TeleMDID: Mobile Technology Applications for Interactive Diagnoses in Teledermatology Clinics

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Abstract — Over the past two decades, teledermatology has typically applied a hybrid model with both live-interactive and store-and-forward imaging technology during the diagnosis process. The primary challenges for teledermatology are integrations of diagnostic information and images captured by heterogeneous digital cameras used by the far sites, image sharing tools by the dermatologists and patients, and means for longitudinal diagnosis of skin diseases. These challenges not only cause disruptive clinic flow, but also limit the capability for the efficacy of diagnoses. The objectives of this study are to adapt mobile applications from in-person clinical to telehealth settings, and evaluate and compare its usability, effectiveness, and changes in clinic flow.

Keywords—telehealth, telemedicine, dermatology, mHealth, store-and-forward.

I. INTRODUCTION

In the current practice of dermatology, about 85% of providers capture digital images of patients at least occasionally, and about 20% obtain images from all of their patients [1][2][3]. For dermatology clinics that provide telehealth services, almost all teledermatology is done using image-based technologies, making reliable image capture tools a necessity. In the United States, teledermatology has been used to improve access to care in rural and medically underserved areas [4]. However, for teledermatology to be successful, it must be clinically effective [5] with easy access and visualization of store-and-forward images and an increased level of image quality.

Although there have been several studies evaluating store-and-forward teledermatology [6][7][8][9], as well as patient and provider satisfaction with telehealth [10][11][12][13], we found that mobile applications in dermatology are still in their infancy, and there is a great need to assess and evaluate their effectiveness.

II. BACKGROUND

Nearly 80% of the state of Missouri is rural, with about 30% of the population living in rural areas. Access to specialty care for these residents is limited, because most of the rural clinics do not have specialists on site and travel to urban hospitals and clinics can be very costly. In order to bridge health disparities and increase access to care for rural residents, the Department of Dermatology at the University of Missouri (MU) has provided telehealth services to patients via the Missouri Telehealth Network (MTN) since 1995. Each year, through the MTN, hundreds of patients remotely see dermatologists at MU via telehealth. The clinic uses a hybrid telehealth model, with both live-interactive video via the Polycom system and store-and-forward images. This hybrid model has been empirically proven successful in providing patients timely access to quality care. However, the digital cameras are cumbersome, due to limited flexibility to provide necessary functions that are commonly seen in mobile applications, and the tedious process to switch input between camera (still images) and the Polycom system (real-time video) during diagnosis. Moreover, the images are deleted from the far site without depositing them into an image repository for long-term storage and future diagnoses.

There are several challenges that have been identified through observations of teledermatology clinics. For instance, physicians rely on presenters from the far sites to switch between patients’ pictures and video with no control over the digital camera. This lengthens patients’ appointments by having to provide instructions to the patient presenter. While viewing images on the screen, the dermatologist is unable to see the patient – making the visit impersonal, while the patient is unable to see their own image when watching the video – limiting the ability to educate the patient regarding their skin condition. Additionally, in contrast to the radiology community, which has had picture archiving and communication systems (PACS) for decades, dermatology is lacking proper image management systems to help dermatology providers organize images collected at both local and far site clinics. Therefore, these challenges motivated the design and development of mHealth and eHealth solutions to meet the needs of dermatologists in clinical practices, research, and education.

mHealth and eHealth solutions are critical to successful practices, as the adoption of mobile technology is on the rise. A recent study identified 79 apps specific to dermatology that can be reached through a major app store. A majority of them (62%) allow users to access dermatology reference materials, databases, textbooks and journals. Other apps can be grouped into 3 categories: apps that offer dermatology-based questions; apps intended for assisting in diagnoses; and apps with other
miscellaneous uses, such as tutorials on how to perform biopsies [14]. However, what absent is the integration of these apps in a telehealth setting, although it is important to note that mobile apps are gaining popularity as components in telehealth settings [15]. In our particular case, these kinds of mobile apps would not adequately address the identified challenges mentioned above. They did not provide picture-sharing capabilities and a storage repository is needed to make telehealth visits more efficient, improving teledermatology with face-to-face interaction and medical education.

