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Evaluating Artificial Intelligence and Telemedicine-based Care Models in Dermatology

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Background: To compare screening referral recommendations made by remotely located ophthalmic technicians with those of an ophthalmologist examining digital photos obtained by a portable ophthalmic camera system powered by an iOS handheld mobile device (iPod Touch).

Methods: Dilated screening eye exams were performed by ophthalmic technicians in four remote districts of Nepal. Anterior and posterior segment photographs captured with a Paxos Scope ophthalmic camera system attached to an iPod Touch 6th generation device were uploaded to a secure cloud database for review by an ophthalmologist in Kathmandu. The ophthalmic technicians' referral decisions based on slit-lamp exam were compared to the ophthalmologist's recommendation based on the transmitted images.

Results: Using the transmitted images, the ophthalmologist recommended referral for an additional 20% of the 346 total subjects screened who would not have been referred by the ophthalmic technician. Of those subjects, 34% were referred to the retina clinic. Conversely, among the 101 patients referred by the technician, the ophthalmologist concurred with the appropriateness of referral in more than 97% of cases but thought eight (2.8%) of those patients had variants of normal eye pathology.

Conclusion: An ophthalmologist who reviewed data and photos gathered with the mobile device teleophthalmology system identified a significant number of patients whose need for referral was not identified by the screening technician. Posterior segment pathology was most frequently found by the remote reader and not by the technician performing dilated slit lamp examinations. These results are promising for further clinical implementation of handheld mobile devices as tools for teleophthalmic screening in resource-limited settings.

Keywords: telemedicine, rural population, ophthalmology, referral and consultation, global health
Introduction
The utility of eye screening examinations using portable mobile devices such as smartphones and tablets in developing countries is still largely unexplored. However, several publications and systematic reviews suggest that teleophthalmology can provide cost effective ophthalmic assessments comparable in quality to an in-person exam. This can be feasible even in the most rural corners of the world as the rate of mobile phone usage and wireless internet connectivity is increasing fastest in low and middle income countries to near ubiquitous levels, often surpassing access to clean water and food. The growing availability of mobile devices with wireless connectivity and high quality in-phone camera technology combine to make mobile device-based teleophthalmology a promising diagnostic tool in resource-limited settings.

The first point of medical contact for a patient with eye complaints in rural Nepal is often at their nearest community eye center (CEC) where they are evaluated by ophthalmic technicians who have completed at least three years of basic science, ophthalmic theory, and clinical practice training. Technicians learn through on-the-job apprenticeship from senior technicians how to conduct eye exams similar to those performed in a developed country’s emergency room with a tonometer, slit lamp, and visual acuity chart. They are educated on treating basic eye complaints like corneal abrasions and refractive error and trained to identify candidates for cataract surgery and which patients to refer. The main eye hospital in the capital city of Kathmandu is the only location where ophthalmic sub-specialty and surgical services are offered. Rural patients must frequently travel hundreds of kilometers to obtain subspecialty, surgical, or postoperative care. The arduous journey by car, bus, or foot is often medically necessary; however, many routine follow-up visits or non-urgent consultations could also be managed at the nearest CEC.

In this study, the Paxos Scope teleophthalmology platform (Fig 1) was implemented in select remote CECs of the Tilganga Institute of Ophthalmology (TIO) Health Care System in Nepal to characterize referral patterns based on routine exam and photos from a specialized portable mobile device. TIO is the largest provider of ophthalmic care in Nepal, including cataract surgery camps, hospital-based surgery, subspecialist consultation, medical residency training, and research. CECs are permanent rural satellite locations of TIO, staffed by non-ophthalmologists using slit lamps to screen for eye disease warranting subspecialty referral. These differ from mobile itinerant screening camps that are periodically conducted within different remote villages; the latter primarily use visual acuity and flashlight exams to screen for cataracts requiring surgery at a future mobile cataract surgical camp.

Previous studies showed that excellent high-quality images could be taken with both an older and current version of the Paxos Scope. It is a medical device attachment that requires about six hours of supervised practice screening per day for four days to become proficient. This portable technology enables an accurate diagnosis to be made remotely. A validation study suggested that high definition photos viewed on a mobile device are comparable in quality to those viewed on a desktop, enabling supervising ophthalmologists to provide real-time feedback to the field while attending to their clinic duties.

Teleophthalmology consultations with TIO ophthalmologists in Kathmandu could potentially provide rural CEC staff with additional support in making referral decisions. Properly identifying patients that should see an ophthalmologist targets care and reduces missed diagnoses. The objective of this study is to assess the impact of the Paxos teleophthalmology platform at four Nepali CECs in making referral decisions.

Methods
Research adhered to the tenets of the Declaration of Helsinki and was performed ethically in accordance with the Institutional Review Board at the Tilganga Institute of Ophthalmology. All image acquisition and transmittal was handled with strict attention to the confidentiality of personal data in accordance with the Data Protection Act of 1998 and Access to Health Records of 1990. Verbal informed consent was obtained from subjects and the study was conducted in a Health Insurance Portability and Accountability Act (HIPAA)-compliant manner.

Over a four-day period, Community Eye Center ophthalmic technicians in the Nepali districts of Ramechhap, Jiri, Dolakha, and Charikot were trained by authors JW, EP, and MO on the use of the Paxos Scope, a 510k-registered ophthalmic camera system (commercialized by DigiSight Technologies, which is now Verana Health, San Francisco, CA, USA). This small, portable device allows for magnified anterior segment and fundus photography (Fig 2).
when attached to an iOS mobile device (iPod Touch, 6th generation, Apple, Inc, Cupertino, CA, USA). Secure cloud based storage of all patient information was accomplished using HIPAA compliant Paxos software, available on the iOS App Store for all iOS devices.

