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Sustainable Technology for Surgical Referrals: Pilot Implementation of an Electronic Referral System for Short-Term Surgical Missions

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Abstract: We present an investigation into the feasibility of implementing an electronic medical referral application for short-term surgical missions in rural Guatemala, where the local infrastructure does not support the demand for the surgery. An electronic referral application was implemented for Android smartphones and tablets which allowed the input, aggregation, and secure transmission of patient information that is currently collected on paper forms during surgical missions. The user interface and SMS text message-to-database feature allowed case management data to be entered and transmitted in real time. The referral application was piloted over a 3-day period with a collaborating NGO during a short-term surgical mission in rural Guatemala and was compared to the current standard-of-care paper medical record. This study also assessed the cell phone access and use of community attendees to identify the potential for communication with patients in an integrated electronic referral system. Participants in this study included nine medical mission staff members who used the referral application during the pilot, eight of whom took an end-user survey, 53 patients whose medical information was entered into the referral application, and 93 local attendees who participated in a community survey on cell phone usage. Overall, end-users expressed positive opinions of the application, which they found relatively easy to use. Data loss using the application was minimal in comparison to a 17% permanent data loss of paper records, and the electronic medical records had high internal validity. Widespread cell phone use among community attendees suggests an opportunity to expand the referral application to further improve the surgical referral process.

Keywords: Electronic Referral System; electronic medical records; surgical missions.

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1. INTRODUCTION

Each year, an estimated 313 million surgical procedures are performed around the world; however, only 6% take place in low- and middle-income countries (LMICs) where over one-third of the world's population resides [1]. Even within LMICs, access to surgical resources is uneven, with a disproportionate amount of the unmet surgical need concentrated in rural and marginalized populations [2]. Key barriers to surgical care in LMICs include: difficulty accessing surgical services due to distance, poor roads, and lack of suitable transport; lack of local resources and expertise; direct and indirect costs related to surgical care; and fear of undergoing surgery and anesthesia [3]. Further, monitoring and evaluation of surgical care in LMICs is often rudimentary and inconsistently implemented, leading to lost opportunities to improve resource allocation and quality improvement [4]. The health sector in Guatemala faces many of these challenges.

Consistently underfunded, Guatemala's national health system experiences frequent stock outs, worker strikes, and facility shut-downs [5,6]. Within Central America, Guatemala has the lowest density of specialist surgical workforce per population: 3.4 specialists per 100,000 population, three times less than the country with the second lowest density in the region (Belize) and twelve times less than the country with the highest density in the region (Mexico) [7]. Poor access to surgical care is especially common in rural areas, which have fewer surgeons and operating facilities [8]. Accessing specialized care at the tertiary level often requires extensive (and costly) travel to major cities [5,9]. Although some patients obtain surgical services in the private health sector, for most such care is prohibitively expensive [10]. Gaps in coverage in the public and private health sectors are partially filled by Guatemala's ever-growing "third sector" of healthcare: non-governmental organizations (NGOs) [10]. Many of the country's estimated 10,000 NGOs have ties to the Global North, and some bring down teams of volunteer surgeons and support staff to deliver direct patient care for short periods of time in "medical missions" [11–13]. Guatemala's proximity to North America, coupled with its large, unmet health needs, makes it a popular destination for visiting medical teams, especially since the signing of the Peace Accords in 1996 [11,14,15].

Although visiting medical teams often represent a patient's best chance at receiving care, the growing body of literature on medical missions has highlighted numerous challenges associated with this mode of care delivery [16–19]. Within the Guatemalan context, a major barrier to providing surgical care via visiting medical teams is the lack of a standard process for referring patients to surgical missions, or to other healthcare institutions when the surgical mission is unable to provide the needed care [20]. NGOs often gather critical patient data during surgical missions via patient screenings [13], yet their ability to share this data with other healthcare-providing organizations is limited because most of the information is collected via non-standardized paper medical records. The lack of a standard referral process and mechanism for the transfer of patient data results in several inefficiencies, including patients receiving duplicate tests and procedures at both the referring and recipient organizations [20]. In some cases, a patient may be screened at one organization and referred to a surgical mission, but when it comes time for the surgery, the visiting medical team lacks sufficient patient information or the appropriate clinical specialization to proceed with the surgery. When this happens, surgical slots go unused, and the visiting medical team works below capacity, an inefficient use of the resources mobilized to conduct the surgical mission. On the other hand, overbooking practices to correct this sometimes means that surgeries must be re-scheduled for a later date, thereby lengthening the time between screening and surgery—a known predictor of surgery completion in the Guatemalan surgical mission context [21]. Further, follow-up care to detect and treat surgical complications is challenging, as surgical teams depart the country soon after surgeries are performed.

In previous research, NGOs connected to surgical missions indicated a desire for a shared, streamlined referral system to facilitate the collection and transfer of patient information and coordination of care across organizations [20]. They expressed particular interest in a low-cost solution for secure, electronic information sharing. Mobile phone use is widespread in Guatemala, even in rural areas, where an estimated 75% of households have cell phones [22]. We therefore developed a prototype electronic referral application (app) for surgical missions that leveraged this information communication technology to obtain and share patient data.