III. MATERIALS AND METHODS

A. Dermatology Image Database

A novel, web-based dermatology image management application, Missouri Dermatology Image Database (MDID), has been developed to facilitate the practices in the Department of Dermatology at the MU. The digital images captured at clinics are transferred to MDID’s secure server via an encrypted connection and sufficient user authentication. Uploaded images are organized by multiple criteria, including basic patient demographics (medical record number, name, gender, date of birth), clinic visit number and date, free text annotation, etc. DermLex™ [16] is used to annotate images with standardized diagnoses, as well as body locations where images are taken. Patients and images can be easily searched by previously introduced criteria. Therefore, MDID provides the dermatologists an instant tool to organize and search images. For example, 1) finding all past images of a specific patient; 2) finding images with the same diagnosis, e.g. “acne”; and 3) finding images of patients who were seen at a specific clinic within a period of time. Images in MDID can also be organized based on users’ preferences into customized online folders. With MDID alongside the dermatologist, images are archived systematically and securely, and can be retrieved efficiently for use by daily practices in clinics, research, and education. Currently, there are 2,973 images in MDID from 878 patients. Extending the MDID to meet the needs of telehealth settings, we have developed the TeleMDID mobile application. In this paper, we outline a number of differences in the requirements and considerations for telehealth compared to the traditional clinical setting, and make recommendations for the community to integrate mobile applications for teledermatology.

B. Considerations of a Telehealth Setting

Prior to the design of the mobile application, we conducted an informal observation of the telehealth workflow. A typical MTN telehealth dermatology session lasts between 15-25 minutes, and follows a procedure similar to a clinic visit, as shown on the left panel of Figure 1. The following discussion of Figure 1 will use lettered annotations to refer to the various components as marked. Due to the educational setting, a patient will typically visit with a resident prior to seeing a dermatologist. The visit is conducted over a Polycom system with high-resolution video displayed on a television screen. Images from the far site clinic are transmitted through the Polycom system by attaching a digital camera on a secondary input through a hybrid store-and-forward solution. The patient photos are normally taken prior to establishing the telehealth session to save time during the actual visit (A).

There are a number of limitations to using the digital camera on a secondary input. First, the dermatologist has minimal control over the images being displayed. There is significant overhead associated with switching to secondary input, and the clinician must ask the far site to step through the images manually (B). This also interrupts communication with the patient, since the dermatologist no longer receives the video feed on the monitor. Additionally, the images must be presented twice for the resident and dermatologist (C). The staff at the far clinic must also be careful to remember to delete the photos from the digital camera after each session to maintain the confidentiality of each patient (D). Most significantly, once these images are deleted, they are no longer available to the dermatologist for historical, diagnostic, or training purposes, as well as meta-data analyses.

Scheduling and availability are also significant considerations in a telehealth setting. Missed or late appointments can mean delays at both near and far clinics, as well as affecting other remote clinics. Even ensuring the right patient at the right location at the right time is complicated in a telehealth setting, as there are frequently multiple scheduling/registration systems and numerous opportunities

<table>
<thead>
<tr>
<th>Old Workflow (Polycom only)</th>
<th>New Workflow (TeleMDID + Polycom)</th>
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<tbody>
<tr>
<td>near clinic</td>
<td>far clinic</td>
</tr>
<tr>
<td>Patient Arrives</td>
<td>Patient Arrives</td>
</tr>
<tr>
<td>Photo via Digital Camera</td>
<td>[photos available]</td>
</tr>
<tr>
<td>Wait for Connection</td>
<td></td>
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<tr>
<td></td>
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<tr>
<td>Patient Documents via Polycom</td>
<td></td>
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<tr>
<td>Request Photo</td>
<td>Patient History</td>
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<tr>
<td>Request Zoom/Pan</td>
<td>Education &amp; Case Study</td>
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<tr>
<td>Low Dermatologist</td>
<td>Research</td>
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<td></td>
<td></td>
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<tr>
<td>Patient History</td>
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Figure 1. Old and new workflows with the introduction of the TeleMDID application and image storage in the MDID system. Primary improvements include more efficient preparation, simplified appointment discussions, and the ability to utilize the photos beyond the appointment.
for miscommunication. Based on these considerations, we have identified a number of ways for adapting mobile technologies from a clinical setting to telehealth. The first is the functionality to provide offline and interactive viewing of patient photos by the dermatologists. The second is the improvement of scheduling and appointment. Finally, the photos and accompanying meta-data must be transmitted securely to an image repository during the appointment without leaving any copy on the local device.