Patients giving informed consent were enrolled in the study during their normal CEC appointment. The participant first underwent nonmydriatic anterior photography of both eyes with the mobile device attached to a Paxos Scope anterior adaptor. The Paxos mobile device application was used to focus and capture all photos and served as the HIPAA-compliant patient medical information and image repository. The adaptor consisted of a macro lens that slides in front of the mobile phone’s camera lens to provide the right amount of magnification to capture a photo of the anterior segment of the eye when the mobile device and adaptor unit is held a few centimeters from the participant’s eye. An LED light on the adapter provided uniform lighting for adequate image detail. Pressing down on the mobile device screen in the Paxos application captured multiple photos. The best in-focus photos were saved into the patient’s virtual chart, per the ophthalmic technician’s discretion. The technician then conducted their ophthalmic exam as usual, which included visual acuity, refraction, and dilated slit lamp examination (using a 90 D lens). The ophthalmic technician recorded their binary decision (yes/no) regarding whether or not the participant warranted referral to TIO. The decision was based on identified pathology that could not be treated at a CEC such as glaucoma or poor visual acuity uncorrected by refraction. Next, a lens-holding adapter
containing a 20D indirect ophthalmoscopy examination lens was locked into place to the anterior attachment with the proper alignment and working distance to obtain the fundus photo of each eye. During posterior segment photography, the macro lens was slid to one side to prevent obstruction of the mobile device camera lens. The 20D lens was brought close to the participant’s eye, then using the view on the screen of the mobile device, the technician ensured the retina was in focus and filled the image capture frame before image capture. Of note, mature cataracts were not referred because these patients were given information on the next local mobile surgical camp. The medical information and photos could either be viewed on the Paxos application or online on a HIPAA-compliant password-protected website.

A patient’s profile in the Paxos application was deemed complete if it contained anterior and posterior segment photos of both eyes, as well as visual acuity. The technicians chose to record other elements of their normal exam as they thought relevant to the patient’s case. One ophthalmologist at TIO (author ST) served as the blinded photo grader. Along with the photos, the study reviewed additional patient information including visual acuity, refraction, and IOP to determine whether the patient could be managed at the local CEC, or whether they should be transported to TIO for care and evaluation by an ophthalmologist. The decision to refer was based on the identification of ocular pathology that could be treated or needed to be monitored by a subspecialist, like a retinal detachment or advanced diabetic retinopathy. ST also determined the subspecialty clinic to which the patient should be referred, which the ophthalmic technicians were not asked to assess.

Statistical analysis was performed in STATA 15. Descriptive data were presented as means and
standard deviations, or counts and percentages as appropriate. The primary outcome measure was a calculated unweighted Cohen’s kappa coefficient for inter-rater agreement on referral status. The ophthalmologist’s referrals were categorized by referral subspecialty. Discrepancy in the referring decisions between the ophthalmologist and the rural technicians were analyzed with respect to disease type. All cataract clinic referrals made by the ophthalmologist were categorized as “no referral” because, although technicians and ophthalmologists agreed regarding the need for cataract surgery, technicians generally recommended that these patients return to the CEC in the next several months to attend a local surgical camp, rather than traveling to Tilganga. These surgical camps are organized and conducted by TIO ophthalmologists, and happened at least once every year at each of Tilganga’s sixteen CECs.

**Results**

Over a ten month study period, 346 total patients were enrolled in the study from the Ramechhap (n=126), Charikot (n=55), Dolakha (n=124), and Jiri (n=41) CECs. Of those, 54% were male and the mean age was 63 years old (Table 1). All recruited subjects were included in this study, with 72.5% having “complete” teleophthalmology exams, including basic health demographic information and bilateral anterior segment and fundus photos (total of at least 4) stored in the Paxos application. The technician and ophthalmologist made the same referral decision 77.4%, not 77.5% of the time (Table 2), resulting in a Cohen’s unweighted kappa of 0.56 (95% CI of 0.46-0.65), which is suggestive of moderate agreement.

Among those patients that were not referred by the technician, the ophthalmologist identified 56 subjects (19.7%) that needed referral to TIO for evaluation or care. The TIO subspecialty clinics to which patients were referred based on photo examination by the ophthalmologist were retina (33.9%), glaucoma (30.4%), general clinic (17.9%), neuro-ophthalmology (5.4%), cornea (1.3%), and oculoplastics (1.3%) (Fig 3). Of the 101 patients referred to TIO by the technician, the ophthalmologist felt that referral was unnecessary for eight (2.8%) because the eyes were variants of normal in all cases. Reasons that the ophthalmologist wanted to see a patient that the technician did not refer included asymmetrical cupping, elective pterygium, and left macular hole (Fig 4) that were either missed by the ophthalmic technician or they did not feel warranted specialist referral.

Out of all the TIO referrals that the ophthalmologist decided to make, the sub-speciality referral trends were similar to those described above that the ophthalmic technicians made, with retina (43.8%), glaucoma (26.7%), general clinic (17.1%), neuro-ophthalmology (7.6%), cornea (1.9%), and oculoplastics (1.9%), and low vision clinic (0.9%) as the distribution of referrals.

