not studied and it is therefore not possible to assess the congruence of the organisation around these aspects of burns emergency care. The studies took place before the app is in place which is why the development of the accuracy, how it develops over time and the dynamics around it have not been captured. Neither has it been possible to measure the output and the outcome of the system, in terms of net benefits for the healthcare system, patients, users and society at large.

**Implications for research, policy and practice**

The studies forming the thesis took place before the actual implementation of the app and the findings point to a few areas of research that would be valuable to focus on during implementation of the app or thereafter. To start with, the potential gender differences in referral and outpatient care seen in this material warrant further research in order to follow up and deepen the understanding on whether they actually exist, and if so, study plausible reasons behind them and how to counteract them to even out the differences. Another area of research is to examine the diagnostic accuracy of remote consultations of burns in real practice by using data related to the consultations made through the app. That kind of study could also explore whether the accuracy and advice change over time and are affected by certain injury and patient characteristics like, for example, mechanism and sex. It would also be of value to see if and in what way the use of the app affects the skills of POC staff. Furthermore, studying the perceptions of the experts when the app is in place would help clarify how and why it is used or not used and what obstacles exist, whether the use has a
positive effect on work flow and relations to other healthcare providers and to identify any unexpected consequences of its use.

From an implementation point of view, studies including all users focusing on usability and satisfaction, as well as studies on formal and informal organisation, outputs and outcomes would make an important contribution to expanding the evidence base of mHealth. The public health impact should also be assessed but the widespread use of WhatsApp and other smartphone messaging apps makes it difficult to perform well-designed outcome studies.

The use of WhatsApp and the discomfort communicated by the experts around security and patient confidentiality issues emphasise the need of regulations regarding the use of different types of social media in healthcare. The need for legal and ethical standards is emphasised in several studies, both in relation to mHealth in general [57,91,106,114] and to informal systems using WhatsApp [89,91]. The discussion around how to develop guidelines of mHealth and the use of mobile phones in medical practice is ongoing [257,258] but clear guidelines remain to be put in place. South Africa is one of many countries where legislation around telemedicine is still lacking [91]. If such a regulation would restrict the use of WhatsApp due to patient confidentiality and data security issues, functioning alternatives should be available to not risk a backlash in patient care since the use of images is perceived to improve the consultation process.

The fact that the majority of the patients came in with burns of a less severe nature indicates that people are actually reaching care. A large share of the burns that were treated fulfilled, either by age or other factors indicating complex burns, the provincial criteria for referral to specialised care implemented by the Western Cape Government Department of Health. Those burns would potentially be the target for remote consultation. An increased demand on specialised care can be expected if these criteria are followed. The findings also point to a need to dedicate more resources to burns care to deal with the structural problems that were highlighted.

Given the differences seen between the two South African specialties and the possible advantage of being familiar with the type of cases, it is possible that training on making image-based diagnoses could be a way forward to improve the accuracy of assessments.

Looking at the app from the experts’ perspective, they were in general positive towards a dedicated burns app in their practice. The findings point to the importance of including communication alternatives within the app, for example a chat function (which is now included in the current version of the app) and maybe even the possibility for verbal communication.
CONCLUSIONS

As a whole, the results of the thesis contribute important information regarding the implementation of a mHealth application for diagnostic consultation among clinicians in resource-poor settings in the particular case of acute burn injuries.

To begin with, emergency care services seem to treat burns patients with individual and injury characteristics comparable to those described in other levels of care, including a predominance of children and of injuries caused by hot liquids and a large proportion of relatively minor or moderate burns. Not surprisingly, gender-based analysis also indicates that adult males are more at risk of sustaining burns than females. Yet, for unclear reasons, men tend to receive more care than women do for seemingly similar injuries.

When it comes to images, a fundamental element of the type of consultation at stake, it seems that the use of a smartphone as a way for clinical experts to view the images that are sent to them finds support in two different ways. First, experts from the field consider that images are of better quality when they see them on smartphones and tablets than on computers. Second, experts can accurately assess burn size by simply looking at images on their smartphones. In the case of burn depth, pictures alone may not be sufficient and additional information could be required. In real clinical practice, with the possibility of asking for more information, more accurate results could be expected.

