Telemedical Wound Care Using a New Generation of Mobile Telephones

A Feasibility Study

Ralph Peter Braun, MD; Jean L. Vecchietti, MD; Luc Thomas, MD; Christa Prins, MD; Lars E. French, MD; Aron J. Gewirtzman; Jean-Hilaire Saurat, MD; Denis Salomon, MD

Background: Leg ulcers are an important cost factor in health care systems. It has been shown that a telemedical wound care consultation can improve quality of care and help reduce costs. In this study, we evaluated the feasibility of telemedical wound care using a new generation of mobile telephones with integrated cameras.

Observations: Three physicians separately evaluated 61 leg ulcers for the following 9 variables: epithelialization, fibrin, necrosis, and granulation tissue at the center and normal border, erythema, cyanosis, eczema, and hyperpigmentation at the periphery. One physician performed the face-to-face consultation (gold standard), and 2 others performed the remote evaluation. The image was obtained with the mobile telephone and immediately sent via e-mail. To measure the agreement of the evaluation among the 3 physicians, we used Cohen κ statistics. Overall, the agreement between the remote and face-to-face evaluations was very good, with κ values of up to 0.94. The image quality was judged to be good in 36 cases (59%) and very good in 12 (20%). The participants felt comfortable making a diagnosis based on the pictures in 50 cases (82%).

Conclusion: Although this study was performed with the first generation of these devices, we were able to demonstrate the feasibility of such a telemedical wound care consultation.

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TELEMEDICINE IS DEFINED BY the World Health Organization as the practice of health care using interactive audio, visual, and data communications. This includes health care delivery, diagnosis, consultation, and treatment as well as education and transfer of medical data. The term teledermatology was introduced by Perednia and Brown1 in 1995. It uses new technologies to allow dermatological consultations at a distance. Telemedical wound care is one of the potential applications of teledermatology. Leg ulcers and chronic wounds represent important cost factors for health care systems, and transportation costs of the patients can be estimated to be a high percentage of the total costs for these patients.2-8 Depending on the organization of the health care system, part of the care is provided by visiting nurses who see the patients at their homes or at special leg ulcer clinics.9,10 Because we often receive telephone calls from visiting nurses who have a question or a problem with the leg ulcers, and although the oral description of the nurse can be of excellent quality, we thought it could be useful to have an image of the leg ulcer immediately available during such a discussion. For this purpose, we thought about the possibility of taking images of the leg ulcers, transmitting them to an expert at a distance, and getting the expert’s advice immediately.

New developments in the field of mobile telephones allow us to take images of good quality with the mobile telephones and transmit them directly to other computers or mobile telephones.

Because there is evidence that telemedical wound care is feasible with images similar to the ones provided by these devices,11-17 we performed a prospective study to address the question whether a teleconsultation for wound care is feasible using this new generation of mobile telephones. For this purpose, we compared the face-to-face evaluation with the remote evaluations of 2 physicians (Table).
tal Geneva, Geneva, Switzerland. All 3 participating physicians were board-certified dermatologists who had been involved in the outpatient leg ulcer clinic for several years. They were all familiar with the evaluation and management of leg ulcers and had a similar degree of experience.

MOBILE TELEPHONES

Since 2002, a new generation of mobile telephones on the market has built-in digital cameras. These devices allow physicians to take images of acceptable quality that can be sent via Multi-media Message (Globe Telecom; http://www.cellular.co.za/technologies/mms/mms.htm) to another mobile telephone, via e-mail to any other computer, or via a wireless connection (Bluetooth; http://www.bluetooth.com) to a computer.

The first mobile telephone of this kind available in Switzerland was the Nokia 7650 (Nokia, Espoo, Finland), which was the reason for our choice of this system. There are many similar mobile telephones that are commercially available today.

The built-in camera stores up to 50 images on its internal memory, has an automatic gain control, and provides images with a resolution of 640 × 480 pixels. For the storage, a JPEG format (Joint Photographers Experts Group; http://www.jpeg.org) with medium compression is used that corresponds to an average image size of approximately 15 to 22 kilobytes.