Of note, 18.4% of the ocular photos were missing, which meant 27.5% of the participants had to be excluded from analysis because they had an incomplete chart, per the analysis inclusion criteria definition. Out of all the participants with missing photos, 40.4% had only posterior photos missing, 14.0% had only anterior photos missing, 13.2% had a combination of anterior and posterior photos missing, and 32.5% had all photos missing. Of the participants that had all photos missing, 89.2% came from Jiri district.

<table>
<thead>
<tr>
<th>Participants, n (%)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>187 (54%)</td>
<td>159 (46%)</td>
</tr>
<tr>
<td>63 (12)</td>
<td>62 (13)</td>
</tr>
</tbody>
</table>

**Table 1:** Demographics at the Community Eye Centers in Ramechhap, Jiri, Dolakha, and Charikot districts

<table>
<thead>
<tr>
<th>Ophthalmologist (Tilganga)</th>
<th>Referral</th>
<th>No Referral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ophthalmic Referral</td>
<td>32.7% (93)</td>
<td>2.8% (8)</td>
</tr>
<tr>
<td>Technician (CEC) No Referral</td>
<td>19.7% (56)</td>
<td>44.7% (127)</td>
</tr>
</tbody>
</table>

**Table 2:** Referral rates from Community Eye Centers to Tilganga Institute of Ophthalmology Health Care System
Discussion

The TIO CEC ophthalmic technicians do an outstanding job in spite of limited resources and direct oversight—highlighted by the fact that remote eye MD readers agreed 77.4% of the time with them. This is a testament to the excellent training they have received through TIO and their conscientious work in the field, in particular in screening for cataracts and identifying “normal” exams as well as anterior segment pathology. The technicians indicated after study completion that they missed some posterior pole pathology because they did not have previous experience identifying them, but with feedback through the Paxos fundus photographs and telecommunication with the ophthalmologist, they have enhanced their arsenal of knowledge. They did not refer some...
pathology like pterygiums because it did not clinically impact the patient’s quality of life, which the remote ophthalmologist could not take into account. Therefore it is important to acknowledge that the technician is crucial to patient-centered care because the clinical context of the whole patient cannot always be fully be captured in a teleophthalmic photograph.

The results from this study also suggest that mobile device teleophthalmology could serve as a useful adjunct to the screening exams performed by ophthalmic technicians in CECs. Use of the Paxos teleophthalmology system in four community eye centers in Nepal did improve the percentage of patient identified with referable pathology. Of the patients screened, nearly 20% merited referral for conditions that were not identified via technician slit lamp examination at the CEC. Disagreements about whether or not to refer a patient were most frequently related to retinal or glaucoma pathology, while referral-warranted anterior segment pathology was rarely missed. When a technician did decide to refer a patient to TIO, the ophthalmologist almost always agreed. Therefore, technician referral decisions were characterized by few false positives, but a higher rate of false negatives. Using a camera-enable mobile device may be a way to capture all necessary referrals to TIO. As technicians learn from feedback through synchronous or asynchronous communication with an ophthalmologist, this may help lower the rate of presumed false negatives.

In addition to detecting significant ocular pathology that might otherwise be missed, mobile device teleophthalmology has many other potential benefits. From the patient perspective, the reduced need for travel provides convenient access to healthcare; patients appreciated the convenience of having remote digital evaluation by an ophthalmologist without having to travel to Kathmandu. In fact, one study reports similar patient satisfaction scores whether their exam was done in-person or through teleophthalmic means.\(^\text{18}\) The technicians appreciated the opportunity to evaluate the photos, although they were not allowed to change their referral decision for purposes of the study. Lastly, obtaining the feedback and diagnoses from the reviewing ophthalmologist provided significant continued on-the-job training to the technician on more subtle pathology, particularly in the posterior segment. The Paxos System provides a posterior pole photograph of the fundus which is similar to an examiner’s view during indirect ophthalmoscopy, a rare luxury as part of the rural ophthalmic exam something that is typically not available in settings outside of an eye clinic, and particularly in rural areas.

There are numerous studies evaluating the rural use of teleophthalmology using table-top cameras and their outcomes in India\(^\text{19,20}\), Australia\(^\text{12}\), Spain\(^\text{22}\), USA\(^\text{23–25}\), Kenya\(^\text{26}\), China\(^\text{27}\), Greece\(^\text{28}\), Brazil\(^\text{11}\) and the UK.\(^\text{29}\) Most research has been done with diabetic retinopathy screening, for which there is a general consensus that teleophthalmology efforts increase the number of screened patients without sacrificing quality of care or visual outcomes.\(^\text{21,29,30}\) Comparing data from the Beijing Eye Public Health Care Project to our own findings, subspecialty referrals had similar trends (excluding cataract surgery due to Nepal’s unique local cataract camps): retinal disease (including macular and retinopathy changes) was the most commonly detected pathology, followed by glaucomatous optic neuropathy.\(^\text{22}\) In a study conducted in rural Brazil, teleophthalmology was highly specific and sensitive in detecting urgent eye conditions.\(^\text{11}\) An internet-based initiative in rural Australia found that using an online photographic repository helped to triage ocular emergencies remotely.\(^\text{12}\) The low-cost, portability, and wireless connectivity inherent to a handheld, mobile device-based teleophthalmology system like Paxos Scope expands the reach of expert ophthalmic care to remote locations similar to the CECs included in this study.