This paper reports the results of our two-part feasibility study. First, we tested the usability and acceptability of a novel electronic smartphone-/tablet-based application for referring patients to visiting medical teams. Second, we surveyed community members on their cell phone usage. These components centered on the questions: 1) What is the feasibility of implementing an electronic referral application in surgical missions in rural Guatemala?

2) What are the current cell phone use patterns among community members that seek care from surgical missions? We hypothesized that a shared referral application would be well-received by surgical mission staff, that data integrity would increase, and that community members would report high usage of cell phone technology.

2. METHODS

2.1 Application Development

In July 2014, our research team of three biomedical engineers, one medical anthropologist, and four public health and social science students traveled to the study site for a two-week planning and development period, immediately prior to deployment. Our goal was to design and test an electronic referral app for use during surgical missions, based on stakeholder input and previous research on surgical missions in rural Guatemala [20,27]. The application was designed to leverage the informatics backbone of an SMS-based mHealth system previously developed for an intervention to improve oral rehydration reporting in rural Guatemala [28, 29].

Compared to the existing practice of pen and paper, a smartphone- or tablet-based input modality allowed for the processing of complex data, and downstream decision support. Because internet connectivity via smartphones is sometimes spotty in rural Guatemala, ensuring data transferability under any connectivity condition was crucial. We therefore created a hybrid smartphone system that leveraged an intuitive touch screen interface but could transmit data to our secure servers via SMS (text messages). The app was designed to parcel the entered data into multiple SMS, each with a unique identifier tag to allow for later reassembly into a single medical record. A total of seven simple "screens" were used to collect the data of interest, including a registration/user entry screen to log in, a central "root" menu screen to show progress of data entry, and a final review screen to flag any missing information before data submission. Users could also take and store photographs with the record. The device (i.e., the smartphone or tablet), along with its microSD card, could be secured using Android's native encryption. An SMS back-end system was designed using a web "Ruby on Rails" interface, operating on Mozilla Firefox and Google Chrome web browsers. Frontline SMS—an open-source SMS management tool—was installed on an ASUS Eee box server, which was subsequently connected with a GLGIX GPRS modem and a pay-as-you-go SIM card on a national 3G network. The app, which was Spanish- and English-compliant, was designed with four main components:

1. Administration portal – for project admins to view, edit, and manage platform activity
2. SMS registration and communication framework – allowing individuals to register in the system from Guatemala and the UK, and subsequently interact remotely with the web system
3. SMS template construction – allowing generation and delivery of customizable queries and questionnaires to registered users
4. Data collection and analysis – detailed logs of incoming and outgoing SMS, as well as detection algorithms included in the back-end logic

To test the hardware-dependence of the app, we deployed it on a variety of systems compliant with Android versions v2.2 - v4.3: a Samsung 8 tablet, 3SN-T 310 running Android 4.2.2, a Samsung SCH-1337 s4, a MotorollaA953 running Android 2.2, a Samsung s3 GT-I 9300 running Android 4.3, and a Jpad tablet running Android 4.1.

2.2 Population and Sample Size

This study took place in the central highlands of Guatemala, in a rural town of about 24,000 inhabitants located in the department of Sololá [23]. Like the broader department of Sololá, which is 97% indigenous [23], this town's population is majority indigenous—last assessed as 98% in the 2002 census [24]. Earnings in the town, drawn primarily from agriculture and craftwork, are less than the national average of 1471 Quetzales per month (~USD $209) for rural areas [22,25]. The nearest district hospital is about 40 minutes away by car and has limited surgical capacity. In 2013, this hospital—which has a catchment area population of approximately half a million people [26]—performed about 1800 operations (SIGSA [Sistema de Información Gerencial de Salud]), email communication, October 18, 2013). With limited access to affordable surgical care, some Guatemalans living in this area turn to surgical missions. The collaborating project international NGO regularly hosts surgical missions in the department of Sololá, bringing medical volunteers from North America to the region.