TRAINING PHASE

In a first test phase, we took 20 images and transferred them to the computers of the remote physicians via e-mail and Bluetooth. Both images were then compared in terms of size and image quality, but there was absolutely no difference concerning file size, resolution, and image quality. Once we were sure that sending the image via e-mail did not influence the image quality, we started the imaging training phase. In this phase, the physician who made the face-to-face diagnosis and the imaging evaluated different imaging techniques on 25 chronic wounds. The images were obtained at different distances to determine the best imaging technique. The first 20 cases and these next 25 cases were not included in the final study.

The optics of the device are designed to take pictures of buildings, landscapes, or persons but are not specifically designed for close-up macro images as used in this study. Overview images of leg ulcers can be obtained without a problem, but because the total resolution is 640 × 480 pixels (webcam quality), there may be not enough information (pixels) on the ulcer itself. For example, a small leg ulcer might have only 10 pixels of image information. Although the quality is good, we believed that this was not enough for a precise evaluation. For this reason we chose the option to always obtain a second close-up image, focusing just on the leg ulcer and including a small area of surrounding skin. Depending on the size of the leg ulcer and the resulting distance for the close-up image, many of these images (especially the ones of small ulcers) were out of focus. All 3 participating physicians agreed that this second close-up image, although of inferior quality, was very helpful for the precise evaluation.

The 25 test images were reviewed by all 3 participating physicians. Every lesion was evaluated and discussed to obtain a consensus for the evaluation of the different individual variables that were included in the study.

IMAGING PROCEDURE AND PATIENTS

During a 3-month period, we randomly included patients from our outpatient leg ulcer consultation into this study, regardless of the type of leg ulcer. The patients were informed about the experimental character of this study and about the fact that the images would be transmitted electronically (anonymously) to other physicians for evaluation purposes. After the patients gave their oral consent, 2 images of the leg ulcer were obtained by the physician who made the face-to-face diagnosis (J.L.V.), including an overview image covering the lower leg and the ulcer (Figure 1) and a close-up picture covering the leg ulcer with surrounding skin (Figure 2).

We decided to obtain the images under normal lighting conditions and made no particular effort to improve the illumination (eg, the use of additional light sources or a flashlight). The images were immediately transmitted (via the mobile telephone) to the e-mail accounts of the 2 physicians who then made the remote diagnosis (D.S. and R.P.B.). The transfer to an e-mail account was chosen because it seemed to be the closest to reality.

EVALUATION

The ulcer was evaluated by all of the physicians for the presence and the estimated surface of the following variables: granu-
lation tissue (red), epithelialization (red to rose), fibrin (yellow), and necrosis (black). For example, an ulcer surface could consist of 25% granulation tissue, 10% epithelialization, 60% fibrin, and 5% necrosis. Per definition, the sum of the estimated surfaces had to be 100%. The percentage of these criteria was recorded in the following 4 categories: absent, 10% to 30%, 40% to 60%, and 70% to 100%.

The surrounding skin was evaluated for the presence (yes/no) of the following variables: erythema, cyanosis, eczema, and hyperpigmentation. If none of the previous criteria was present, the border was rated as normal (Table).

In addition, the remote physicians were asked to judge the image quality. For the evaluation we used the following categories: insufficient, sufficient, good, and very good.

The last question was whether the image was good enough to perform the evaluation. The background of this last question was that one might feel comfortable making an evaluation based on an image although the image was not of excellent quality. The evaluation of the image quality alone did not provide this particular information, so we added this second question.

We compared the evaluations of the face-to-face physician (as the gold standard) with those of both remote physicians and compared the evaluations of both remote physicians with each other (Table). Because the treatment modalities for leg ulcers and chronic wounds are extremely variable from one physician to another, we did not include any questions concerning the treatment in this study.

The aim of the study was to evaluate whether the diagnosis and evaluation of chronic wounds and leg ulcers at a distance is possible with this new type of device.

RESULTS

During a 3-month period, we included a total of 61 chronic wounds in 52 patients. Six wounds were imaged several times during the study but only counted once. Twenty-nine (48%) were venous ulcers; 9 (15%), arterial ulcers; 7 (11%), combined arterial and venous ulcers; 11 (18%), related to diabetes; and 5 (8%) of other origin (eg, vasculitis). After the technical setup period, which includes the configuration of the mobile telephones for e-mail transfer and the setup of e-mail accounts and clients, we did not encounter any technical difficulties. The system was feasible and easy to use, even by noncomputer experts. Although the Nokia 7650 was the first mobile telephone with a built-in camera on the market, and recent models are even lighter, its size and weight was considered to be convenient by the physician who did the face-to-face consultation.