C. System Architecture

The TeleMDID application is depicted on the right panel of Figure 1. There are three phases for the workflow as listed in the system architecture, namely Preparation, Appointment, and Data Utilization. In this section, we will provide a side-by-side comparison for all phases with the old workflow. Careful consideration was given to session establishment, management, and teardown for the TeleMDID application.

During the Preparation phase, the TeleMDID session accounts for far site clinics to take photos of the patient prior to connection with the near clinic and make these images available to the dermatologist for assessment prior to establishing the telehealth session (E). This expedites the image review process, and allows the dermatologist to spend the session communicating directly with the patient. It must also handle the synchronization of image upload/download. We used a modified handshake process, with MDID in the middle to provide session management, to allow near and far site clinics to act independently and connect reliably. Authentication is an important component of the application for ensuring proper session establishment between near and far clinics and confirming the correct patient is available at the correct clinic. Each clinic has a unique username/password combination that identifies the location. Near clinic specialists authenticate with their university credentials to facilitate proper organization of the images within the MDID repository. All communication is encrypted via secure socket layer (SSL), and each request contains cross-site reference forgery (CSRF) protection measures to prevent session hijacking and spoofed clinic requests.

To facilitate MDID in cataloging patient visits, TeleMDID allows the clinician to enter a patient medical record number (MRN). Additionally, to save time in establishing the session, the barcode containing the MRN can be scanned directly from the chart, if available. When each clinic connects, they provide a device token, which is used by MDID to send push notifications (discussed below). The clinic is pushed onto a queue, and the second clinic can be notified of the waiting status. The near clinic is prompted with a list of the telehealth clinics and chooses the location with which to connect. The near clinic also enters the patient identifier used in the MDID system. In this way, the near clinic is wholly responsible for the patient and clinic used in the session. As a verification measure, the far site clinic enters the patient name. While establishing the session, this allows each iPad to display the status of the remote location. In the improved workflow, the dermatologist is notified when the far site clinic has logged into the application, when they are taking photographs, and whether the clinic is waiting for a session to be established.

During the Appointment phase, real-time operation is essential to the ease-of-use of mobile technologies in a clinical setting. To achieve real-time session management and image transmission, TeleMDID uses the Apple Push Notification Service (APNS), similar to the Android Cloud to Device Messaging (C2DM) for Android, for best-effort delivery of real-time information to the application. Push notifications deliver data to the application, even if they are in the background, to update the state of TeleMDID.

Once a session has been established, push notifications are used to inform the near clinic of new images and automatically retrieve them for display. Finally, notifications are used within TeleMDID to implement the “sharing” features, where the dermatologist may push an image or handout to the remote screen for discussion with a patient (F). By viewing an image in full screen mode and pressing the “Share” button, the user can send the far site clinic device a notification, causing it to go into full screen mode and display the image, effectively mirroring the display. Because the traditional handouts used in the clinic are not available to far site clinics, TeleMDID contains a database of documents that can be updated and shared with the far site clinic. This allows the patient to receive information comparable to what he/she might receive during a non-telehealth visit, for printing, emailing, or taking notes, without the potential for communication error. Any patient photos taken over the course of a session are stored in main memory and never written to a file on the device. The images only exist for the duration of the session, but are housed in the MDID image repository for future retrieval. In this way, the images are only accessible to a specific clinic for a specific patient to reduce the risk of breach of confidentiality. Figure 2 shows a screenshot of the apps.

All communications from TeleMDID rely on the available wireless connection at the clinic. This frees the staff member to move the camera as necessary, and display the images to the patient on the tablet screen in a natural way. Additionally, the mobility of the tablet allows near clinic residents to take the iPad out of the room to discuss the images with the dermatologist (G). This greatly simplifies the communication between resident and dermatologist, and eliminates the need for multiple reviews of the photos on a secondary input.