Moreover, because the iPod Touch 6\(^\text{th}\) generation has an 8 megapixel camera that is very similar to the iPhone 6, the results from this study can be directly translatable to the use of Paxos Scope with the iPhone 6 or higher. The primary reason that the iPod Touch was used in this study was cost—at a price point (in 2016) of $199 per unit, it was less than a one-third the retail cost of the iPhone 6. Thus, we were able to obtain several units for this study and distribute them to the CECs. We also chose this device because it did not have cellular connectivity. Although cellular connectivity is available in rural Nepal, it is typically lower in bandwidth and more importantly, requires a data plan that charges by the megabyte. Because the images being taken were large in both size and quantity, we decided to avoid the challenges and issues related to the setting up of contracts, cellular data plans, recurring charges, and overages and rely strictly on WiFi connectivity. This decision provided many logistical and budgetary advantages, but also revealed some regional inconsistencies.

This study had several limitations. First, it relied on evaluations by four different technicians whose
training and diagnostic skills may have differed. Second, more than a quarter of the participants had missing photos from their chart and therefore could not be included in analysis. Reasons for missing data included inability of the patient to stay still long enough to capture a photo, poor view into the back of the eye because of a cataract or other obstruction, and inability to upload into the digital cloud in certain situations due to inconsistent WiFi connectivity in the field. Jiri district accounted for most of the participants that did not have any photos because of uploading issues and lack of WiFi access. Even though the technician would capture the correct images, the photographs had to be manually uploaded to a desktop computer because of poor WiFi access and the photographs failed to transfer. This was not an issue at the three other sites because they uploaded their photographs through reliable and stable WiFi. This issue has been resolved with the newer version of the Paxos application through an automatic caching and uploading process. Thus, the data may be biased toward healthier patients who can tolerate sitting still for longer, and those that are in areas that are more developed with strong and stable WiFi.

Third, and perhaps most significantly, there are many subjective factors that affect the referral decision by both technician and ophthalmologist. For instance, a technician may not refer some patients with recognized pathology due to an understanding of a patient’s inability to afford the travel. A remote ophthalmologist may have changed their referral decision if they could have further queried the patient about their main concern as well as their past medical and social history. Decisions could have affected the results either way. In addition, it is possible that some of the WiFi connectivity issues encountered may have been avoided if cellular data plans were used in concert as is often done on consumer cell phones that alternate between cellular and WiFi when the latter is available, in particular for data-intensive transfer activity such as photo uploads to cloud storage. Nonetheless, we feel that the results strongly suggest a role for mobile device-based teleophthalmology systems as they provide more patients the opportunity to access healthcare.

Future studies should focus not just on the ability to properly refer and manage rural patients, but also on outcomes. The correlation between the Paxos photographs and the in-person ophthalmologist findings should be studied. The next step of future studies is to track each patient’s care to identify who required specialty treatment at TIO. Finally, more than 100,000 patients are annually screened without slit lamps at community-based camps, and this dwarfs the number of patients seen at the CECs. These screening camps refer thousands of patients for cataract surgery at CEC based surgical camps. However, very little is known about ocular co-morbidities such as glaucoma or retinopathy. The utility of Paxos Scope should be investigated for these screening camps as well.

In summary, the results reported in this study suggest strongly that mobile device teleophthalmology has the potential to improve patient care in rural Nepal by improving and increasing detection of posterior segment pathology. Previously, the ophthalmic technician fundus screening was performed using only the 90D slit lamp biomicroscopy. Due to its cost-effective, portable, hand-held design, the ophthalmic camera and teleophthalmology system presented here can be obtained and placed in multiple locations within a health care system. In doing so, TIO has the potential to expand the reach of remote ophthalmologists to rural satellite locations.

Conclusions
Based on the results of this study, mobile device teleophthalmology could play an important role as an adjunct to patient care already being delivered by TIO technicians in CEC settings of rural Nepal. Use of a mobile device-based ophthalmic camera improves detection of ocular pathology, particularly that of the posterior segment, and therefore has potential to improve patient management and patient outcomes. Although our study was only in TIO CECs, it is reasonable to suspect that similar results might also be obtained in other rural communities that are served by health care workers trained in the ophthalmic exam. It is likely that mobile device-based ophthalmic cameras would be beneficial tools for teleophthalmology in a number of rural and developing settings due to their excellent portability, durability, affordability, and their ability to take high quality images.

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Declarations
Karen Hong has received a research grant from the Mary Duke Biddle Clinical Scholars Program and Dr. David Myung holds a patent for the Paxos Scope, Digisight Technologies (now Verana Health) provided the Paxos Scope technology for this study. All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and have no other relationships or activities that could appear to have influenced the submitted work.

References


ACCESS AND PREFERENCES FOR MOBILE TECHNOLOGY AMONG DIVERSE HEPATITIS C PATIENTS: IMPLICATIONS FOR EXPANDING TREATMENT CARE

Julie Beaulac\textsuperscript{1,2}, Louise Balfour\textsuperscript{1,2}, Kim Corace\textsuperscript{2}, Mark Kaluzienski\textsuperscript{3}, Curtis Cooper\textsuperscript{2,3,4}

\textsuperscript{1}Department of Psychology, The Ottawa Hospital, Ottawa, Canada; \\
\textsuperscript{2}Ottawa Hospital Research Institute, Ottawa, ON; \\
\textsuperscript{3}Faculty of Medicine, University of Ottawa; \\
\textsuperscript{4}The Division of Infectious Diseases, Department of Medicine, University of Ottawa

Corresponding Author: jbeaulac@toh.on.ca

Background: Mobile technology interventions present opportunities for enhanced patient engagement and outcomes.