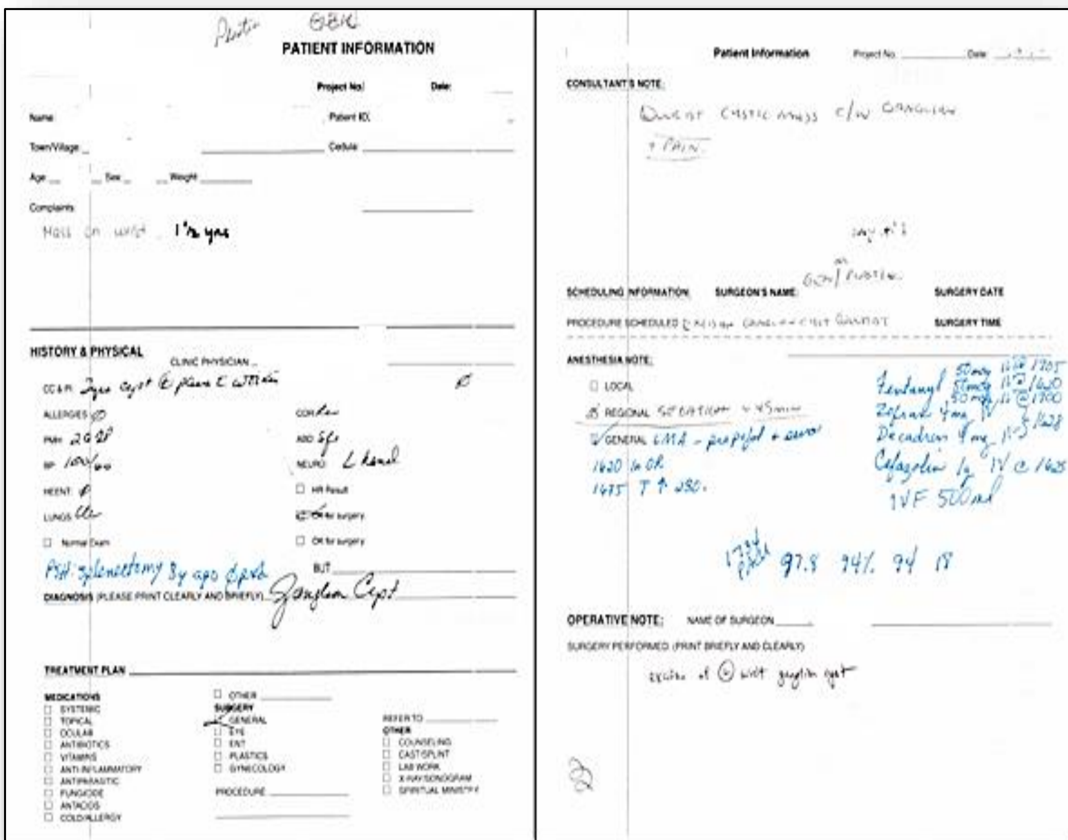
The sampling frame for surgical mission staff participants included surgeons, physicians, and dentists across several different specialties, and medical trainees who used the referral app during the mission hosted by the partner NGO in the study site in July 2014. Participants also had to be adults (age 18+) who could speak English or Spanish. To obtain a variety of user experiences, we employed purposeful sampling to include individuals performing different roles within the mission. Our sample size was determined based on our anticipated ability to conduct observations. Nine staff members participated, including six medical students, one phlebotomist, one obstetrician/gynecologist, and one English-Spanish interpreter. All 9 were North American and spoke fluent English. Eight of these 9 staff members participated in the end-user survey, and most had previously participated in similar surgical missions.

Mission attendees participated in one or both of the following study components: (1) a community survey, and (2) medical records review. For the community survey, our sampling frame included individuals seeking care at the surgical mission and persons accompanying them, who were often family members. Inclusion criteria limited participants to adult Guatemalans who could communicate in Spanish, Kaqchikel, or K'iche'—the three most commonly spoken languages in the study site area. A total of 93 mission attendees participated in our community survey over the 3-day data collection period. They were majority female (73%), with limited formal education (median 3 years). Eighty-eight percent spoke an indigenous language, and 42% were monolingual in an indigenous language. The average distance traveled to the surgical mission was just over four hours (though the median was one hour).

For the medical records review portion of our study, the sampling frame included all mission patients seen by a staff member involved in the piloting of the app. Participants were again limited to adults who could communicate in Spanish, Kaqchikel, or K'iche', as these were the only languages for which an interpreter was available at the mission. Eligible patients seen by a staff member participating in the referral app pilot were enrolled into this portion of the study.

2.3 Data Collection

Surgical missions often involve two stages of patient care. First, mission attendees are screened by clinicians to see if they are candidates for surgery. During this screening process, staff solicit and compile patient data, such as demographic information, medical history, and diagnostic test results. Those individuals found eligible are then scheduled for surgery, which sometimes occurs at a second mission several weeks or months after the initial screening. Given the ad hoc nature of surgical missions and the episodic involvement of multiple clinicians in a single patient's care over prolonged periods of time, maintaining accurate patient records can be challenging. Figure 1 shows an example of a paper-based surgical mission patient medical record with identifiable data redacted. Note the variety of input formats (text boxes, check boxes, free text regions) in the semi-structured form, and the heavy use of abbreviations and multiple handwriting styles of varying quality.


PATIENT INFORMATION

Project No: Date:

Name Patient ID:

Town/Village Cedula

Age Sex Weight

Complaints

HISTORY & PHYSICAL

CLINIC PHYSICIAN

ALLERGIES

HEENT

LUNGS

Normal Exam

DIAGNOSIS (PLEASE PRINT CLEARLY AND BRIEFLY)

TREATMENT PLAN

MEDICATIONS

SURGERY

REFER TO

OTHER

PROCEDURE

Patient Information Project No. Date

CONSULTANT'S NOTE:

SCHEDULING INFORMATION SURGEON'S NAME: SURGERY DATE

PROCEDURE SCHEDULED SURGERY TIME

ANESTHESIA NOTE:

LOCAL

REGIONAL

GENERAL

OPERATIVE NOTE: NAME OF SURGEON

SURGERY PERFORMED (PRINT BRIEFLY AND CLEARLY)

Figure 1. Paper-based surgical mission medical record. Patient data is typically recorded over the course of one or two days by multiple clinicians. Notation styles vary, and handwriting is often difficult to read, even immediately after the data is recorded. Identifiable health information has been redacted.

