ORIGINAL ARTICLE

Mobile teledermatology in the developing world: Implications of a feasibility study on 30 Egyptian patients with common skin diseases

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Background: The expansion of store-and-forward teledermatology into underserved regions of the world has long been hampered by the requirement for computers with Internet connectivity. To our knowledge, this study is one of the first to demonstrate the feasibility of teledermatology using newer-generation mobile telephones with specialized software and wireless connectivity to overcome this requirement in a developing country.

Objective: We sought to demonstrate that mobile telephones may be used on the African continent to submit both patient history and clinical photographs wirelessly to remote expert dermatologists, and to assess whether these data are diagnostically reliable.

Methods: Thirty patients with common skin diseases in Cairo, Egypt, were given a diagnosis by face-to-face consultation. They were then given a diagnosis independently by local senior dermatologists using teleconsultation with a software-enabled mobile telephone containing a 5-megapixel camera. Diagnostic concordance rates between face-to-face and teleconsultation were tabulated.

Results: Diagnostic agreement between face-to-face consultation and the two local senior dermatologists performing independent evaluation by teleconsultation was achieved in 23 of 30 (77%) and in 22 of 30 (73%) cases, respectively, with a global mean of 75%.

Limitations: Limited sample size and interobserver variability are limitations.

Conclusion: Mobile teledermatology is a technically feasible and diagnostically reliable method of amplifying access to dermatologic expertise in poorer regions of the globe where access to computers with Internet connectivity is unreliable or insufficient. (J Am Acad Dermatol 10.1016/j.jaad.2010.01.010.)

Key words: global health; mobile teledermatology.

Teledermatology, or the use of modern telecommunications technology to provide dermatologic care from a distance, has become an increasingly important and impacting subject of study in recent years. Multiple authors have elucidated the potential of teledermatology as a diagnosis

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Disclosure: ClickDoc, used in this study, was developed by the United States–based mobile telemedicine company ClickDiagnostics. Mr Chowdhury is Chief Executive Officer and Co-Founder of ClickDiagnostics. Dr Ayad is a consultant for ClickDiagnostics. Drs Tran and Kovarik, Ms Weinberg, Mr Cherng, Dr Monir, and Dr El Hariri have no conflicts of interest to declare.

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and management tool for health care providers, as an educational support tool for junior clinicians,[1-3] and as a possible cost-savings mechanism for patients and medical systems.[3-8] Store-and-forward teledermatology using digital cameras has also recently been associated with reduced patient wait times, high patient satisfaction,[9-13] promising diagnostic reliability,[14-17] and clinical outcomes similar to conventional, face-to-face clinical care.[18,19]

To date, however, the vast majority of teledermatology studies and projects have focused on industrialized nations, whereas the potential need for teledermatology may be most profound in the developing world. Patients living in developing countries experience a large proportion of the world's burden of skin disease, which is compounded by very limited public health resources and little or no access to specialists with dermatologic expertise. The World Health Organization's 2001 report on the global burden of disease, for instance, found that skin diseases were associated with mortality of 20,000 in Sub-Saharan Africa that year.[20] Meanwhile, the global physician and health care worker shortage remains most severe in that same region.[21] Teledermatology has the potential to make a profound impact in regions such as these by dramatically amplifying access to dermatologic expertise where it would otherwise be unavailable.

The number of teledermatology projects initiated in developing countries, although growing steadily,[22-30] has remained somewhat limited owing to a number of considerable barriers. One of the most significant of these is the underdevelopment of information technologies infrastructure in many of the poorest regions of the globe, where the computers with Internet connectivity needed to perform standard store-and-forward teledermatology are a rare and precious commodity. Remarkably, however, many of the same regions are supported by surprisingly robust cellular telephone coverage, with the majority of the world's approximately 4 billion cell telephone subscriptions now arising in the developing world.[31] As such, teledermatology, or the use of specialized mobile telephones to perform store-and-forward teledermatology, may quickly become instrumental in expanding the role of dermatology in the global health arena.