Aims: To assess the feasibility and patient attitudes toward using mobile technology in HCV care.

Methods: Cross-sectional survey data were collected from HCV patients (N=115) at two sites, an academic hospital-based outpatient viral HCV program (n= 92) and a mostly low SES community-based site (n = 23). Measures included demographics, HCV disease status and risk factors, and mobile technology access and preferences. Differences in mobile technology access, use, and preferences by treatment site, treatment experience, ethnicity, gender, education level, and income level were assessed by Mann-Whitney and chi-square tests.

Results: 78\% owned a mobile device. Of these, 69\% reported having Internet access and 72\% unlimited text plans. 66\% reported comfort in texting. Half liked the idea of using a cell phone for HCV clinical care; others expressed dislike/uncertainty. Poorer access to mobile technology was reported by treatment naïve, community site, and non-White participants (p values ranging from 0.02 to 0.01). Respondents from the community rated lower comfort in texting (p = 0.01). A similar trend was noted for respondents with incomes below $30,000 as compared to higher income (p = 0.09). Yet, groups similarly liked the idea of using mobile technology in HCV care.

Conclusion: Mobile technology is an alternative model to augment existing HCV care. Variability in acceptability and accessibility of this approach was highlighted. Tailoring care delivery to individual patients with a particular focus on patients being served in community-based programs with low SES will be critical.

Keywords: Hepatitis C, Patient Engagement, Patient Attitudes, Cell Phones, Cross-Sectional Survey
Background

Compared to other common infectious diseases in Canada, chronic hepatitis C (HCV) is associated with high morbidity and mortality (1). Health related quality of life and productivity loss is diminished. Of the 110,000 Ontarians infected with HCV, 35,000 are unaware of their status (1-3). The Ottawa Hospital Viral Hepatitis Program (TOHVHP) is the primary referral centre for Eastern Ontario, Canada providing interdisciplinary care to over 5000 patients with HCV. Canadians have access to publically-funded provincial health care. However, coverage for medication costs varies by provincial funding criteria and, in some cases, by private health benefits (4). Although successful in engaging many living with HCV, current TOHVHP initiatives face challenges in reaching all individuals with HCV in Eastern Ontario. HCV disproportionately affects vulnerable populations, who can be difficult to engage and retain in treatment due to issues related to mental illness, substance use, legal problems, social determinants of health (e.g., unstable housing, limited finances), discrimination and distrust, amongst other barriers (5, 6). Loss to follow-up remains a common problem. In this era of well tolerated and highly curative treatments, gaps in access directly result in individual harm via disease progression and threats to public health via viral spread. With expensive HCV treatments, suboptimal adherence can lead to costly treatment failures, viral resistance and transmission to other at risk individuals of refractory virus.

Innovative and integrative approaches of engaging HCV patients are needed in order to respond to the complexities of HCV care, including different treatment delivery methods. Approaches to help bridge the gap between HCV patients and treatment are particularly important. In addition to tertiary clinic hospital-based care, two innovative services within TOHVHP seek to reach patients who might not otherwise access hospital-based clinics: (a) a Telemedicine Program (TM) and (b) a Community Liaison Patient Support Program (CLP). These services include dedicated staff that facilitate the linkage of patients to services, and in the case of TM, offer “real-time” HCV specialist visits to increase access to care in underserviced communities (e.g. rural communities, marginalized populations) (7-10). These programs have been valuable in providing HCV care to a population facing individual and systemic barriers to accessing traditional models of hospital based care. The TM and CLP programs are integrated innovations but limited by expensive clinician hours.

Given Ontario’s 110,000 HCV infected patients, novel strategies will be needed to expand expert care in a cost effective manner. Mobile interventions represent another approach to engaging this population into care with the further possibility of enhancing care during treatment. Mobile technology could provide information and support in a format that is often more accessible and less resource intensive (11). Research has highlighted limited HCV knowledge among HCV patients (12) and the particular need for new and more accessible delivery of HCV educational information and support to marginalized individuals living with HCV (13).

Mobile technology interventions present opportunities for patient self-monitoring, intervention, and facilitating contact and engagement between patients and health care providers. A growing body of research demonstrates the value of mobile applications for enhancing patient engagement, retention, satisfaction, and health outcomes (10, 14-18). This technology has been evaluated in HIV populations in both higher (15) and lower-income regions (10). Important lessons learned from this ground breaking work include 1) most people have cell phones and are willing to consider mobile device use for communication with healthcare team members; 2) the technology can be consistently and confidentiality maintained; 3) high frequency messaging has little additional impact on improving outcomes compared to once weekly messages; and, 4) supportive / caring messages are more effective than simple reminder messages or messages that provide instruction. In the context of HIV, evidence suggests that mobile technology adherence applications can be used to make people feel cared for which in turn improves measurable clinical outcomes. Research has supported the use of mobile technology for augmenting health services in the context of lower income and marginalized populations (e.g., HIV and medication adherence) (19). This mobile application has also been assessed in tuberculosis with similar positive outcomes but has yet to be investigated in the HCV population. (16)

Study Objectives

We aimed to lay the ground work for implementation and evaluation of a cell phone based application seeking to increase patient engagement and retention in care, improve treatment adherence and completion, and ultimately increase successful HCV treatment delivery. A convenience sample survey conducted at The Ottawa Hospital Viral Hepatitis Program (TOHVHP) from August to October 2015...
determined that over 90% of TOHVHP clinic patients own a cell phone (20). We report on our formative evaluation, which systematically assessed feasibility and patient attitudes toward using mobile technology in HCV care.