The study surgical mission took place in a multi-purpose facility comprising medical buildings (consultation rooms, operating theaters, a post-anesthesia care unit (PACU), and patient rooms), a cafeteria, and a dormitory for staff. The host NGO also set up a patient triage tent, which had dedicated areas for pediatrics, ophthalmology, gynecology, and general medicine consultations. Each day, patients began arriving in the early morning. Although a minority of patients had been screened at a previous surgical mission and were scheduled to receive surgery at this mission, most came without an appointment in the hope of being seen by a medical professional. The number of patients who were seen varied daily depending on the availability of surgical slots, beds, and staff, but on average the surgical mission saw about 150 patients per day, most of whom received non-surgical care. During the data collection period of the surgical mission, staff performed 58 surgeries, and 394 clinical consultations.

Data for this feasibility study was collected through direct observation, surveys, and the creation and transferal of patient information via paper and electronic medical records. A semi-structured observation guide was used to capture the app interface workflow, tutorial design, and any usability issues potentially related to language or culture. An end-user survey was implemented with surgical mission staff who used the referral app. It included eight demographic items and six open-ended questions that solicited information about end-users' assessment of the app. The community survey was used with community members who attended the surgical mission to seek medical care or to accompany someone else seeking medical care. The community survey comprised five demographic items and eight questions that assessed respondents' personal cell phone use and cell phone use in their home communities. Both survey instruments were translated to Spanish, piloted with surgical mission NGO staff, and revised for clarification and feasibility.

Data collection occurred over a 3-day period that coincided with Days 1, 2, and 3 of the five-day surgical mission, when the bulk of patient registrations are completed. Surgical mission staff members who agreed to pilot the referral app collected patient information in two formats. First, during each consultation with a patient study participant, they completed a traditional paper record (Figure 1) verbally (with the use of an interpreter, if needed) and handwrote the responses. In the minutes following the consultation's end, the staff member transcribed the information into the referral app (Figure 2) and took a photo of the paper record and the patient's informed consent form. Upon submission in the referral app, the data was transferred via a series of SMS to a secure server. Patient data was also recorded on the original data entry device so that any lost transmissions could be identified. Members of the research team observed this process. At the end of the 3-day piloting period, all staff members who had used the app were invited by a member of the research team to participate in the end-user survey.

During each day of data collection, research team members also administered the community survey. These researchers approached mission attendees as they waited to be seen by a clinician. If the person preferred to speak in Kaqchikel or K'iche', the study introduction, consent, and survey were administered with the assistance of an interpreter. Otherwise, the survey was administered in Spanish by the researchers, all of whom had intermediate or advanced Spanish language skills.

Patient ID	**Chief complaint**
Name	Pertinent physical findings (e.g., tumor or lesion dimensions)
Town/village	Diagnosis
Cell phone number	Surgery type (if applicable)
Date of birth	Procedure performed (if applicable)
Date seen at mission	Medicines prescribed & other treatments received at mission
Age	Refer to (+ specific surgical service within mission or external agency name)
Sex	Photo of patient information sheet
Medical history (e.g., diabetes, previous surgeries)	Photo of signed informed consent form
Weight	
Blood pressure	
Allergies	

Figure 2: Patient data collected in the referral app

2.4 Ethical Considerations

Prior to all data collection, informed consent was obtained from participants. Among surgical mission staff participants who completed the end-user survey, written informed consent was obtained in English, their native language. Among mission attendee participants who completed the community survey and patients whose information was entered into the app, verbal informed consent was obtained, with two members of the research team signing the consent form as witnesses. For participants who preferred to speak in Kaqchikel or K'iche', an interpreter was used. No compensation was offered to participants during this project. Use of the app did not interfere with patient treatment. The study was approved by the IRB of Guatemalan NGO Wuqu' Kawoq.

The app followed HIPAA guidelines for data security and storage. Users were pre-authenticated for device usage, which required a pin log-in to access the application. Only users who had created patient entries were able to query and continue to view and modify existing entries. Patient information was saved locally on each device on encrypted internal storage, either by encrypting the device itself or the SD memory card. When the devices were synced for collected data, the sync was done through a HIPAA-complaint data transfer and saved on an encrypted drive partition using BoxCryptor software (Secomba GmbH, Augsberg, Germany). The app's web platform was also designed with authentication on access. All stored data is hosted through a HIPAA-complaint server.

