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Mobile teledermatology: a feasibility study of 58 subjects using mobile phones

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Summary
We investigated the diagnostic agreement between teledermatology based on images from a mobile phone camera and face-to-face (FTF) dermatology. Diagnostic agreement was assessed for two teledermatologists (TD) in comparison with FTF consultations in 58 subjects. In almost three-quarters of the cases (TD1: 71%; TD2: 76%), the telediagnosis was fully concordant with the FTF diagnosis. Furthermore, the diagnosed diseases were almost all in the same diagnostic category (TD1: 97%; TD2: 90%). If mobile teledermatology had been used for remote triage, TD1 could have treated 53% subjects remotely and 47% subjects would have had to consult a dermatologist in person. TD2 could have treated 59% subjects remotely, whereas 41% subjects would have had to consult a dermatologist in person. Forty-eight subjects responded to a questionnaire, of whom only 10 had any concerns regarding teledermatology. Thirty-one subjects stated that they would be willing to pay to use a similar service in future and suggested an amount ranging from €5 to €50 per consultation (mean €22) (€ = £0.7, US $1.4). These results are encouraging as patient acceptance and reimbursement represent potential obstacles to the implementation of telemmedicine services.

Introduction
Teledermatology is a slowly but steadily growing field in dermatology. Mobile teledermatology may be useful in emergency situations or during travelling when neither a dermatologist nor stationary telemmedicine equipment is accessible.

The purpose of the present study was to examine the feasibility of teledermatology consultations using mobile phones with built-in cameras. We assessed the agreement between the diagnoses from teledermatology and those from face-to-face (FTF) consultations. We also investigated the potential of mobile teledermatology for triage.

Methods
The study was conducted from April to October 2005. The study population was recruited from subjects who attended the outpatient clinic for an urgent-care dermatology visit. Subjects were eligible to participate if they met the following criteria: adult with visible skin lesions; willing to participate; and able to provide informed consent. Children, subjects with skin lesions that could not be visibly documented (e.g. phlebothrombosis) or subjects who were not willing to provide informed consent were excluded. The study was approved by the appropriate ethics committee and all subjects provided written informed consent.

For each subject, a form was completed to capture basic clinical and demographic data, including age, gender, daily medications and medical history of the skin lesion, including self-treatment of the lesion. Each subject was given a mobile phone (Nokia 6230i, Nokia, Espoo, Finland) with a built-in camera (1280 x 1024 pixel resolution). Subjects were taught how to use the camera and asked to take three photographs of their skin lesions using the mobile phone camera. The physician photographed the
skin lesions for any subjects who did not want to take pictures on their own. The captured images were stored in JPEG format and transferred to a PC via the Nokia Connectivity Wire DKU-2. Subjects were asked to complete a questionnaire regarding:

1. possible concerns about teledermatology;
2. opinions about the possible benefits of teledermatology;
3. willingness to spend money using a similar service in the future.

**FTF consultation**

The FTF consultation was carried out by the dermatologist on call immediately after the teledermatology study procedures at the initial clinic visit. The dermatologist who performed the FTF consultation made a diagnosis based on direct physical examination. According to this diagnosis, subjects were divided into three FTF-triage groups (Figure 1). Triage options consisted of the following:

1. dermatology diagnosis using standard procedures with classical conservative treatment recommendations (FTF-Standard Group);
2. immediate clinical admission to our dermatology unit (FTF-Admission Group);
3. follow-up visit for a surgical procedure with a dermatologist in our outpatient service or our surgical theatre (FTF-Surgery Group).

The FTF diagnosis and treatment recommendation were taken as the reference standard for the statistical analysis.

**Teleconsultation**

Each image was re-sized to 800 x 600 pixels using a standard package (Image Viewer version 1.0). Images were stored on a database and were evaluated using a proprietary web application designed for telediagnosis. Two teledermatologists (TD1 and TD2) were instructed to evaluate the images and provide a telediagnosis for each subject. Each teledermatologist worked independently and was blinded to the other’s diagnoses. Names were not provided in the information given to the TD, and they did not meet or perform a direct consultation with any of the subjects.

The TDs were asked to provide a diagnosis of each skin lesion, along with a differential diagnosis, and to suggest patient management using a ‘virtual triage’. The teletriage options consisted of the following recommendations (Figure 1):

1. dermatology diagnosis using standard procedures with classical conservative treatment recommendations (Standard);
2. immediate clinical admission to a dermatology unit (Admission);
3. follow-up visit for a surgical procedure with a dermatologist in our outpatient service or our surgical theatre (Surgery);
4. visit a dermatologist for FTF consultation (Consult Dermatologist).