**Methods**

A cross-sectional survey was conducted among HCV patients with The Ottawa Hospital Viral Hepatitis Program (TOHVHP) including the hospital site and a Community Liaison Program community partner site. Participants from the hospital site were approached between March and December 2016 as they waited for an appointment, many completing the survey at that same time, while participants from the community site completed the survey during a December 2016 drop-in clinic breakfast. Individuals were eligible to participate if they were over the age of 18 years, had a current or past diagnosis of HCV and were able to complete the survey in English. Pre-, peri- and post-HCV antiviral treated patients were included. Participants received $10 for survey completion. The study was approved by the Ottawa Health Science Network Research Ethics Board (REB #2015-0909) and all participants completed a consent form.

The survey included questions on demographics (e.g., age, ethnicity, level of education, adapted from questions used by the Centre for Addiction & Mental Health), HCV disease status and risk factors (e.g., time since diagnosis, previous treatment experience), and mobile technology use. Mobile technology questions assessed feasibility (e.g., access to devices) as well as patient opinions and preferences regarding communication via cell phone texts and e-mails. This portion of the survey was adapted from questions validated in the HIV population and included 19 items (17). For instance, participants were asked to rate how comfortable they were using a cell phone to send and then to receive text messages along a 5-point Likert scale (1=not at all, 5=extremely). They were also asked open-ended questions such as what they would want text messages to say if they were able to receive these from their health care provider, and what they would want to tell or ask of their providers by text. Administrative data was also utilized from a clinic database for patients followed at TOHVHP (REB 2004-196), including demographic and health information (e.g., HCV disease status, HCV treatment history). This information supplemented data collected through survey format.

**Statistical Analysis**

SPSS version 24 was used for statistical analyses. Data were prepared for analysis (20% of data verified for accuracy, all data checked for outliers and discrepancies) and missing values were not imputed. Standard descriptive statistics were used to summarize the characteristics of the participants and their access to and attitudes toward using mobile technology in HCV care. Qualitative responses to open-ended questions regarding preferences and concerns about using mobile technology in HCV care were compiled and summarized. Mann-Whitney tests were used to assess for differences in reported comfort with mobile technology use in HCV care (ordinal dependent variable) between patient groups. Chi-square tests were used to assess for differences in mobile technology access, use, and preferences (nominal dependent variables) by categorical independent variables (treatment experienced vs. naïve; gender – male vs. female; ethnicity – White vs. other; site – hospital vs. community; education - completed high school vs. less than high school; income: up to $29,999 vs. $30,000 or more). No formal sample size calculation was conducted. Our aim was to complete questionnaires with at least 100 participants which we predicted would allow for robust descriptive and comparative analysis.

**Results**

Of 165 participants approached across hospital and community sites, 140 (85%) agreed to participate. Of the 140, 115 completed and returned the survey, (23/24 for the community site, 92/117 for the hospital site; 82%). Participants declining to participate commonly cited the following reasons: no time, not being interested, or not being able to read or speak English.

Survey participants (N=115) had a mean age of 52 years (range 23 to 78), 64% were male and 82% White. Half of participants (49%) were on the Disability Leave and 60% reported high school vs. less than high school; income: up to $29,999 vs. $30,000 or more). No formal sample size calculation was conducted. Our aim was to complete questionnaires with at least 100 participants which we predicted would allow for robust descriptive and comparative analysis.

In terms of the health characteristics of the sample, almost all participants were diagnosed with HCV two or more years prior and most were HCV antiviral treatment naïve. The majority reported past incarceration, injection and/or oral drug use, and past treatment for mental health, alcohol, and/or drug use (Table 2).
Mobile Technology Access and Preferences

Most reported having regular access to mobile technology. 92% of hospital site participants and 71% of community site participants reported owning a mobile device (cell or tablet); most of these mobile devices had access to the Internet (74% for hospital site and 47% for community site), could send/receive texts (87% vs. 72%) and were set up with unlimited text plans (75 % vs. 56%). Most reported sending/receiving on average 1-10 or 10-100 texts per week from their mobile devices (37% and 37%, respectively for hospital site vs. 33% and 22%, for community site). Similarly, most reported sending/receiving about the same amount of emails (28% and 42% for 1-10 and 10-100, respectively for hospital site and 43% and 36% for 0 and 1-10, for community site).