2.5 Data Analysis

All surgical mission patient information entered into the app was collated and synced to a Microsoft Access database. Descriptive statistics of demographic data were calculated in Matlab. Data loss was assessed at the record level by comparing the number of records created in the app versus the number retained through the end of the mission. Data validation was conducted through manual comparison of the content of each referral against the original paper copy of the Patient Information Sheet. During the validation process, data transcription was assessed via frequency count of the number of transcription errors, using the data field as the unit of analysis. Data conversion was assessed via frequency count of the number of SMS-to-database conversion errors, again using the data field as the unit of analysis. Lastly, overall transcription accuracy percentage was then calculated for each data field by dividing the number of records with neither transcription nor conversion errors by the total number of records.

Hand-written notes taken during direct observations, surveys of staff members, and surveys of attendees were typed, collated into a single document, and analyzed qualitatively for major themes using directed content analysis. After creating a preliminary codebook, five members of the research team independently coded the notes. Discrepancies in coding were resolved by consensus. Descriptive statistics of survey questions with categorical response choices were analyzed using Matlab.

3. RESULTS

3.1 Assessment of Referral App Data

3.1.1 Data Loss

Table 1 summarizes the data loss that occurred at the record-level as patient information was transferred from the paper-based medical record to the referral app. A total of 70 records were initiated in the app over the 3-day data collection period. Notably, 31% of the paper records initiated experienced temporary or permanent data loss at some point during the data collection period; however, 14% of records were recovered, resulting in a final permanent data loss of 17%.

Jornada Day	No. of records initiated in app	No. of records missing at end of day	No. of records recovered	No. of records permanently lost	Total no. of records collected
Day 1	25	12	3	9	16
Day 2	42	10	7	3	39
Day 3	3	0	0	0	3
Total	**70**	**22**	**10**	**12**	**58***

*Since 5 records were duplicates, the number of unique patient records was 53.

Table 1. Summary of data loss during referral app piloting

There was no centralized facility to store paper medical records, and the large triaging area, coupled with the busy work environment, allowed for some loss of files. Over the 3-day data collection period, many paper records were lost. Some paper records were recovered by the research team after extensive searches of the triaging facilities and patient waiting areas.

3.1.2 Data Validation: Comparing Paper-Based and Electronic (App) Records

Data was validated by comparing the referral app data to the paper-based data. Two types of errors were assessed: transcription errors—human data entry errors that occurred when data from the paper-based record was input into the referral app—and conversion errors—errors that occurred within the app when SMS were assembled into an electronic medical record. Overall, transcription errors occurred in 62 records and conversion errors occurred in 10 records. Errors most commonly occurred in the data fields for “chief complaint”, “town”, and “diagnosis”. Table 2 displays the error frequency by error type and data field.

Data field	No. of records with transcription error only	No. of records with conversion error only	No. of records with both types of errors	Transcription accuracy*	Description
Cell phone number	0	0	0	100% (58/58)	--
Patient ID number	1	0	0	98% (57/58)	1 patient was a minor so parent's government ID no. should have been assigned as patient ID no., but patient's own government ID no. was used instead.
Surgery type	1	0	0	98% (57/58)	1 contained data that was absent in the paper record
Refer to	1	0	0	98% (57/58)	1 wrote "none" when should have left blank
Medicines & other treatments	1	0	0	98% (57/58)	1 missing
Age	3	0	0	95% (55/58)	[#] ages missing; [#] month/year incorrect
Medical history	3	0	0	95% (55/58)	2 had "none" written when should have left blank; 1 included an incorrect English translation of a Spanish word
Blood pressure	3	0	0	95% (55/58)	3 missing
Pertinent physical findings	3	0	0	95% (55/58)	2 had spelling mistakes; 1 missing
Procedure	3	0	0	95% (55/58)	1 contained data that was absent in the paper record; 2 lacked data that was present in the paper record
Date of data entry	4	0	0	93% (54/58)	1 incorrect date; 3 had wrong month/day format
Name	1	4	0	91% (53/58)	1 incorrect last name; 4 text-conversation errors of foreign characters (e.g., accent marks).
Weight	5	0	0	91% (53/58)	1 incorrect; [#] incorrect; [#] did not specify units used (kg or lb)
Date of birth	5	0	0	91% (53/58)	3 missing; 2 incorrect (wrong month/day format or incorrect year)
Allergies	5	0	0	91% (53/58)	5 wrote "none", "nka" (no known allergies), or "nkda" (no known drug allergies) when should have left blank
Sex	6	0	0	90% (52/58)	6 incorrect
Diagnosis	7	0	0	88% (51/58)	6 had spelling mistakes; 1 missing
Town	2	6	0	86% (50/58)	[#] locale more specific than required; [#] text-conversation errors of foreign characters.
Chief complaint	8	0	0	86% (50/58)	4 had spelling mistakes; 4 lacked the specific medical complaint as noted in the paper record
Total	**62**	**10**		**--**	--

***Calculated as the number of electronic records containing neither a transcription nor a conversation error in the specified data field divided by 58, the total number of electronic records retained at the end of data collection.

Table 2. Frequency and description of transcription and conversion errors discovered during data validation comparing 58 paper-based records with their electronic counterparts.