The integration with the MDID system creates a new phase in the workflow that occurs after the appointment. During the Data Utilization phase, images that are taken during a session and stored in the MDID repository can be used for case
studies and discussions, to conduct research on dermatology imagery, or even to be displayed during a subsequent appointment to show improvement or worsening of the patient’s symptoms (H).

Figure 3. (left) Diagnosis process from a near-site provider using the mobile apps. (right) The mobile app was deployed in both near and far sites in Missouri, USA.

D. Survey and Assessment Methods

The iPad apps were deployed to 10 far sites, as well as MU dermatology clinics. Two pre-launch and two post-launch internet-based surveys were distributed to far site patient presenters and dermatology clinic providers in April 2013. Provider surveys were anonymous, while patient presenters were asked to specify clinic name and location for the purposes of identifying clinics that wanted to replace their digital dermatology cameras with iPads and TeleMDID apps. This research protocol has been approved by the University of Missouri Institutional Review Board (IRB) #1207257.

Pre-launch surveys examined the current experience with teledermatology, experience with portable medical devices, as well as any challenges with telemedicine technologies in current teledermatology clinics. The post-surveys examined the experience with TeleMDID, changes in teledermatology clinic workflow, and also asked for user recommendations. The surveys were emailed to participants, including presenters and coordinators from far sites and dermatologists from MU, prior to installation and deployment of iPads containing TeleMDID apps. Non-respondents were sent one reminder about 5 days after the initial recruitment email was sent. Post-launch surveys were sent after the use of the app, with a reminder email sent to non-respondents five days later. The duration between pre- and post-survey for this study is 45 days to obtain initial assessments that are timely and providing preliminary findings for this ongoing research.

Table 1. Experience with teledermatology for Telehealth providers and patient presenters.

<table>
<thead>
<tr>
<th>Experience with teledermatology</th>
<th>&lt; 1 year</th>
<th>1-2 years</th>
<th>3-5 years</th>
<th>&gt; 6 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telehealth Providers</td>
<td>33.3%</td>
<td>11.1%</td>
<td>33.3%</td>
<td>22.2%</td>
</tr>
<tr>
<td>Patient presenters</td>
<td>16.7%</td>
<td>16.7%</td>
<td>33.3%</td>
<td>33.3%</td>
</tr>
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</table>

III. RESULTS AND DISCUSSIONS

The pre-launch survey of the teledermatology near-site providers showed that all of them (100%) have used both Polycom and digital cameras. However, their experience with teledermatology (Table 1) differs from the experience of far-site patient presenters.

When it comes to assessing the providers and telehealth presenters’ expertise with telehealth on a scale of 0 (beginner) to 100 (advanced), the mean was 53.56. All providers, as well as far site presenters (100%), stated they would be willing to use an iPad in conjunction with main telehealth equipment.

When it comes to challenges with the traditional teledermatology clinic, 77.8% of providers reported experiencing problems establishing the telehealth session, while 100% of providers reported telehealth scheduling errors resulting in delayed, missed or incorrect appointments, etc. A high percentage of providers also report relying on still images, with a mean of 87 on the scale of 0 (never) to 100 (always). Providers report occasionally having difficulties viewing still images (mean 55.33), and receiving poor quality images (mean 55.89).

All of the far site rural clinics (100%) that participated in the survey reported using a Polycom telehealth system, and of those, 61.1% used digital dermatology cameras, and 16.7% used other telehealth technologies, such as digital stethoscopes, otoscopes, or document camera.

Although 77% of the far-site clinics report that they have a protocol to delete patient images from digital dermatology cameras, of those 33% reported that images might be kept in the camera after the teledermatology sessions. This may cause patient privacy and confidentiality concerns, since photos left in the camera can be shown during other patient appointments. Also, there was no mechanism for storing these images for future clinical or educational use. Telehealth clinics did not link to the MDID database used for face-to-face patients, so the patient photos were lost once the photos were deleted from cameras.