Table 1: Demographic Characteristics of Participants

<table>
<thead>
<tr>
<th></th>
<th>Hospital Site (n=92)</th>
<th>Community Site (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male / female)</td>
<td>64/36</td>
<td>61/39</td>
</tr>
<tr>
<td>Mean Age (SD; range)</td>
<td>54 (10.94; 27-78)</td>
<td>46 (11.99; 23-61)</td>
</tr>
<tr>
<td>Relationship Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married or Steady Partner</td>
<td>41</td>
<td>35</td>
</tr>
<tr>
<td>Single</td>
<td>40</td>
<td>48</td>
</tr>
<tr>
<td>Widowed</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Separated</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Born in Canada (%)</td>
<td>82</td>
<td>86</td>
</tr>
<tr>
<td>Cultural Background</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>84</td>
<td>70</td>
</tr>
<tr>
<td>Aboriginal</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>Black</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grades 8 or Less</td>
<td>14</td>
<td>33</td>
</tr>
<tr>
<td>Completed High School</td>
<td>43</td>
<td>38</td>
</tr>
<tr>
<td>College Diploma</td>
<td>30</td>
<td>24</td>
</tr>
<tr>
<td>University Degree</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>Employment Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working Full-Time</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>ODSP/Disability Leave</td>
<td>49</td>
<td>82</td>
</tr>
<tr>
<td>Retired</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Social Assistance</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Other (e.g., Working Part-Time)</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Housing Status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renting</td>
<td>51</td>
<td>65</td>
</tr>
<tr>
<td>Own Home</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>Supportive Housing Group Home</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Homeless</td>
<td>3</td>
<td>21</td>
</tr>
<tr>
<td>Other (e.g., Correctional Facility)</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Family Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-$29,999</td>
<td>50</td>
<td>67</td>
</tr>
<tr>
<td>$29,999-$59,999</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>$59,999-$89,999</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>$89,999-$119,999</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>$120,000 or More</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Prefer Not to Answer</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Do Not Know</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
Fewer reported using non-mobile technology: 46% (hospital site) and 8% (community site) indicating that they owned a landline phone and 56% (hospital site) and 26% (community site) reporting regular use of a desktop computer (see Table 3 for more details on mobile technology access). In terms of experience with mobile technology, the majority reported having used mobile devices to install an app, send a text, access the Internet, and/or look up health information (Table 4). Fewer community site participants reported such use.

Although most indicated that they had never used mobile technology to communicate with a health care provider, 21% of community site participants and 14% of hospital site participants reported email correspondence and 17% of community site participants and 16% of hospital site participants indicated interaction by text. According to the survey responses, the contact was initiated by the health care provider (44% of cases for community site, 20% of cases for hospital site), the patient (31% for community site, 32% of cases for hospital site), or both patient and provider (25% for community site, 48% of cases for hospital site). When asked who they would prefer to contact them by text or email for health advice, the highest rated health care providers were the physician (42% for community site, 32% for hospital site) and nurse (21% for community site, 22% for hospital site). No preference was indicated by 32% of community site and 30% of hospital site of participants.

Comfort in texting varied by site (see Table 5). When asked directly if they liked the idea of using a cell phone for HCV clinical care and follow-up, 61% of community site participants and 49% of hospital site participants reported affirmatively, citing reasons including ease, efficiency, convenience, and speed. In contrast 22% of community site participants and 34% of hospital site participants reported that they would not like using cell phones, identifying concerns

<table>
<thead>
<tr>
<th>Past treatment for HCV</th>
<th>% Hospital Site (n=92)</th>
<th>% Community Site (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Naive</td>
<td>48</td>
<td>91</td>
</tr>
<tr>
<td>Currently on Treatment</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Completed Treatment but not Cured</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Treatment Experience but did not Complete</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Treated and Cured</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Have Cirrhosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>No</td>
<td>54</td>
<td>35</td>
</tr>
<tr>
<td>Don’t know</td>
<td>15</td>
<td>61</td>
</tr>
<tr>
<td>When Diagnosed with HCV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 6 months Ago</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>6 Months to 1 Year Ago</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>2 to 5 years Ago</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td>6 to 10 years Ago</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>More Than 10 Years Ago</td>
<td>48</td>
<td>62</td>
</tr>
<tr>
<td>HIV Coinfection (HIV Positive)</td>
<td>7</td>
<td>25</td>
</tr>
<tr>
<td>Past Incarceration</td>
<td>48</td>
<td>63</td>
</tr>
<tr>
<td>Past Injection Drug Use</td>
<td>54</td>
<td>79</td>
</tr>
<tr>
<td>Past Non-IV Drug Use (Oral, Sniff, Snort, Smoke)</td>
<td>69</td>
<td>88</td>
</tr>
<tr>
<td>Past Treatment for Mental Health Problems</td>
<td>43</td>
<td>83</td>
</tr>
<tr>
<td>Past Treatment for Alcohol Problems</td>
<td>31</td>
<td>70</td>
</tr>
<tr>
<td>Past Treatment for Drug Problems</td>
<td>34</td>
<td>83</td>
</tr>
</tbody>
</table>

Table 2: Health Characteristics of Participants
related to cell/network access issues, the impersonal nature of method, a preference for in-person or other method of communication, concerns about texting being too slow to receive answers to their questions, and language and/or technology literacy issues. Some (17% of community site and 17%) also reported uncertainty, indicating that they would need to try this method before deciding. Many participants shared ideas for text content should they be able to communicate with their health care provider by text (Table 6). Key patient concerns related to HCV care and texting included privacy issues and losing meaning of information in exchange.