Transcription (human) errors were primarily due to (1) data entry errors due to illegible handwriting in the paper record (i.e., handwriting illegible and end-user incorrectly interpreted what was written and entered it into the referral app); (2) data entry errors unrelated to paper record (e.g., misspellings, incorrect numeric value entered); and (3) end-users entering details of the patient exam that they remembered but were not documented in the paper record. Paper-based records were not systematically assessed for errors; however, during observations, research team members noted several instances in which multiple paper records were created for the same patient. For example, on Days 1 and 2, two separate triage forms were filled out for a single ophthalmologic surgery patient, with inconsistent name and town pairing, and missing government ID number.

3.1.3 Data Transmission

SMS data transmission was conducted on the JPad device during Day-1 of the study. Eight patient records were collected successfully on the Android device and transmitted without error to the web system in three SMS packets, relating to patient registration, patient history, and treatment plan. There was no data loss reported, and 0% data discrepancy with the referral app data. However, further reconciliation between the Android device and the web-database was not possible due to a malfunction of the JPad hardware on Day-2. As the data transmission on Day-1 between the JPad device and the web platform was 100%, the discrepancies between the paper records and SMS server are analogous to the ones found between the Android devices and SMS server, albeit with much lower numbers.

3.1.4 Observations of App Use & End-User Survey Results

Over the 3-day data collection period, the research team performed 20 observations of the 9 staff members using the app. All medical information was entered into the app in English, and each patient record took, on average, 5-7 minutes to transcribe.

3.1.5 Utility of the App

Overall, end-users felt that a referral app like the one piloted in our study could facilitate referrals to surgical missions. Some participants believed it could potentially enable better continuity of information for both patients who visit missions fairly regularly and the clinicians who treat them: “This would be great for referral purposes within Guatemala and for [the patient’s] future visits to *jornadas* [medical missions].” Other participants focused on the app’s potential to reduce loss to follow up: “In the [triage] clinic, [the app] seemed to go quick [and] smoothly and worked well…It would be nice to have better surgery referral and a way to get in touch with those patients [that we found eligible for surgery today].” Some participants also commented on how the app was better than paper-based records. One participant explained, “Handwriting on [paper] charts [is] frequently illegible. Much information is lost between providers when relying on charts. [It] often requires conversations to clarify.” Another stated, “[The] eliminat[ion] [of] illegible handwriting and the ability to send data electronically over distance are [the app’s] greatest benefits.”

With respect to improvements, some participants recommended separating certain data entry fields. For example, the app had one field called “Meds/Allergies”. One participant stated, “[The] ‘Meds/Allergies’ [field] must be separate…entries [in the app]. It is very dangerous to combine them, especially in situations with a language barrier. Patients could be given meds they are allergic to or denied meds that they require.” Notably, this field was copied directly from the paper-based record. The comment nevertheless highlights how two users may interpret the same information differently and pinpoints a need for adjustments to prevent variation in interpretation.

A few participants suggested adding additional buttons or features to help guide users through the app interfaces. For example, the app did not allow for navigation between pages but instead featured just one button that brought users back to the table of contents. One participant recommended adding “next page” and “previous page” buttons to facilitate navigation. Others suggested the addition of drop-down menus and the ability to search for already-registered patients.

The photo documentation component of the application also created some challenges. Since photos were taken by different end-users on different devices, image quality varied. For example, some participants placed the patient forms on the ground and took a photo from afar. Others placed the form on their laps or held the forms in their hand while taking the photo. There was also some confusion about what to photograph at what time. As one research team member noted during observations: “The doctor questioned how he should photograph the patient’s forms, [asking] ‘Should he [photograph] the front and back? Should he photograph it after the patient has seen the doctor?’”

3.1.6 Issues not addressed by the app

A major challenge faced by surgical mission staff was the language barrier between them and patients. This barrier was apparent in most of the observations conducted by the research staff. In general, communication between the staff member and the patient required the help of a translator. As one end-user described: "The language barrier [made it] very difficult to determine the exact chief complaint." Language barriers, of course, would still exist even if the referral app replaced the paper-based record system.

A second challenge—observed in one-fifth of the 20 observations—was patient concern about the confidentiality of information entered into the app. One patient asked if her information was going to be posted on Facebook. Others expressed more general concerns about their information being photographed and entered into the app.

Third, some staff also expressed initial hesitation about using the app. Many of the clinician participants practice in North American health facilities that use electronic medical record systems, and several expressed ambivalence about the usefulness of their home institution's system. However, once the purpose of the referral system was explained to participants, participants' initial hesitation dissipated. Most end-users ultimately expressed very positive feelings about the referral app after using it. However, resistance to begin using the app may be a barrier to its implementation in other settings.

Lastly, some participants experienced data entry issues that were not related to the app but to the device on which the app was used. For example, participants using the Motorola A953 device experience difficulty entering data due to the small size of the keys on the phone.

3.1.7 Community Survey Results

Table 3 displays results from the community survey about cell phone usage. In our sample of 93 mission attendees, 97% reported using cell phones in their home communities. Similarly, 96% stated that cell phone credit was available for purchase in their home communities. About half of participants (47%) had either a basic phone or a smart phone, and over two-thirds (82%) said that they purchase phone credit on a daily or weekly basis.