The feasibility of using mobile telephones and other handheld devices to collect and transmit diagnostically reliable dermatologic information has now been successfully demonstrated in several recent studies. In the last 5 years alone, mobile telephones have been shown to be potentially useful tools in guiding wound care,[32] screening for melanoma,[33] diagnosing teledermatoscopic images,[34] and supporting longitudinal management of psoriatic skin lesions.[35] Concordance rates between face-to-face diagnosis and remote teledermatology diagnosis of patients with typical skin diseases have ranged from 70% to 76%,[36,37] comparable with diagnostic concordance rates afforded by standard teledermatology with digital cameras.[14-17,38,39] Mobile telephone technology is also continuing to advance at a rapid pace, with significant improvements being made in photographic resolution and speed of data transfer.

CAPSULE SUMMARY

- The expansion of store-and-forward teledermatology into underserved regions of the world has been hampered by the requirement for computers with Internet connectivity. This study demonstrates the feasibility of teledermatology using newer-generation mobile telephones with specialized software and wireless connectivity to overcome this requirement in a developing country.
- Thirty patients with common skin diseases in Cairo, Egypt, were given a diagnosis by face-to-face consultation and independently using mobile telephone teleconsultation; diagnostic agreement was achieved in 75% of cases.
- Mobile teledermatology is a technically feasible and diagnostically reliable method of amplifying access to dermatologic expertise in underserved regions where access to Internet-capable computers is unreliable or insufficient.

In this article, we describe a feasibility study of mobile telephone–based store-and-forward teledermatology that was recently conducted at Al-Azhar University in Cairo, Egypt. The study sought: (1) to demonstrate for the first time that mobile teledermatology works from a technical standpoint in wirelessly relaying both patient history and clinical photographs from an on-site physician to a remote physician, and in relaying the remote physician's diagnostic impression and comments back to the on-site physician; and (2) to evaluate, through measurement of diagnostic concordance rates between face-to-face diagnosis and remote teleconsultation diagnosis, whether the quality of the history and physical examination photographs collected and transmitted by the mobile telephone is diagnostically reliable.

To our knowledge, this study represents one of the first successful demonstrations of mobile telephone–based teledermatology on the African continent and

in the developing world. It also represents one of the first demonstrations of a mobile telephone transmitting both patient history and clinical photographs for diagnosis, and receiving teleconsultants' diagnostic impressions and comments, entirely through cellular connectivity. The performance of this study in a developing nation suggests the potential of mobile telephones to eliminate one of the most long-standing barriers to teledermatology expansion into the most underserved regions of the globe.

METHODS

Setting, recruitment, and data collection

The study was conducted in November 2008. The study population included 30 patients with skin disease randomly selected from the outpatient clinic of the Department of Dermatology, Venereology, and Andrology at Al Hussein University Hospital of Al-Azhar University in Cairo, Egypt. Eligibility criteria were the following: (1) a patient with visible skin lesions; and (2) the patient or the patient's guardian indicated willingness to participate in the study through informed oral consent. Both adults and children were eligible to participate. The study was approved by the research review board of Al-Azhar University.

Each subject was examined in face-to-face consultation at the outpatient clinic by an on-site junior dermatologist from the department, who formulated a diagnosis for each patient's skin disease. The dermatologist then used a mobile telephone (see requirements) to record appropriate medical information and to capture dermatologic photographs of each patient. They transmitted this information via the telephone's wireless Internet connectivity to an online patient database.

Each subject was then examined via teleconsultation by two senior dermatologists, respectively, from the same department. The teleconsultants logged onto the patient database using a World Wide Web–based interface (http://click.telederm.org) from an Internet-capable computer and viewed cases from a remote location. For each subject, the two remote dermatologists independently formulated a diagnosis based on the patient history and images collected by the on-site resident. The senior dermatologists were blinded to each other's diagnostic impressions, and to the on-site resident's impressions. The on-site physician, finally, retrieved the comments and feedback of the remote specialist through the same telephone.

The diagnoses formulated through face-to-face examination by the on-site physician were tallied and compared with the diagnoses formulated through teleconsultation by the two remote specialists, respectively, and diagnostic concordance rates were tabulated.

Technical requirements

The mobile telephone used in this study was the Samsung U900 (Samsung Electronics, Ridgefield Park, NJ), a cellular telephone with wireless Internet connectivity and an in-built 5-megapixel camera. The telephone was enabled with ClickDoc (Click Diagnostics, Boston, MA), an easily downloaded Java-based mobile telephone application (JAVA, Oracle Corporation, Redwood Shores, CA) that facilitates the collection, storage, and wireless transmission of pertinent dermatologic medical information by way of a multiple-choice questionnaire designed by the authors of the current study (Table I). Responses to the questionnaire, which elicits crucial elements of the patient history, may be keyed numerically into the telephone keypad. The dermatologic resident examining patients in this study was trained in the use of the telephone and software application before examining patients.