The image quality (after e-mail transfer) was rated very similarly by both physicians involved in the remote diagnosis (Figure 3). Most of the images (36 [59%]) were judged to be of good quality, and 12 (20%), of very good quality. In 3 cases (5%), the images were judged by both physicians to be of insufficient quality.

Concerning the satisfaction, both remote physicians felt comfortable with the evaluation based on the image in 50 cases (82%). In only 1 case (2%), both physicians did not feel comfortable (Figure 4). Concerning the different criteria that were evaluated, we considered the face-to-face evaluation to be the gold standard because the physician saw the patient, saw and smelled the ulcer and the wound dressings, and was able to judge the context of the whole patient, his or her medical history and medical chart, and the presence of other diseases such as diabetes mellitus or arterial insufficiency.

To compare the results, we performed the Cohen κ statistical analysis. This measures the agreement between the
evaluations of 2 raters when both are rating the same object. A value of 1 indicates perfect agreement. A value of 0 indicates that agreement is no better than chance. The summary of the $\kappa$ values can be found in the Table.

We also calculated the mean values of all $\kappa$'s. The mean $\kappa$ value for physician 1 was 0.815; for physician 2, 0.741; and for the agreement between both remote physicians, 0.75.

Concerning physician 1, the highest agreement was obtained concerning the epithelialization ($\kappa=0.94$) and the lowest concerning granulation tissue ($\kappa=0.69$). Physician 2 had the highest agreement compared with the face-to-face physician concerning the erythema of the surrounding skin ($\kappa=0.92$) and the lowest agreement concerning the presence of necrosis in the ulcer ($\kappa=0.49$). Comparing the agreement of both remote physicians, the highest agreement was obtained for cyanosis of the surrounding skin ($\kappa=0.91$) and the lowest agreement for necrosis ($\kappa=0.57$).

Hyperpigmentation in the periphery of the ulcer was only found in 1 case. The clinical findings were so impressive that this was recognized by all physicians as such, and the $\kappa$ values were at 1.00, which is virtually impossible. Therefore we decided to exclude peripheral hyperpigmentation from the analysis. If we had considered the $\kappa$ values for this criterion, the mean $\kappa$ values would have been even higher.

**Comment**

Chronic wounds and leg ulcers are important cost factors for the health care system, and transportation is estimated to represent an important percentage of the total costs. For this reason, in many countries the care is provided by visiting nurses who go to the patient's home or by nurses in specialized leg ulcer clinics. Very often these nurses have questions for physicians, and physicians receive telephone calls concerning ulcer-related problems. At present, nurses usually provide an oral description of the leg ulcer and the problem via telephone. Since we are involved in such a system, we believed that having immediate access to an image of the ulcer would be of considerable help and improve the quality of patient care. The new generation of mobile telephones is the ideal tool for this task, because they are small portable devices. Images of acceptable quality can be taken and sent immediately via e-mail from the patient's home while the nurse is still beside the patient. The remote physician has the image on a computer screen and can immediately talk to the nurse via the mobile telephone to give his or her feedback in a direct and interactive way. To evaluate whether this scenario is feasible, we performed a feasibility study at our hospital. The purpose was to perform this evaluation in a setting as close to reality as possible. This is why we chose to obtain the images under routine conditions without additional light sources or flashlights, and to transfer them via e-mail although the 2 remote physicians were only some meters from the physician who performed the face-to-face consultation.

Because these mobile telephones are not specially designed for this use, our main concern was the image quality. For this reason we ran an evaluation phase in which the physician who performed the face-to-face evaluation obtained a series of images from 25 patients who were not included in this study. All 3 physicians evaluated these images to determine together the best imaging technique. No problems were detected with the overview images of the whole leg, because the optics of the camera are designed to take pictures at this distance. The total resolution of the camera is $640 \times 480$ pixels, and because most of the leg ulcers had a surface of 10% to 20% of the overview image, the information on the ulcer was 10% to 20% of $640 \times 480$ pixels, which is not enough for the evaluation of small ulcers. For this reason we decided to take a close-up picture of the ulcer and a small area of surrounding skin. Because the optics of the telephone are not designed for this kind of close-up macroimaging, some of the close-up images were slightly out of focus. Despite this technical restriction, the evaluation of the remote physicians was excellent compared with the face-to-face evaluation. Although the close-up macroimages were out of focus, the remote physicians felt comfortable with the evaluation based on these images in 82% of cases. Image quality is very important in telemedicine applications, because the diagnosis and the therapeutic decision are both based on this image. For this reason, we critically evaluated the image quality using the remote physicians' quality score. To our surprise, the image quality was judged to be good in 59% of the cases and very good in 20% of the cases for this particular use.

