Point of Care Image Capture with a Custom Smartphone Application: Experience with an Encounter-Based Workflow

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Published online: 29 May 2019

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Abstract

Medical documentation is one of the primary methods by which physicians share clinical information and impressions over time with one another. As the adage says, “a picture is worth a thousand words,” and physicians have started leveraging consumer mobile technology to share images with one another. However, image sharing often uses short message service texting and similar methods, which can be noncompliant with privacy regulations and can also limit the ability to communicate information longitudinally and across specialties. Sharing of such information is increasingly important, however, as smaller practices are joining to create large geographically spread out health care networks. To this end, we developed an application to acquire and store images via smartphone and seamlessly transfer into the patient’s electronic medical record (EMR) to enable digital consults and longitudinal evaluation in a private and compliant method.

Keywords Smartphone · Telemedicine · Electronic health records

Background

The present era of ubiquitous smartphones has enabled health care professionals to easily capture and share images for clinical care [1]. Increased complexity of large health care organizations and sub-specialization of physicians in a fragmented digital health care landscape has necessitated coordination among physicians using a variety of health care applications. Sharing images of physical exam findings that could previously only be described may be one step toward an integrated health care network. Wounds, skin lesions, and paper documents may be captured as digital images and shared with other providers for the purpose of advancing a patient’s health [2]. While consumer image capture technology has advanced, the systems and procedures for integrating these data into the electronic medical record have lagged. Therefore, a situation exists where data may be captured and shared using insecure systems that are not integrated with electronic medical records (EMRs) [3].

Asynchronous image-based capturing can be utilized by clinicians in the health care system to improve diagnosis and

treatment. Such modalities have clear advantages for patients; however, the technology is often insecure and not integrated to electronic medical records (EMRs) [3, 4].

Image capture modalities not only can serve to more precisely document the current state of a condition but also can be utilized to improve access of care to patients. With a simple transfer of an image, consultations can be made available to patients who might not otherwise have access to a specialist. For example, one pilot investigated the technology to improve access and treatment initiation for dermatologic concerns. With asynchronous telehealth, access to care increased from 70 days to a first appointment time of 0.5 days. Initiation of treatment was accelerated, from 73.5 to 3.0 days, thereby improving patient satisfaction and access to care [5].

In some cases, image-based care can be as effective as traditional in-person visits. In one study, diagnosis based on ophthalmic photographs of the anterior and posterior eye was nearly 100% specific for disease pathologies when compared to in-person exams [6]. In another study, photo-based telemedicine for identification of diabetic foot ulcers approached 98% specificity, when compared to in-person visit [7].

Despite the benefits of asynchronous image-capturing, there are some downsides to this practice. In its current practiced state, asynchronous care can create data silos hidden from other users of the EMR. The care continuum is fluid, and patients often require multiple visits to track treatment progress. When pictures are sent directly from one provider

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to another and are not stored within the medical record, it creates barriers to multi-disciplinary teams collaborating in the monitoring, tracking, and management of the patient.

As importantly, mobile devices are often unencrypted, and images and related communications can contain identifiable protected health information (PHI) that may not be compliant with HIPAA. This type of data should be private, and some studies have shown that this may not be the case [8]. For example, in a recent survey, 69% of dermatologists note sending images via text messages, and only 24% admit to adhering to proper security protocol [9].

Integration of images obtained at the point-of-care into the official medical record is not trivial [10]. The image must be captured and correctly associated with the metadata that describes the patient, date, time, body part, and description of the findings. Two workflows are described to capture images and ensure correct association of metadata [10].

In an order-based image capture workflow, such as used in a radiology department, an order is placed for an imaging study in an electronic provider ordering system within an EMR. The order may travel through several electronic systems before ultimately populating a worklist on the image capture device. When the correct patient is chosen on the imaging modality, the captured images will be associated with this patient and any metadata entered in the order. This workflow, although allowing multiple checks and balances to ensure correct metadata association, is time consuming and labor intensive.

Point-of-care images may be frequently captured spontaneously. There is no need to communicate an order from a referring physician to another department to capture the images. Encounter-based imaging can be defined as “imaging as being performed during a clinic visit or procedure when image content acquisition is not considered the purpose of the visit.” [11] This approach streamlines the process at the time of image acquisition at the risk collecting inherently “dirty data” in exchange for fewer clicks. Currently, there is limited ability within encounter-based workflows for data/exam validation the way there is with order validation. [11]

Unlike other medical images that may be acquired directly from a modality in a radiology department, the workflow at the point-of-care image capture is much less orchestrated. Providers are frequently capturing images in addition to their other clinical duties. Some providers may only infrequently capture images when needed and therefore be unfamiliar with the workflow.