When asked about problems they experience with using their cell phone, participants mentioned issues getting a signal, particularly during inclement weather, and difficulties charging the phone battery due to electricity outages. Nearly all participants (97%) expressed a desire to receive information from surgical mission organizers via cell phone.

	% (n)		% (n)
Use cell phones in community	97% (90/93)	Phone credit available for purchase in home community	96% (89/93)
Receive and send text messages	84% (78/93)	Frequency of purchasing phone credit: -Daily -Weekly -Monthly -Variable -Random	 32% (30/93) 50% (46/93) 2% (2/93) 13% (12/93) 3% (3/93)
Frequency of cell phone use: **-Daily** **-Weekly** **-Monthly** **-Unknown**	65% (60/93) 26% (24/93) 3% (3/93) 6% (6/93)	Would like to receive information from *jornada* organizers via cell phone	97% (90/93)
Type of phone used:* **-Feature** **-Basic phone** **-Smartphone** **-Unknown**	 39% (35/90) 40% (36/90) 7% (6/90) 14% (13/90)	*Out of n of 90 respondents who said they use cell phones. A feature phone was defined as a cell phone that does not have internet capabilities or a working camera. A basic phone was defined as a phone that has a working camera and basic internet capability. A smartphone was defined as a phone that has internet and camera capabilities, running an operating system such as Symbian, Android, iOS, or Windows Mobile.	

Table 3. Results from community survey with *jornada* attendees about cell phone usage (n=93)

4. DISCUSSION

To our knowledge, this study is the first to test the feasibility of implementing an electronic medical referral system in the medical mission setting. Our results suggest that a simple tablet- or phone-based data entry system is reasonably acceptable to end-users, feasible to implement, and reliably produces electronic medical records with high validity that have several advantages over paper-based medical records. However, we did identify some areas for app improvement and potential barriers to implementation. Below we discuss the implications of our findings for short-term medical mission stakeholders.

4.1 Benefits of a Referral System

Our referral app represents one potential tool to integrate discrete episodes of surgical mission care into a continuum of care. Like most surgical care, surgical mission care occurs in stages. First the patient undergoes screening, which may require additional tests and procedures, and gets referred for surgery. Then, usually at a later time, the patient receives surgery. However, in the surgical mission setting, care continuity is challenged by the fact that those clinicians who conduct the screening are rarely the same clinicians who perform the surgery. Breakdowns in the referral process stem, in part, from insufficient quantity and/or quality of patient data. Successful patient referral requires thorough, accurate patient data collection during screening, as well as a mechanism for data storage, transfer, and updating. Other LMIC-context studies have found similar results in reduction of data loss when testing an electronic medical record in comparison to paper records [30, 31]; however, we are unaware of other studies of electronic medical record use in the STMM context. As shown in our pilot, our referral app allowed for the creation of an enduring "snapshot" of the patient's medical history and health status at the time of patient screening that can facilitate the referral process by providing information for patient tracking as well as for informing future treatment decisions. Although further research is needed, the potential benefits that using an electronic referral system may have are numerous:

(1) **More effective utilization of limited health care resources**. For example, if diagnostic test results are in the patient's electronic medical record and accessible to clinicians in subsequent care visits via a scaled-up version of the referral app, this could result in fewer duplicate tests. The electronic referral system could also help avoid under- or overbooking of surgical missions by providing a database of referred patients who can be tracked in the time leading up to their surgery. NGOs could use information about patients' medical needs to inform the type of clinicians they bring down for missions. The database could also help ensure that visiting medical teams have the information they need to clear the patient for surgery on the day of the operation, resulting in fewer rejections of previously-screened patients. Lastly, electronic data could also expedite the patient intake process, as those patients with a scheduled surgery could bypass the triaging step. While much has been written

highlighting the need for improved access to surgery globally [2, 3] and the difficulties of delivering high-quality surgical care via STMMs [17, 19], little research has explored the prospects of EMRs and low-cost mobile phone-based technologies to address these problems.

(2) **More accurate patient data**. Electronic medical records avoid issues stemming from the illegibility of handwriting on paper-based records. In our pilot, handwriting was still an issue because surgical mission staff entered electronic data from paper-based records; however, in future surgical missions, patient data could be entered directly into the referral app.

(3) **Less data loss**. Although some of the electronic records were lost during transmission, based on our observations and surveys of end-users, electronic data loss appeared lower in the electronic referral system than in the paper-based system. Our hybrid system used an asynchronous store-and-forward technique so that GPRS or SMS could perform handshaking with the server and synchronize data through both a local server attached to a WiFi router and a remote server. This setup helped protect against message delivery failures, which are common even under normal operation conditions [32] and synchronization issues. Other studies have similarly shown improved data capture using electronic medical records in LMIC contexts [30, 31].

(4) **Increased data security**. Given the high patient volume at surgical missions, it can be difficult for staff to keep track of all paper records. In our pilot, research team members helped mission staff track down misplaced paper records, and some records were never located. The data in our referral app, on the other hand, was highly secure due to features such as pre-authentication of users and data encryption.