Providers’ post-launch survey showed that 100% of the providers who used TeleMDID during our pilot study prefer using TeleMDID to the digital dermatology camera, while the far site telehealth presenters had 75% of the preference using TeleMDID. The mean for the ease of use was 74.25. Providers reported not experiencing change in the connection using the TeleMDID, with the mean of 49.25. Far site patient presenters reported that TeleMDID was somewhat easy to use, with the mean of 52. When asked if they had difficulty connecting via TeleMDID, 66.7% of the far clinics reported not having any difficulties, while 33.3% had difficulties, mainly due to sporadic wireless connections from their clinics. The results indicate that proper training and printed instructions for quick reference are needed to have successful deployments for the far sites.

Our aim was to adapt the in-person clinical technologies to the teledermatology clinic to compare its usability and effectiveness with current teledermatology modalities. Table I lists the experience with teledermatology for the provider and patient presenters of the far-site clinics. The subjects in our study have an adequate range of experience covering from new to seasoned practitioners.

Providers reported greater satisfaction with the TeleMDID app than far site clinic presenters, and they also viewed it as an improvement to the clinic flow. All of the providers had
previously been using mobile technologies, iPhone, iPad, or Android, daily, compared to 30% far site rural clinics, which may have influenced their satisfaction level.

We have observed changes to all three phases of the workflow. During the Preparation phase, TeleMDID allowed for images to be transmitted to the provider-side prior to the appointment and connection through the Polycom system. This allowed providers to ensure that the patient was ready for the visit before dialing the far site. It also allowed them to view and prepare the images prior to interviewing the patient. This step ensured the connection to the appropriate far site and minimized the errors in dialing the incorrect location. This workflow improvement is shown in Module E of Figure 1.

During the Appointment phase TeleMDID allowed for providers, patients, and telehealth presenters to view the images at the same time, increasing the awareness and education opportunities. Providers were able to switch between photos, and zoom in and out as needed, which allowed for a more efficient and uninterrupted visit. Providers reported an increase in efficiency of the appointment, with the mean of 65.50. Due to limited accessibility to technical support and expected learning curve, the far-site clinics reported that the efficiency of appointments has decreased, with the mean of 44.

Before installation of TeleMDID, all of the photos taken during teledermatology appointments were deleted after each visit. This resulted in inability to compare patient photos during follow up visits, use them as a teaching tool for students, residents and fellows, or conduct research and present case studies. The Data Utilization Phase has allowed for images to be stored, which had a major impact on workflow improvement is shown in Module E of Figure 1.

In this study, we have observed that the appointments with TeleMDID were more efficient, since the photos taken by the iPad app were ready prior to the connection via Polycom. This results in a shorter visit time for the patients in the clinic, and providers are able to spend more time on diagnosis without waiting for the far site telehealth presenters to show photos on the screen and switch between inputs. While this study did not examine cost improvements, it is our empirical observation that the TeleMDID app has increased user and patient satisfaction by allowing for a more streamlined and better organized appointments that are as close to in-person appointments as it is possible with telehealth.

Our future work has both implementation and research goals. For implementation, it is desirable to develop new functionalities for the mobile apps, and launch of a full-scale deployment of TeleMDID to 150 sites currently on the MTN network. Future improvements to this application include an interface for dermatologists to provide detailed meta-data about the images and annotate regions of an image, including the ability to view these highlighted regions on the far-clinic device in real-time. Additionally, patient history and diagnosis information will be available to the clinician to give a more complete picture of the patient. For far sites, improved training and technical support are needed. Further research is required to include potential cost savings specific to this solution, which includes the commonly used off the shelf technology, instead of costly cameras designed for one purpose. The use of TeleMDID app showed clear improvement in teledermatology work flow which is valuable information gained from this pilot study that could be verified in a large, more inclusive, rollout of the technology.

CONCLUSION AND FUTURE WORK

In this study, we have observed that the appointments with TeleMDID were more efficient, since the photos taken by the iPad app were ready prior to the connection via Polycom. This results in a shorter visit time for the patients in the clinic, and providers are able to spend more time on diagnosis without waiting for the far site telehealth presenters to show photos on the screen and switch between inputs. While this study did not examine cost improvements, it is our empirical observation that the TeleMDID app has increased user and patient satisfaction by allowing for a more streamlined and better organized appointments that are as close to in-person appointments as it is possible with telehealth.

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[16] DermlEx™ (http://www.aad.org/DermlEx/)