Finally, clinical experts describe four positions in remote consultation practices – clinical specialist, gatekeeper, mentor and educator – all of which are expected to change with the introduction of the new app. The fact that most experts are familiar with clinical communication via WhatsApp indicates a feasibility of the concept although voluntariness might play a role in their acceptance. The app is expected to improve security issues, approachability of the experts and information quality compared to current image-based consultation. The difficulty to replace verbal communication and to integrate with the informal organisation could challenge the implementation of the app.
ACKNOWLEDGEMENTS

My deepest gratitude goes to the participants in the studies, thank you for generously sharing your valuable time and experiences. I feel humbled by the great work that you are doing.

I have been privileged to have a magnificent team of supervisors: Professor Lucie Laflamme, Associate Professor Marie Hasselberg, Dr. Helle Mölsted Alvesson and Professor Lee Wallis. Thank you for your guidance, inspiration and support during these years.

Lucie, I feel so fortunate to have been given the opportunity to be a student of yours. Thank you for the patience and the strong support you have given me, both professionally and personally. You inspire me with your passion for research, quick mind, strong will and enthusiasm, always finding a solution, a plan b, c or d. Thanks also for giving me a chance to enter the world of injury prevention and for introducing me to South Africa.

Marie, thanks for being the wise, calm and considerate person you are, always with great input and thoughts. Thanks for listening, asking good and tricky questions and for the encouragement, support and positive energy that you have given me, both in work and life.

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Lee, being a true emergency medicine specialist, you really make things happen! Thanks for finding solutions, for having the clinical eye on everything, and for your generous hospitality and making me feel welcome during all my stays in Cape Town. Thanks also for the unforgettable experience of grape harvesting.

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A special thanks to the ISAC group: Constance, for being a great co-author, accurate and careful and a very considerate and amusing friend. Thanks for thoughtful advices and encouragement, I am deeply grateful for having you by my side. Mathilde, for all the supportive talks and empowering energy and for your engagement with my family. Anders, for good company and well performed field work. Encarna, for being the beautiful character you are and always caring, thanks for checking in on me. Ritva, for insightful comments regarding research and family matters. Chris for being a great office-mate and for encouragement. Hans-Yngve, Joel, Alicia and Uzma for good discussions and friendship.

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Johan Lundin, for being the brains behind the technology, for nice conversations and for your considerate and wise words in relation to our little Ingo.
Those who have enlightened my stays in South Africa:

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Thank you Pontus, Sazia, Henrik and Rimy for helping out collecting data and Sharon for great translation support during field work.

Christa and Frans, I wish we did not live on different sides of the globe. Thanks for great moments together.

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At Karolinska Institutet:

Thanks to all fellow PhD and colleagues at IHCAR, such a beautiful bouquet of people. I have really enjoyed being among all of you friendly, hardworking and inspiring individuals: Anna B, Sandeep, Ashish, Krushna, Meena, Netta, Joanne, Lien, Hind, Elin, Anastacia, Linus, Xin, Ketkesone, Eladio, Senia, Hamideh, Tazeen, Salla, Yanga, Hanani, Abela, Ziad, Klara, Agnes, Christine, Justus, Owolabi, Hana, Patricia, Susanne, Ulrika, Helga, Linda, Martin, Galit, Veronica, Erika, Andreas, Lungile, Juliet, Gaetano, Ingvild, Karin, Rocio, Jhon, Tjede, Theodora, Tim, Oliver, Jesse, Arun, Cecilia, Guobin, Dorcus, Dell, Anna M, Anna K, Emilia, Nada, Sigga, Helena, Olivia and many more.

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Thanks also to the senior researchers at IHCAR and PHS for your encouraging words and for checking in to hear about how everything is going in life and research: Asli Kulane, Vinod Diwan, Rolf Wahlström, Cecilia Stålsby Lundborg, Mariano Salazar, Primus Che Chi, Elisabet Faxelid, Birgitta Rubenson, Anna-Mia Ekström, Claudia Hanson, Tobias Alfvén, Johan von Schreeb, Anneli Eriksson, Jette Möller, Karin Engström, Anna-Berit Ransjö-Arvidsson, Kerri Viney and Birger Forsberg.

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Lasse and Ellinor, Lotta and Kent, I appreciate your encouragement and consideration.

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Mom and dad, thank you for a childhood full of love and for the unconditional love you show Anna, me and our families every day. Thanks for always being there, for all your dedication and support in everything. You are simply the best!

Anna, my strong, multi-talented, extremely efficient and, above all, caring and loving sister. I am so happy that we have each other. Thanks for bringing Åke and Ingrid into my life and for everything you do for us. Åke and Ingrid – please continue being those great role models you are for Ingo and Sonja – you are outstanding!