Wireless 3G and 2G network coverage were used in this study to transmit dermatologic cases, although other technologies such as WAP and WIMAX may be used with the Samsung U900 as well.

RESULTS

The software-enabled mobile telephone was successful in transmitting the medical information and dermatologic photographs of 30 patients with skin disease to an online database without any technical issues. The two senior teledermatologists were able to view all 30 cases via the World Wide Web–based interface. Finally, the on-site physician successfully retrieved the diagnoses and comments of the teleconsultants through the same mobile telephone.

Diagnoses rendered by the on-site resident dermatologist and by the two senior teledermatologists for the 30 cases are shown in Table II. Overall, diagnostic agreement between the face-to-face dermatologist and the two mobile teledermatologists (senior physicians) was achieved in 23 of 30 (77%) and in 22 of 30 (73%) cases, respectively, with a global mean of 75%.

The most common reasons given by teledermatologist 1 for diagnostic nonagreement were incorrect diagnosis by the on-site (junior) physician (3 cases), insufficient history taken (two cases), and need for an additional test (one case). For teledermatologist 2, the most common reasons for diagnostic nonagreement were insufficient history taken (3 cases), incorrect diagnosis by the on-site (junior) physician (two cases), need for additional test (two cases), and poor image quality (one case).

Table I. ClickDoc multiple-choice questionnaire

Multiple-choice question	Answer choices
Age of patient	Newborn
	<1 y
	1-10 y
	10-20 y
	20-40 y
	40-60 y
	>60 y
Sex	Male
	Female
Is the patient: (check all that apply)	Pregnant?
	Very ill due to the current skin condition?
	Living in poor conditions?
	Infected with HIV?
	Infected with hepatitis C?
	Infected with tuberculosis?
How long has the patient had this skin condition?	1-2 d
	3-5 d
	About a week
	About 2 wk
	>2 wk
	>1 mo
	>1 y
Does anyone in the family have a similar condition?	Yes
	No
Where was the first area where the rash began?	Back, chest, abdomen, arms, legs, scalp, face, eyes, mouth, back of hands, palms, around fingers, on top of feet, between toes, on bottom of feet, genital areas, buttocks, all over
Which areas of the skin are currently involved? (check all that apply)	Back, chest, abdomen, arms, legs, scalp, face, eyes, mouth, back of hands, palms, around fingers, on top of feet, between toes, on bottom of feet, genital areas, buttocks, all over (including inside mouth), all over (not in mouth)
What are the symptoms? (check all that apply)	Constant itching around rash
	Occasional itching around rash
	Itching all over
	Constant pain in skin
	Occasional pain in skin
	Burning in area of rash
	Associated fever
Check all that apply:	Rash comes and goes
	Rash has worsened over time
	Rash has gotten better over time
	Rash is the same as when it started
Has the rash been treated with: (check all that apply)	Steroid creams
	Antifungal creams
	Antibacterial creams
	Antifungal pills
	Antibiotic pills
	Other creams or pills
Is the patient currently taking medication for: (check all that apply)	HIV infection
	Hepatitis C infection
	An infection that is not on the skin
	High blood pressure
	Diabetes
	Other

Table II. Concordance between face-to-face diagnosis and mobile teledermatology diagnosis