![Figure 1](image-url) Diagnostic concordance of triage groups. The 58 subjects were first selected into three triage groups according to the FTF diagnosis (Standard, Admission and Surgery Groups). The table shows how the two teledermatologists (TD1 and TD2) put the identical subjects of the three FTF-triage groups into teletriage groups (Standard, Admission, Surgery and Consult Dermatologist). One individual was recommended to consult the dermatology unit immediately since no diagnosis was possible due to low image quality.
Statistical analysis

Complete agreement was defined as full accordance between the diagnosis of the TD and the FTF diagnosis. Relative agreement was defined as differing diagnoses in the same diagnostic category. We calculated the proportion of cases with agreement by dividing the cases with agreement by the total number of cases. The proportion of cases is given as a percentage. We did not perform a categorical data analysis because of the relatively small number of participants and observations per category.

Results

Eighty-three outpatients were invited to take part in the study. Of these, 25 did not participate for the following reasons: 13 showed no clearly visible skin lesions; four were children; seven chose not to participate in the study; and one subject could not provide consent due to language difficulties. The study population thus consisted of 34 women and 24 men with a median age of 41 years (range 18–85 years), with visible skin lesions.

FTF examination

After images of their skin lesion were captured using the built-in camera on the mobile phone, the subjects were examined by the dermatologist on call. The 58 subjects were divided into the aforementioned three FTF-triage groups as follows:

1. forty-eight (83%) were given diagnoses and treatment recommendations as part of the FTF consultation (FTF-Standard Group);
2. six subjects (10%) were immediately admitted to the dermatology unit including short-term observation (FTF-Admission Group);
3. four subjects (7%) were advised to return for elective surgery within the next few days (FTF-Surgery Group).

Dermatologic diagnosis using standard procedures

Diagnosis and treatment recommendations were given to 48 subjects during the FTF consultation (FTF-Standard Group). The conditions diagnosed according to our diagnostic categories were: dermatitis/eczema (13 subjects, 27%); herpes zoster or herpes simplex outbreak (4 subjects); soft tissue infections (4 subjects); scalded or burned skin (4 subjects); facial dermatoses (3 subjects); urticaria/drug reactions (3 subjects) and arthropod reaction (3 subjects). The remaining 14 subjects had the following diagnoses: pityriasis rosea (3 subjects); acne and acneiform dermatitis (2 subjects); ulcus cruris (1 subject); ulcus durum in syphilis (1 subject); epidermis cyst (1 subject); infected scar (1 subject); stasisdermatitis (1 subject); clavus (1 subject); erythema migrans (1 subject); Sweet syndrome (1 subject); and psoriasis vulgaris (1 subject).

Immediate clinical admission to the dermatology unit

The six subjects admitted to the dermatology unit (FTF-Admission Group) were: one subject with a soft tissue infection of the left lower extremity; one with haemorrhagic erysipelas of the right lower extremity; one with recurrent erysipela of the face; one with multiforme-like macular exanthem on both lower extremities; one with an abscess formation within an erysipela on the left lower extremity (Figure 2); and one subject with an acute urticarial reaction following arthropod bite.

Figure 2 An 80-year-old male patient with erysipelas on the left lower leg. The images were taken with the mobile phone camera.
Follow-up visit for surgical procedure

At the FTF consultation, four subjects were advised to schedule an appointment for elective surgery (FTF-Surgery Group). One subject had a pilonidal sinus infection. The other three subjects had a single suspicious nevus located on the planta (1 subject), back (1 subject) and chest (1 subject).

Usability of mobile phones

The study coordinator photographed the images for 50 (86%) of the 58 subjects. Of these, 40 subjects (age range 18–85 years) were unable to use the built-in camera of the mobile phone unassisted and 10 subjects chose not to attempt to photograph their lesions. The remaining eight subjects (14%), who were aged 19–45 years, successfully captured images of their skin lesions following a short instruction.