I will never be able to thank enough Dirk Wackernagel, Martino Corrias, Ewa Henkel, Mats Blennow, Tulliki Stendahl, Stella Lisroth, Katja Fogelberg, Jessi Stenqvist and all the other extraordinary people at K76-78, Karolinska University Hospital in Huddinge, who helped our family during the critical early months of Ingo’s life. We are forever grateful.

Mattias, a lot has happened since that early Sunday morning eight years ago. I am so happy that it was you I had by my side when our life turned upside down. Thanks for being the most beautiful father to our kids, for taking care of the ground work during busy periods, for the late nights you spent making me a cover illustration and for waking up smiling with me.

Ingo and Sonja, my little trolls, you put magic into my life. I cannot believe how lucky I am to have you.
REFERENCES


57


[126] Lemaire J. Scaling up mobile health: elements necessary for the successful scale up of mHealth in developing countries. 2011.


## Appendix 1. Injury case report form

<table>
<thead>
<tr>
<th>Name of hospital:</th>
<th>Patient/hospital number:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of admission:</th>
<th>Time of admission:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date of injury (if different than consultation hospital):</th>
<th>Time of injury:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Injured person

<table>
<thead>
<tr>
<th>Age:</th>
<th>Sex:</th>
<th>Place of residence:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>☐ Male ☐ Female ☐ Unknown</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupation:</th>
<th></th>
</tr>
</thead>
</table>

### Health condition of injured patient

#### Pre-existing illness

- HIV/AIDS
- TB
- Diabetes
- Depression
- Other (specify):

#### Drug therapy

- Antidepressant
- Steroids
- Other immune-suppressing medications (specify)

#### Allergy

- Known allergy
- Drug allergy/sensitivity (specify name of drug)
- Other (specify):

### Injury description

#### Mechanism: How was the burn inflicted?

- Fire/Flame
- Hot object
- Hot liquid
- Steam
- Chemical
- Frozen object
- Electrical
- Other (specify):
- Unknown

#### Intent

- Unintentional
- Self-Harm
- Intentional (assault)
- Other (specify):
- Unknown

#### Body part(s) injured

- Head
- Neck
- Upper extremities (without hands)
- Hands
- Trunk /back
- Trunk /chest
- Lower extremities
- Multiple body parts
- Unknown

#### Injury Severity

- Body surface injured: %
- Burn depth:

#### Abbreviated Injury Severity Scale (burn wound)

- Minor
- Moderate
- Serious
- Severe
- Critical
- Fatal
**Injury treatment**

How were the injury and patient managed?

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dressings</td>
<td>2. IV fluid</td>
<td>3. Nutritional supplementation</td>
</tr>
<tr>
<td>7. Other (specify):</td>
<td></td>
<td>99. Unknown</td>
</tr>
</tbody>
</table>

**Injury circumstances**

Place of injury

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Other (specify):</td>
<td></td>
<td>99. Unknown</td>
</tr>
</tbody>
</table>

Activity at time of injury

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Sport</td>
<td>6. Travelling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Other (specify):</td>
<td></td>
<td></td>
<td>99. Unknown</td>
</tr>
</tbody>
</table>

Alcohol use: Did you use alcohol within 6 hour of the incident?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Suspected by report or confirmation</td>
<td>2. No information</td>
</tr>
</tbody>
</table>

Substance use: Did you use a mood-altering substance?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Suspected by report or confirmation</td>
<td>2. No information</td>
</tr>
</tbody>
</table>

**Additional information about the injury circumstances**

<p>| |</p>
<table>
<thead>
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</table>

**Transport to and disposition at the hospital**

Transport to hospital

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Self/Private</td>
<td>2. Police</td>
<td>3. EMS</td>
<td>4. Other (specify)</td>
</tr>
</tbody>
</table>

Transported from

<p>| | | | |</p>
<table>
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<tr>
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</table>

Disposition at hospital

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Treated and discharged</td>
<td>2. Admitted to ICU</td>
<td>3. Admitted to burn unit</td>
</tr>
<tr>
<td>4. Transferred to other hospital</td>
<td>5. Died</td>
<td></td>
</tr>
<tr>
<td>6. Other (specify):</td>
<td></td>
<td>99. Unknown</td>
</tr>
</tbody>
</table>

**Length of hospital stay**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. _____ hrs</td>
<td>2. Overnight</td>
<td>3. _____ days</td>
</tr>
</tbody>
</table>
Appendix 2. Image quality questionnaire

Example of the questions asked in relation to each image:

How would you rate the overall quality of this picture when viewed on this device?