4.2 Barriers to Implementation of an Electronic Referral System

Despite these advantages, several potential barriers to implementing a referral app exist. First, buy-in from the target end-user and patient populations is a prerequisite. In our study, a few mission staff members and patients expressed hesitancy to use the app or allow their information to be entered into the app. This barrier may be mitigated thorough identification and training of "app champions," such as respected surgical mission clinicians who can get their colleagues on board with using the app, or influential community members who can provide detailed information to their peers about the app's purpose and the intended use of data. Additional strategies to increase buy-in could include informational brochures, videos, radio announcements, and other forms of media. As the app's end-user population expands to individuals outside of the visiting medical team, additional consideration must be given to differences in language, culture, and familiarity with technology.

For this study, the national identification card was used to identify patients. Although many patients possessed a national ID card with a readable chip, this was not always the case, and there may be reluctance to allow the clinical teams' access to the ID, particularly electronically. Transcription errors can occur on the national number, and the photograph is small and often hard to match to the user. Names are not useful identifiers, as the same or similar given and surnames tend to occur frequently in rural communities. Moreover, concerns were voiced by mission organizers that some patients may sell their appointment slots to others, and hence there is a possibility that patients may be using assumed identities. Multiple identifiers would help clarify identity and ensure correct pairing of patient with electronic medical record. Other possibilities for identifying the patients include face recognition or biometrics (such as finger printing).

Technical issues with connectivity and electricity supply are other potential barriers to implementation. We anticipated connectivity issues and designed our electronic referral system to function even in the absence of internet signal. We also had a battery contingency plan in case the electrical supply failed. Lastly, language barriers between end-users and patients can continue to hinder implementation as in paper records. Our referral app was designed for English- and Spanish-speakers, so soliciting patient information still required either knowledge of the patient's language or assistance from an interpreter. In the future, an electronic referral system could potentially mitigate this barrier by providing end-users and/or interpreters with specific vocabulary or alternative ways of asking the same question. In our pilot, most mission attendees had only a few years of formal education, so it is important to ensure that mission staff use language that is appropriate to the patient's health literacy level.

4.3 Study Limitations

The main limitation of our investigation is that it is a single site study with a relatively small convenience sample, thereby limiting generalizability of our findings to other settings and populations. Our sample of end-users was fairly homogenous: mostly medical students under the age of 30. Given that younger generations tend to be more tech-savvy than their older counterparts, our end-user data on the app's utility may be skewed toward positive impressions. Further testing of the app in different end-user populations is needed. Although mission attendees were not sampled randomly, the linguistic and educational composition of our final cohort was fairly representative of rural Guatemala as a whole, and the high cell phone usage reported by participants aligns closely with national survey data [22].

As with any survey, there is a risk of social desirability bias. All of the researchers on our team were foreigners and may have been perceived by community survey participants as members of the visiting medical team. However, this risk may have been mitigated by the fact that questions on the community surveys were not sensitive and did not have a clear "desirable" answer. It is also possible that end-users may not have wanted to express negative opinions of the app to the app's designers. But fear of "offending" the research team may have been assuaged by informing end-users that the purpose of the surveys was to solicit honest critiques that could be used to improve the app.

Lastly, the use of a variety of devices may have skewed end-user impressions towards the negative. We piloted the app on different devices to see if app performance varied by device type. Issues with the device, however, may have impacted end-users' impressions by leading to survey responses and observations based primarily on technical aspects of using the device rather than the referral app itself. Still, of the 8 end-users surveys, all expressed predominantly positive opinions, so the effect of skewing toward negative opinions, if any, was likely minimal.

5. CONCLUSION

The aim of this research was to explore the utility of an EMR in the context of short-term medical missions. Our tablet-/smartphone-based electronic referral application proved feasible to implement in the short-term surgical mission setting in rural Guatemala. Data loss using the application was minimal in comparison to a 17% permanent data loss of paper records, and the electronic medical records had high internal validity. End-users, who were medical staff, expressed positive opinions of the application, which they found relatively easy to use. Community survey data further indicate a desire to receive communications about STMM care via cell phone. These results indicate that there is substantial merit in pursuing EMR implementation in the STMM setting.

Our findings highlight several areas for future research. The rising use of cell phone technology, coupled with decreasing costs of cell phones, has created an opportunity for e-health applications to complement in-person healthcare delivery in resource-limited settings [33]. The referral app functionality could, for example, be expanded to share information with patients about upcoming surgical missions, pre- or post-surgical care instructions, appointment reminders, and follow-up care. Future research would be necessary to explore the feasibility of adding such features and to assess their use and utility, with particular attention given to patients' ability to understand the information they receive and respond. The referral app could potentially help transform medical missions from a "push system" in which volunteers express interest in coming and NGOs find patients they can treat, to a "pull system" in which patient need determines visiting medical team composition [34].Finally, future research is also needed to see whether this app could be implemented successfully on a larger scale, including options such as using open-source libraries for sending high volumes of encrypted SMS.

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