Case No.	Dermatologist (junior physician) Diagnosis (Face-to-Face)	Teledermatologist (senior physician) 1 Concordant diagnosis (Y/N)	Teledermatologist (senior physician) 1 Comments from senior physician	Teledermatologist (senior physician) 2 Concordant diagnosis (Y/N)	Teledermatologist (senior physician) 2 Comments from senior physician
1	Acne vulgaris	Y		Y	
2	Impetigo	Y		Y	
3	Pediculosis	Y		Y	
4	Intertrigo	Y		Y	
5	Scabies	Atopic dermatitis	Insufficient history	N diagnosis	Insufficient history
6	Alopecia areata	Y		Tinea capitis	Poor image quality
7	Common wart	Y		Y	
8	Lichen simplex chronicus	Y		N diagnosis	Insufficient history
9	Pityriasis lichenoid chronicus	Y		N diagnosis	Requested physical test
10	Traction alopecia	N diagnosis	Insufficient history	N diagnosis	Insufficient history
11	Herpes zoster	Y		Y	
12	Sycosis barbae	Y		Y	
13	Lichen planus	Lichen simplex chronicus	Corrected on-site junior physician	Y	
14	Lichen nitidus	Lichen planus	Corrected on-site junior physician	N diagnosis	Need biopsy
15	Actinic lichen planus	Y		Y	
16	Pityriasis versicolor	Y		Y	
17	Pityriasis alba	Y		Y	
18	Papular urticaria	Y		Y	
19	Drug eruption	Y		Y	
20	Candidiasis	Y		Y	
21	Tinea pedis	Y		Y	
22	Seborrheic dermatitis	Y		Y	
23	Tinea capitis	N diagnosis	Differential diagnosis offered (kerion/tinea circinata)	N diagnosis	Corrected on-site junior physician
24	Alopecia areata	Y		Y	
25	Erythrasma	N diagnosis	Requested Wood light examination	Y	
26	Fissuring	Y		Y	
27	Hairy nevus	Y		Y	
28	Candidiasis	Y		Y	
29	Nevus of Ota	Y		Y	
30	Eczema	Urticaria	Corrected on-site junior physician	Urticaria	Corrected on-site junior physician
Overall diagnostic concordance rate		23/30 = 77%		22/30 = 73%	

N, No; *Y*, yes.

DISCUSSION

Findings, limitations, and implications

The requirement for Internet-capable computers has long hindered adoption of store-and-forward teledermatology using digital cameras in underdeveloped parts of the world. Fortunately, in recent years, modern telecommunications technology has rapidly advanced such that mobile telephones are now capable of transmitting high-resolution dermatologic images to remote specialists via wireless connectivity. Coupled with the remarkable expansion of mobile telephone use and cellular network coverage in the developing world, this could enable access to dermatologic expertise in previously unreachable areas of global geography. In this study, a new-generation mobile telephone was successfully used to capture and transmit wirelessly both medical history and dermatologic images belonging to 30 patients with common skin diseases in Egypt. During evaluation of cases by two remote teleconsultants, only one image was deemed by a teleconsultant to be of insufficient quality for making

a diagnosis. The mobile telephone was then successfully used by the on-site physician to retrieve the diagnostic impressions and feedback of the remote teleconsultants. This study thus demonstrates the technical feasibility of using mobile telephone–based teledermatology to expand access to dermatologic expertise and teaching where computers and Internet are absent, as long as adequate wireless mobile telephone data coverage is available. This study was performed successfully in Egypt, and expansion into more underserved parts of the world is certainly within reach.

The second objective of this study was to assess whether the quality of the patient history and dermatologic images collected and transmitted by the mobile telephone was sufficient for teledermatologists to render accurate diagnoses. The results show that diagnoses given by the two remote senior dermatologists to patients via mobile telephone–based teleconsultation were concordant with those given by the on-site junior dermatologist through face-to-face consultation nearly three quarters of the time (73% and 77% concordance for the two teleconsultants, respectively). Although imperfect, a global diagnostic concordance rate of 75% is certainly favorable and falls virtually within the range found in previous mobile teledermatology feasibility studies[36,37] and those established in studies of standard teledermatology using digital cameras.[14-17,38,39] In the coming years, improvements in diagnostic accuracy might certainly be achieved through improvement in technical capacity of mobile telephone cameras and through better training of health care workers to take high-quality dermatologic images.

Notably, diagnostic concordance in this study may have been confounded by interobserver variability because the face-to-face and remote examinations were not performed by dermatologists at the same level of training. Interobserver variability refers to the idea that a certain proportion of diagnostic discordance must always be attributable to differences in physicians' subjective interpretation of data, rather than to any defect in a diagnostic tool's ability to relay those data. However, the fact that diagnostic agreement remained high in this study despite such a confounding variable, should be taken, if anything, as reassuring that concordance would be even higher were both the face-to-face and remote examiners at a senior level of dermatologic training. Furthermore, the inequality in level of training between the on-site and remote health care providers modeled in this study demonstrates the considerable potential of mobile teledermatology to serve as an educational support, as the junior physician was able to learn from the corrections and feedback given by his seniors.