<table>
<thead>
<tr>
<th>Excellent</th>
<th>Very good</th>
<th>Good</th>
<th>Neither good nor bad</th>
<th>Poor</th>
<th>Very poor</th>
<th>Terrible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

Comments

Questions regarding perception of image quality and use, asked for each device:

Having been exposed to all the images, please provide your comments on features of image quality:

- Definition of Terms:
  - Colour – The colour of the patient’s skin, injuries, etc.
  - Contrast – The difference in brightness between the light and dark areas of a picture
  - Resolution – The fineness of detail that can be distinguished in an image
  - Focus – The distinctiveness or clarity of an image
  - Composition – The general makeup of the image (in terms of the body, etc)

Please rank the features of image quality you find most important, with 1=most important and 5=least important.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contrast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Focus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Did you use the zoom to look at the images?

- Yes, for all
- Yes, for many
- Yes, for a few
- No

If you used the zoom, how useful was it to make your decisions regarding imaging quality?

<table>
<thead>
<tr>
<th>Totally useful</th>
<th>Useful</th>
<th>Neither useful or not useful</th>
<th>Not useful</th>
<th>Not useful at all</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments

How often do you use this type of device to look at images for personal purposes?

- Every day
- Once a week
- A couple of times a month
- Once a month
- A couple of times a year
- Never

Other (please specify)

- Please specify
How often do you use this type of device to look at images for professional purposes?

- Every day
- Once a week
- A couple of times a month
- Once a month
- A couple of times a year
- Never

Other (please specify)

How often do you use this type of device for image-based teleconsultation?

- Every day
- Once a week
- A couple of times a month
- Once a month
- A couple of times a year
- Never

Other (please specify)

Would you feel comfortable using this type of device for image-based consultation?

<table>
<thead>
<tr>
<th>Very Comfortable</th>
<th>Comfortable</th>
<th>Neither comfortable nor uncomfortable</th>
<th>Incomfortable</th>
<th>Very Incomfortable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you have any additional comments?


Demographic data collected at the end of the final survey:

What is your age?

What is your qualification?

What is your country of practice?
Appendix 3. Diagnostic accuracy questionnaire

**moBurnZA Handheld Diagnosability**

**Device information**

* 1. Please specify the type of device you are using to answer this survey:
   - [ ] Smartphone
   - [ ] Tablet

* 2. Please select the brand of the device:

[ ]

* 3. Please specify the model of your device with as much details as possible:

[ ]

* 4. How often do you use this type of device for image-based remote assessment?
   - [ ] Every Day
   - [ ] A few times a week
   - [ ] Once a week
   - [ ] A few times a month
   - [ ] Once a month
   - [ ] A few times a year
   - [ ] Never
* 1. What is your country of practice?

* 2. What is your age?

* 3. Please enter your medical qualification(s):
   - Medical Officer
   - Registrar
   - Specialist Surgeon
   - Specialist Emergency Physician
   - Other Specialist
   Other (please specify)

* 4. How would you describe your experience with acute burn care:
   - Extensive
   - Moderate
   - Minimal
   - None

* 5. Please estimate the number of burn patients you have managed over the past 6 months:
Example of one of the 51 cases:

**Case**

Description: 1 year old, female, hot water burn, right arm

---

* 1. Please choose the depth of this burn injury:
  - [ ] Superficial partial thickness
  - [ ] Mid partial thickness/indeterminate
  - [ ] Deep partial thickness
  - [ ] Full thickness
  - [ ] Other (please specify)
Confidence Assessment

* 1. Please rate your confidence in making a diagnosis from the images in this survey:

<table>
<thead>
<tr>
<th>Completely Confident</th>
<th>Mostly Confident</th>
<th>Confidence varied depending on image</th>
<th>Poor Confidence</th>
<th>No Confidence</th>
</tr>
</thead>
</table>

* 2. How comfortable would you be to use a telemedicine system, using similar images and information, for the management of burn patients in the future?

<table>
<thead>
<tr>
<th>Completely Comfortable</th>
<th>Somewhat Comfortable</th>
<th>Somewhat Uncomfortable</th>
<th>Completely Uncomfortable</th>
</tr>
</thead>
</table>

* 3. How helpful are images in making a diagnosis and providing advice in burn care?