Teleconsultation – TD1

(1) Diagnostic agreement. In 41 cases (71%), the diagnosis provided by TD1 was the same as that given in the FTF examination (full agreement). In 15 cases (26%), the diagnosis differed, but was in the same diagnostic category (relative agreement). In only two cases (3%) did the diagnoses conflict (disagreement). In one of these two cases, TD1 offered no diagnosis because he considered the photographic quality of the image to be too poor to allow evaluation. In the second case, pilonidal sinus was interpreted as dermatitis (Table 1).

(2) Triage groups. The further management procedures recommended by TD1 were compared with those recommended in the FTF examination. The 48 subjects in the FTF-Standard Group were managed by TD1 according to the teletriage as follows: 31 subjects (65%) were telediagnosed including treatment recommendations (Standard); 14 subjects (29%) were given a recommendation to consult a dermatologist (Consult Dermatologist); and two subjects (4%) were advised to consult a dermatological unit immediately for admission (Admission). In one case that could not be evaluated due to poor image quality, the subject was recommended to consult a dermatologist immediately (Consult Dermatologist).

<table>
<thead>
<tr>
<th>Table 1 Diagnostic agreement between face-to-face (FTF) diagnosis, teledermatologists (TD) 1 and 2</th>
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<td>FTF vs TD1</td>
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<td>Complete agreement</td>
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<td>Relative agreement</td>
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<tr>
<td>Complete agreement</td>
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<tr>
<td>Relative agreement</td>
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<td>Disagreement</td>
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</tbody>
</table>

Complete agreement was defined as full accordance between the diagnosis of the TD and the FTF diagnosis. Relative agreement was defined as differing diagnoses in the same diagnostic category.

In full agreement with the FTF consultation, TD1 advised the six subjects in the FTF-Admission group to go to the dermatology unit as soon as possible (Admission). In addition, TD1 advised the four subjects in the FTF-Surgery group to consult a dermatologist to perform elective surgery (Surgery).

Teleconsultation – TD2

(1) Diagnostic agreement. The diagnosis provided by TD2 showed complete agreement with the FTF examination in 44 cases (76%) and relative agreement in eight cases (14%). In six cases (10%), the diagnoses provided by TD2 disagreed with those provided by the FTF examination (Table 1).

In the first case, in which there was disagreement, an acute irritative contact dermatitis was diagnosed as an acute urticarial reaction. The second case, a third-degree burn injury with inflammation on the right fifth finger, was interpreted as a pyoderma. In the third case, seborrheic dermatitis of the face was diagnosed as acne comedonica. The fourth case showed an infection with herpes zoster on the right upper extremity by FTF examination and was diagnosed virtually as an eczematous reaction. In the fifth case, the signs of early syphilis on the penis were interpreted as signs of a genital herpetic infection. In the last case, pilonidal sinus was diagnosed as intertriginous dermatitis.

(2) Triage groups. The 48 subjects in the FTF-Standard Group were managed by TD2 according to the virtual triage as follows: 34 subjects (71%) were telediagnosed including treatment recommendations (Standard); 10 subjects (21%) were advised to consult a dermatologist (Consult Dermatologist). Immediate admission to a dermatology unit was recommended for four subjects (8%) (Admission).

Management recommendations by TD2 were consistent with those of the FTF consultation for the six subjects in the FTF-Admission group. Finally, the four subjects who were advised by the FTF consultation to schedule an appointment for elective surgery were telediagnosed for elective surgery (Surgery).

Inter-observer agreement

There was complete agreement between TD1 and TD2 in 43 cases (74%) and relative agreement in nine cases (16%) (Table 2). There was disagreement in six cases (10%).

<table>
<thead>
<tr>
<th>Table 2 Inter-observer agreement between the two teledermatologists (TD)</th>
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<tr>
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<tr>
<td>TD1 vs TD2</td>
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<td>Relative agreement</td>
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<td>Disagreement</td>
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</table>

Complete agreement was defined as full accordance between the diagnosis of the TD and the FTF diagnosis. Relative agreement was defined as differing diagnoses in the same diagnostic category.
Table 3 Non-validated questionnaire revealing the feelings of the patients about teledermatology

<table>
<thead>
<tr>
<th>Question</th>
<th>Yes (%)</th>
<th>No (%)</th>
<th>Total (%)</th>
</tr>
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<tbody>
<tr>
<td>Do you feel any concerns regarding teledermatology?</td>
<td>13 (22)</td>
<td>35 (60)</td>
<td>58 (100)</td>
</tr>
<tr>
<td>Do you see any possible benefit by using teledermatology in your case?</td>
<td>40 (69)</td>
<td>8 (14)</td>
<td>58 (100)</td>
</tr>
<tr>
<td>If a similar teledermatological service will be implemented in the future, would you spend money for using this service?</td>
<td>31 (53)</td>
<td>17 (29)</td>
<td>58 (100)</td>
</tr>
</tbody>
</table>