Another limitation of this study was the lack of a histologic gold standard for diagnosis, which might have provided an optimal baseline from which to assess diagnostic accuracy. Histologic diagnosis might have also provided clues where diagnostic concordance was not achieved between the junior and senior physicians. Notably, transmission of dermatopathologic images via mobile telephone could certainly be further investigated in the coming years.

It should also be noted that this study used ClickDoc, a specialized mobile telephone application consisting partly of a multiple-choice questionnaire, to direct the on-site examiner into inputting certain essential medical information about each patient into the telephone. In the near future, a free-form text area and a prompt to make an optional voice recording will also be added to the ClickDoc application. This option would allow the recording of additional history and might address one of the factors that may have limited diagnostic concordance in this study. Ideally, ClickDoc and other future mobile telephone applications similar to it will be able to guide even the least experienced health care workers through the appropriate clinical questions for patients with skin disease. Mobile teledermatology could thus be used by even medically untrained health care volunteers in the most remote parts of the world. Further studies evaluating the use of mobile teledermatology in rural settings, by health care workers lacking advanced medical training, should be undertaken in the future.

Future directions and challenges

We expect that in the next few years, the use of mobile telephone–based teledermatology could surpass the use of standard teledermatology with digital cameras in the lower-income regions of the world. Mobile teledermatology requires very little physical hardware, eliminates many of the steps required to transmit digital camera images, and is easy to learn to use. Importantly, mobile teledermatology also takes advantage of the explosion of "cell phone culture" that has taken place recently around the globe. A new report from the United Nations indicates that there were an astonishing 4.1 billion cell telephone subscriptions in the world at the end of 2008,[31] with the majority of these now arising from developing nations. Mobile telephony is now the dominant form of information technology in poorer countries, with the greatest increase in cell telephone subscriptions occurring in Africa.[40] It seems only natural that dermatologists should take advantage of

these circumstances in helping to reduce the great burden of skin disease worldwide.

Mobile teledermatology is still a field in its infancy, however. Like the current study, the few existing primary publications on the subject are feasibility studies performed on relatively small numbers of subjects. In the coming years, the usefulness of mobile telephones in the diagnosis, management, and treatment of skin diseases should be assessed on a wider scale, with greater numbers of patients, health care providers, and types of skin diseases involved. Ideally, mobile teledermatology initiatives should also be established and assessed in nations that have no trained dermatologists, such as throughout much of Sub-Saharan Africa, where the HIV/AIDS pandemic has made the gap in dermatologic care especially pressing. In these same regions, mobile telephones could be used to collect the epidemiologic data about burden of dermatologic disease that are often sorely lacking.

Furthermore, it remains to be determined how mobile teledermatology could be made a sustainable practice in countries with very limited resources. Although mobile teledermatology initiatives will likely be supported by the telecommunications industry in the immediate future, sustainable integration into existing health care systems requires long-term commitment from a great variety of stakeholders. Ultimately, the optimal structure of mobile teledermatology initiatives will likely be established on a case-by-case basis, with ample consideration given to factors such as a nation's existing public health infrastructure, strength of support from its national ministry of health, cultural beliefs and attitudes, availability of cellular telephone coverage, and local disease burden. Although the development of mobile teledermatology applications is only just beginning, a recent upsweep of interest in mobile telephone–related provision of health care services among cell telephone carriers and health organizations[41] could make the execution of all this work a nearby reality.

Finally, we note that although mobile dermatology has an obvious potential role in expanding the presence of dermatologists in the global health arena, it could also soon play a major part in amplifying access to dermatologic care in underserved regions of industrialized nations. In the United States, for instance, medical workforce data have indicated a dramatic maldistribution of dermatologists in recent years. Mobile teledermatology may help to mitigate this maldistribution by extending dermatologic care to states such as Alaska and West Virginia, which are among those with the fewest practicing dermatologists per capita in the United States.[42] Although progress will require strong collaboration among dermatologists, insurance providers, and telecommunications industry, mobile teledermatology could quickly develop into one more force combating the disparities in access to health care so apparent in our own nation.

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