<table>
<thead>
<tr>
<th>Helpful</th>
<th>Images make no difference</th>
<th>Counter Productive</th>
</tr>
</thead>
</table>

4. Please add any comments regarding your concerns (if any) regarding the diagnosis of the images in this survey.
Appendix 4. Interview guide

Work experience in the health sector and with using telemedicine

We are discussing today a new App which seeks to benefit healthcare by exploiting the use of telehealth, or telemedicine. This kind of technology can obviously take many forms, but we are primarily interested in hearing about your experience of image based telemedicine systems. We would like to begin however, by hearing about your experiences in health care in general.

1) Could you tell me a bit about your current role and how long have you been working there / in this health care facility?

2) Where did you work before here? / Would you describe for me your career path leading up to this point?

3) In your previous roles, aside from this project, have you ever come across or used what you think of as image based telemedicine before?

4) When did you first encounter this particular Telehealth project (mHealth for burns diagnostics and care South Africa)?

Experiences of diagnosing burns patients at bedside and remotely

Before we discuss the App we would like to understand more about the context and your current working practice as an expert, without the App in place. So for these first questions we’d like you to tell us how things work at the moment, without the App.

Assess fresh burns
5) In your current practice, do you regularly assess patients with fresh burns at point of care?

Challenges assessing
6) When you assess a new patient yourself, at bedside, could you tell me, what are the most challenging aspects of assessing a new patient?

Remote advice
7) a) We understand that giving advice remotely on burn patients occurs in your work. Is that correct?
   b) Is there a standard procedure or protocol for this, or how does it happen otherwise?
   c) Do you find advising in this way challenging? And if so, in what way?
   d) We believe a part of your work can also involve discussing referrals. So we would like to know on what grounds the decision is made to refer a patient for further treatment?
   e) In your experience how often is there discordance between the clinical information you receive remotely, say over the phone, and the clinical information you observe when the patient arrives to your care?
   f) When you discuss a case in this way but it is decided that the patient does not need referral, or cannot be referred at this time, is it common that you will give, or be asked to provide management advice for the treatment of the patient in the remote location?
Experiences and views on the new App

Thank you. We would now like to ask about your thoughts or pre-apprehensions about the introduction of the App, so in the following questions we’d like to ask you to imagine the situation you envisage once the App has been implemented as a tool in your work place.

Changes from the App
8) Could you tell me about what sort of effects do you think the App will have on the processes you have described, and your advisory role?

Daily workload
9) a) When first introduced, do you think the App is going to influence your workload or daily tasks? Say during the first 6 months?
   b) And what about it the long term? Could it have any effect on work burden or tasks in a long term capacity?

Colleagues
10) Do you anticipate any changes in your relationship to remote clinicians, considering how you communicate with them now and how you will communicate with the new App?

Patients
11) a) Can you foresee any positive factors or outcomes through introduction of the App, from their points of view?
   b) Do you see any risks or disadvantages for patients with the introduction of the App?

Healthcare System
12) a) Can you foresee any potential challenges in the health care system in relation to the implementation of the App – or of similar systems?
   b) Do these changes (as mentioned) have any implications for your role as expert in the broader healthcare system?

Technology and usability
13) a) From your experience with using the App so far or from your introduction to it, do you anticipate any issues relating to the technology?
   b) And again from your experience so far, do you anticipate any issues relating to the usability of the App, for yourself or others?

Feedback
14) Some telehealth systems are now providing the capacity for users to receive feedback on cases they have advised for. Do you think this would be a useful tool in this system – either for yourself or for other users?

Capture outcome
Finally, being able to assess the impact of the introduction of the App is important. One main area we are concerned to assess is how it may influence patient management and recovery, and we wonder what kind of results measures we should consider to capture this in the best possible way.

15) Do you have any thoughts which could assist us in that?
Final Questions

16) Considering everything we have spoken about today:
   a) What do you consider the most important factors for its success? Could you give us 2 or 3 of the most positive aspects of project as you see it?
   b) What do you see as the weaknesses of such a system that could lead to its failure? Could you give us 2 or 3 of what you consider the most negative aspects of the project?

17) Are there any final points you would like to add on any aspect of the subject, or anything you think we have not covered?

Close

Many thanks for your time, your participation is invaluable for the study. We will contact you once we have transcribed the interview to arrange a time for a brief respondent check to make sure we have understood your views correctly.