We designed a home-grown smartphone application to securely capture photographs and integrate them into the EMR. We utilized a streamlined encounter-based workflow to optimize ease of use and encourage adoption. We hypothesized that this approach would maximize acceptance of the workflow with a minimum of incorrect metadata.

Methods

An observational study was designed to investigate the utility of an innovative home-grown smartphone application to capture medical photos. This mobile application was developed by one author (SB) prior to implementation. It was made available to iOS users through our hospital’s “App Store” using hospital credentials. The software was initially available by invitation only. As the pilot expanded, the application was available to any user with permission to write notes in the EMR. Usage of the application spreads organically; no dedicated awareness campaigns were undertaken during the pilot. The general agreement for patients was amended by the legal department to include consent for photography for clinical purposes. Written informed consent was not required for photography, but verbal patient consent was encouraged.

The software was developed as a native iOS application. The application was made available to providers to install on their personally devices in accordance with our institution’s “Bring Your Own Device” (BYOD) policy. Some clinics, such as dermatology and vascular surgery, chose to purchase shared devices for use. The application server was written in PHP and hosted in the enterprise DMZ to allow continuous access on both WLAN and cellular networks. The server was protected by an enterprise web application firewall that provided authentication by hospital active directory credentials. User authorization was checked within a database within the EHR to assure appropriate user permissions for writing notes. Users could choose to save their credentials to the encrypted storage system on the device and use biometric authentication to log in to the application.

After authentication, the user is prompted to enter a medical record number or scan a patient barcode present on patient wristbands and sticker labels in our institution. Bar code scanning provides insurance against patient misregistration, but may not always be practical. The user must then confirm patient identification. The user is then immediately presented with the camera interface within the application and documentation can begin. After acquisition, images are immediately uploaded to a temporary cache on the server. Images exist only in memory of the user’s device. No images are saved to the local file system. The user can take additional images of the same patient crop, rotate, delete, or annotate images. Annotations are flattened into the source image; no annotation layer is present. Users are able to provide a caption for individual images. A pick list of common phrases is offered for metadata tagging but is not enforced.

The application was designed to explicitly discourage the practice of using the native camera application on a device to capture clinical photographs. However, after initial implementation, the ability to upload previously captured photographs was requested. A utility to upload photos from a user’s camera roll was added. The feature was discouraged through de-emphasis in the user interface. By default, the application launches the camera within the application that does not save photographs to the local device.

After finishing the capture of a set of images, the user must provide a title for the image set. The user's department is pulled from his/her hospital credentials but may be changed. Some trainees, in particular, may rotate through different departments. By default, the image date and time is assumed to be contemporaneous. However, the ability to backdate photographs was added for images uploaded from a camera roll.

After confirmation, the images are assembled into a single portable document format (PDF) on the server. Images are continuously uploaded in the background after capture to avoid a long network delay after finalizing a session. JPEG compression with an 85% quality factor is applied on the device prior to network transmission. Images are kept at full resolution. The assembled PDF includes the images, descriptive title, and descriptive image captions. The PDF is sent to a document server that stores the file and creates a link in the EMR. The EMR associates the photographs with an episode of care based on pre-existing ADT data.

The application allows users to share a secure link to a photo via text messaging, e-mail, and other channels. The recipient receives a link requiring authentication before a photo can be viewed. The application allows two photos of the same patient to be viewed side-by-side for comparison. Given the small form factor of mobile devices, more complicated hanging protocols are impractical.

Images were taken via the app, and patients were confirmed either by entering a medical record number or by scanning the patient's wristband barcode. The photos were never stored on the device, and multiple pictures could be captured in a series, cropped, rotated, annotated, and descriptively captioned. A PDF of the image was then automatically uploaded into the EMR.

Step 1: Scan barcode on wristband; confirm name and age.

Step 2: Select "Take Photos" and capture the image

Step 3: Confirm images taken; pressing "Done" will upload into the EMR securely. Images are never stored on the phone.

The pilot was designed to run for 20 months, starting September 2016 to May 2018, and to be utilized for medical care purposes. Primary observational outcomes were departmental utilization of software and overall adoption over time. Secondary outcomes were aimed at identifying lapses in the homegrown digital device.