Questionnaires

The questions and results of our non-validated questionnaires are shown in Table 3. Ten of 58 subjects (17%) were not willing to reply to the questionnaires, leaving 48 responders. Thirty-five subjects (60%) stated that they were not worried about possible uncertainty due to teledermatology consultation, whereas 13 (22%) subjects were anxious about teledermatology. Forty (69%) subjects were convinced about the usability of teledermatology while only eight (14%) subjects did not see any benefit from a teledermatology service.

Concerning the question of whether subjects would pay to use a similar service in the future, 31 subjects (53%) responded positively. Those 31 subjects who expressed a willingness to pay for a teledermatology service suggested an amount ranging from €5 to €50 per consultation (mean €22).

Discussion

Earlier studies with the first generation of mobile camera phones that emerged in 2003, had limitations due to poor image quality. Since then, image resolution has considerably improved. Image quality of mobile phone cameras is currently mainly limited due to the lower quality of their lenses compared with digital cameras, but this is also improving. Our results show that in almost three out of four cases telediagnosis using a mobile phone is fully concordant with direct, physical examination by a dermatologist. Moreover, diagnosed diseases are, in nine out of 10 cases, in the same diagnostic category.

In the present study, as in other teledermatology studies, the FTF diagnosis represented the pragmatic reference standard. This is a limitation of all these studies. Especially, when it comes to the boundaries of diseases in one category, morphology-based diagnosis can be very subjective. Moreover, an intrinsic difficulty of making dermatology diagnosis exists due to terminology problems. The inter-observer agreement (Table 2) between the two TDs was also completely concordant in 74% of cases, whereas in 16% the diagnoses differed within one diagnostic category. Although there exist other explanations for this (e.g. image quality), it indicates that given the same conditions (identical images and clinical information) diagnoses slightly differ due to subjective perception (inter-observer variability).

A high proportion of subjects preferred not to take the pictures themselves. This was (unexpected) drawback. It has to be considered, though, that we put a mobile camera phone at the subjects’ disposal that was unknown to them. If we had asked them to take photographs with their familiar device (for those who possessed one), probably more of them would have agreed. We could not do so mainly for reasons of storage and retrieval of the photos and because, for study purposes, we did not want to exclude individuals without a camera phone.

Besides investigating the concordance of FTF- and telediagnosis, we paid special attention to the potential of mobile teledermatology for triage. The triage system we used is based on the workflow and realities of the Austrian health system.

In a real setting, TD1 could have treated 31 subjects (53%) remotely, whereas 27 subjects (47%) would have had to consult a dermatologist for direct, physical examination. TD2 could have treated 34 subjects (59%) remotely, whereas 24 subjects (41%) would have had to consult a dermatologist FTE. Remarkably, also in the FTF group, 10 subjects (17%) were advised about further procedures (six were admitted to our dermatology unit and four were scheduled for surgery). In contrast to the FTF visit, 17 subjects (29%) diagnosed by TD1 and 14 subjects (24%) diagnosed by TD2, respectively, would have needed an additional dermatology visit.

Currently, telemedical research is focusing on investigating the applicability of mobile phones and hand-held devices for home monitoring in individuals with asthma, diabetes, hypertension and heart failure, as well as in individuals with chronic wounds. The present feasibility study shows the potential of mobile teledermatology as a triage system for individuals with skin lesions. This may be useful, for example, for travellers or people living in under-served areas. Furthermore, mobile teledermatology also has great value for individuals in the industrialized world in accordance with the concept of a ‘person-centred health system’. In this context, mobile teledermatology has the potential to become a tool for improving self-examination.

Mobile teledermatology, as used in the present study, is complex because it relies on direct contact between patients and doctor, instead of contact between two health-care providers. It cannot work without the cooperation of the individuals concerned. For this reason, we assessed the opinion of the subjects in our study population about teledermatology. The trend that we assessed in this small number of respondents is confirmed by other studies that have revealed a high level of satisfaction with teledermatology services. These results are encouraging as patient acceptance and reimbursement represent potential obstacles to the implementation of telemedicine services.
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