Image quality and resolution are especially important in telemedicine. Perednia et al clearly showed that an image resolution of $574 \times 489$ pixels has the same informativeness as a slide, so that one could imagine that the use of different telemedicine equipment with better resolution would have had an impact on the agreement between the different evaluations ($\kappa$ values).

The Nokia 7650 mobile phone is part of the first generation of these devices. The image quality and resolution are sure to improve, and one could imagine that the next generation of mobile telephones with built-in cameras will provide resolutions and optics that will be comparable with today’s low-end consumer digital cameras.

Concerning the variables to be evaluated, all 3 physicians evaluated and discussed the 25 training cases that were not included in this study. The variables for the evaluation were chosen according to previous publications on the same subject and according to variables that would have an influence on the therapeutic decision (ie, fibrin and necrosis). The 3 physicians evaluated all training cases and discussed their decision to obtain a consensus for the evaluation. The $\kappa$ values for the remote evaluation compared with the face-to-face evaluation as the gold standard were very good, with a mean $\kappa$ of 0.815 for physician 1 and 0.741 for physician 2. When we compared physician 1 with physician 2, the mean $\kappa$ was 0.746. This means that there was a high degree of agreement between these independent evaluations. In our study, we had 1 face-to-face consultation and 2 remote evaluations. For this reason, we are not able to calculate the interobserver agreement concerning the face-to-face consultations. In previous studies using a similar resolution and criteria as this study, the interobserver agreement was similar to our findings.19-22
Because the therapeutic decisions made for leg ulcers are very different from one physician to another, we did not include questions concerning the treatment of the ulcers. This study was limited to the evaluation and the analysis of the ulcer, because these are directly related to the image and the device. If all 3 physicians would have performed a face-to-face consultation, the agreement concerning the treatment would most probably have been rather low. This is independent from the telesconsultation for wound care and related to different concepts and attitudes concerning treatment of leg ulcers. For this reason, this study is focused on the poor morphologic analysis of the leg ulcer independent from its cause (eg, arterial, venous, vasculitis).

During this study, we had the occasion to image chronic wounds in 6 patients more than once at several intervals of time (but these images were only counted once for the study). Based on this small number of cases, we had the impression that this kind of approach could be particularly useful for the follow-up of chronic wounds. The remote physicians found it very easy to judge whether there was any evolution, especially if they had a previous picture of the leg ulcer available. This method also seems to have a high potential for follow-up, and not only for the evaluation of leg ulcers.

**CONCLUSIONS**

In this study, we were able to show for the first time that telemedicine for care of chronic wounds is feasible under routine conditions using this new generation of mobile telephones and direct transfer via e-mail. The agreement between remote physicians and the physician who performed the face-to-face evaluation was very good, with high $\kappa$ values of up to 0.94. The participants judged the image quality to be good in 59% and very good in 20% of the cases and felt comfortable making a diagnosis based on the picture in 82% of the cases. Although this study was performed with the first generation of such devices, we could clearly demonstrate the feasibility of such a telesconsultation for wound care. These new devices will allow nurses who are performing the wound care at the patient’s home or in a leg ulcer clinic to send a picture of the leg ulcer to the wound care center or the physician in charge of the patient immediately and discuss it. The possibility of immediate access to the image and direct interaction between the visiting nurse and the physician has the potential to drastically improve patient care.

We had the impression that a high percentage of the problems related to leg ulcers could be solved with this type of telesconsultation. The transport of the patient to the hospital or the physician’s office could be replaced, and this approach could potentially save the health care system money. After having been able to show the feasibility of telemedical wound care with this device, we plan a second study that will investigate whether this type of telesconsultation can efficiently replace the face-to-face consultation under routine conditions.

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**Correspondence:** Ralph Peter Braun, MD, Department of Dermatology, University Hospital Geneva, 24 Rue Micheli-du-Crest, CH-1211 Geneva 14, Switzerland (braun@melanoma.ch).

**REFERENCES**