Results

During the pilot period, there were 170 unique users across 26 departments. A total of 3389 clinical photograph sets were taken of 2138 patients. Of those patients, more than 1000 patients had multiple images captured.

Dermatology was the most active department in the pilot, taking 1925 photograph sets (57% of all volume). Vascular surgery took 574 photograph sets (17%). Other departments that utilized the application were general medicine, hematology, oncology, emergency medicine, and interventional radiology.

In April 2017, the institutional policy on clinical image capture was finalized and small pilot programs were launched in dermatology and vascular surgery. The app continued to spread across clinical departments and users via word-of-mouth. There were fewer than 50 cases identified in April 2017. By April 2018, 1500 monthly image cases were uploaded. As seen in Fig. 1, by

Fig. 1 Uploaded Image Sets Per Month: August 2016–March 2019

the following month, this number had grown 33% to 2000 image uploads. As in Table 1 (see [Appendix](#)), categorized by department, 34,560 images have been captured since inception.

Physicians had little trouble with implementing the application. Few required installation assistance from the hospital's App Store. In addition to a few bugs reported, three (0.09%) photograph sets were uploaded under the wrong patient's medical record number, which were operator error. Four (0.12%) requests were made to change other incorrect metadata labels for uploaded photographs.

Discussion

Point-of-care image capture is valuable to the medical care of many patients, as it allows for increased accessibility and trending of visual-based complaints. Without formal systems and procedures for capturing images at the point-of-care, the images captured by clinicians are often delivered nonsecurely, exposing patients' personal health information. Furthermore, these images are often not integrated into the EMR and therefore do not allow for coordination of a patient's medical care.

A mobile-friendly application to upload secure images was shown to be heavily utilized by our clinicians. There was a high adoption rate, especially within dermatology. This has future implications for a telehealth image-capturing network to improve access to dermatology within our own health care system. Furthermore, many patients had a series of image-based encounters, therefore allowing for continuous monitoring of pathology.

Our study has many limitations with may prevent generalizability. Our use of an in-house document management system to store images has both benefits and limitations. The document management system is tightly integrated with the EMR, providing ease of use for viewing images. However, this approach may not scale as a complete enterprise imaging solution for capture of video and higher volume data. Additionally, we chose to use PDF to encapsulate images, rather than Digital Imaging and Communications in Medicine (DICOM). The DICOM Part 10 file format cleanly provides association of an image with metadata. In our case, incorrect metadata requires editing of the PDF itself. PACS systems and archives are now available to allow storage and viewing of photographs. At the time of system design, our institution did not have a zero-footprint DICOM viewer. PDF is universally viewable across platforms and requires no user training. A DICOM viewer would allow more easy comparison of images using hanging protocols. Institutions planning a strategy for point of care image capture may want to leverage a PACS or enterprise archive to store images and universal viewer to display images from an EMR context. The challenges of encounter-based workflow can be managed with thoughtful planning.

Such network-wide image-based capturing has beneficial coordination of care in our health system, as well. As a very inexpensive device, it can facilitate transfers to the tertiary care center, consultations from community hospitals, and prevent

unnecessary transfers/re-visits for post-operative complications. Digital health has tremendous implications in decreasing wasted costs.

There were few risks that are inherent in smartphone-mediated encounter-based workflow; these included incorrect metadata labeling. The prevalence of these errors was very low and often identified immediately for remediation.

Conclusion

A secure mobile application can streamline documentation of visual patient findings into an electronic medical record system. It has a potentially high implementation rate and utilized most by visual-driven medical fields and can improve access for patients as well as care coordination across a large health care network.

Appendix

Table 1 Total number of uses per department since inception

Department	Number of images
Anesthesiology	31
Cardiac surgery	4
Cardiology	349
Colon and rectal surgery	24
Dermatology	20,118
Emergency	188
Gastroenterology	34
General medicine/primary care	1686
General surgery	170
Hematology/oncology	649
Hospital medicine	608
Infectious disease	130
Inpatient	201
Neonatology	131
Neurology	9
Obstetrics/gynecology	96
Ophthalmology	221
Orthopedics	251
Otolaryngology	290
Pathology	3
Plastic and reconstructive surgery	33
Podiatry	537
Pulmonary	974
Radiation oncology	19
Radiology	135
Rehabilitative services	13
Rheumatology	60
Surgical oncology	110
Thoracic surgery	122
Transplant	29
Urology	60
Vascular surgery	6493
Venous access	85
Wound/ostomy	647
	34,560

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