<table>
<thead>
<tr>
<th></th>
<th>% Hospital Site (n=92)</th>
<th>% Community Site (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Internet Access</td>
<td>73</td>
<td>42</td>
</tr>
<tr>
<td>Own Basic Mobile Phone</td>
<td>36</td>
<td>58</td>
</tr>
<tr>
<td>Own Smart Mobile Phone</td>
<td>58</td>
<td>8</td>
</tr>
<tr>
<td>Own Tablet</td>
<td>30</td>
<td>8</td>
</tr>
<tr>
<td>No Cell/Tablet</td>
<td>8</td>
<td>29</td>
</tr>
<tr>
<td>Share Phone</td>
<td>14</td>
<td>25</td>
</tr>
<tr>
<td>Mobile can Send/Receive Texts</td>
<td>87</td>
<td>72</td>
</tr>
<tr>
<td>Mobile Text Plan (Unlimited)</td>
<td>75</td>
<td>56</td>
</tr>
<tr>
<td>Mobile Internet Access</td>
<td>74</td>
<td>47</td>
</tr>
</tbody>
</table>

Table 3: Mobile Technology Access

<table>
<thead>
<tr>
<th></th>
<th>% Hospital Site (n=92)</th>
<th>% Community Site (n=23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install an App</td>
<td>61</td>
<td>58</td>
</tr>
<tr>
<td>Sending a Text</td>
<td>81</td>
<td>48</td>
</tr>
<tr>
<td>Accessing the Internet</td>
<td>77</td>
<td>39</td>
</tr>
<tr>
<td>Looking up Health Information</td>
<td>68</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 4: Experience with Mobile Devices

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Rated as Extremely or Very Comfortable (%)</th>
<th>Rated As Not at All or Slightly Comfortable (%)</th>
<th>Mean Rating (95% Confidence Interval)</th>
</tr>
</thead>
<tbody>
<tr>
<td>To send texts</td>
<td>Hospital Site</td>
<td>88</td>
<td>61</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Community Site</td>
<td>23</td>
<td>35</td>
<td>57</td>
</tr>
<tr>
<td>To receive texts</td>
<td>Hospital Site</td>
<td>88</td>
<td>66</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Community Site</td>
<td>23</td>
<td>39</td>
<td>48</td>
</tr>
</tbody>
</table>

Note: Each item was rated on a 5-point rating scale with the anchors 1 (not at all) and 5 (extremely)

Table 5: Comfort Texting

Group Differences Related to Mobile Technology Use in HCV Care

Access to mobile technology significantly differed by past HCV antiviral treatment exposure, ethnicity, and site. Treatment naïve (36/63; 57%) and community site participants (10/24; 42%) were significantly less likely to report access to the Internet (p=0.02 and p=0.01, respectively), as compared to treatment experienced (40/51; 78%) and hospital site participants (66/90; 73%); and to not owning a mobile device (cell or tablet; 12/63; 19% treatment naïve vs. 2/50; 0.04% treatment experienced; p=0.02 and 7/24; 29% community site vs. 7/89; 0.08% hospital site participants;
Preferred Content of Text FROM Providers
- Appointment details and reminders
- Eligibility for treatment and treatment start date
- Test results and updates
- General information about condition
- ‘Anything they want me to do’
- Friendly concern: How are you? Do you need any thing? Any questions?
- Medication reminders
- Inquiry about issues with treatment side effects

Preferred Content of Text TO Providers
- Request a phone call
- Inquire and confirm next appointment
- Tell provider needs and ask for advice
- Inquire about treatment eligibility
- Update provider on treatment progress or side effects
- Provide update on health
- Ask questions about condition and treatment
- Request treatment support

Table 6: Content Preferences of Texts for HCV Care

Discussion
The aim of this study was to evaluate the feasibility and patient attitudes toward using mobile technology in HCV care. Our findings suggest that mobile technology may be an attractive and feasible alternative modality to augment existing HCV care. Consistent with past research (e.g., 18), most participants reported owning a mobile device (basic cell, smartphone, or tablet) and of these, the majority also reported having access to the Internet and to having unlimited texting plans on their devices. Although past experience using mobile technology in their care was limited, the majority reported comfort in sending/receiving texts, and half of respondents liked the idea of using a cell phone for HCV clinical care and follow-up. It was noted that the other half reported not liking this idea or uncertainty about using this modality in their care. Given this, further work is necessary to understand the reasons for this reluctance. HCV stigma may be a factor leading some to fear breaches in privacy/confidentiality when using mobile technologies for HCV care. Strategies to increase patient ease with mobile communication may be necessary. There were no differences between respondents from the hospital outpatient setting and the community-based clinic in reported liking of the idea of using mobile technology in HCV care. However, access to mobile technology differed across some groups as did rated comfort in texting. This variability underscores the heterogeneous nature of the HCV patient population and highlights the need in tailoring delivery of care to specific patient needs and preferences in order to effectively engage all individuals with HCV. There is no one standard practice for engaging patients in HCV care.

The finding that access to mobile technology differed by treatment experience is interesting. Treatment naïve patients were less likely to report access to the Internet and mobile technology; this may suggest a general tendency for patients not previously engaged in treatment to also be less connected to technology and other communication/information systems that could inform them of their treatment options. The finding that access to technology was lower among community site participants was not surprising given the marginalized and lower-income nature of this population. This group was also less comfortable in communicating medical issues by text. This may be due to reduced trust in health care providers or over all less experience in day-to-day use of texts to communicate. Notwithstanding this finding, mobile technology interventions have been shown to positively impact health outcomes in other marginalized and lower-income populations. Given this population is an explicitly targeted priority population for HCV treatment engagement in the province of Ontario (2).
and elsewhere, understanding the particular needs and interests of this group will be critical to fully understand and consider as mobile technology-based HCV treatment programs evolve.

The population captured in this study had high rates of substance use, history of mental health difficulties, and incarceration. The rate of incarceration in Canada (115 per 100 000) is much lower than the 51% reported in our sample patients with HCV. We know that HCV rates are high among prisoners (21). There are a number of reasons that have been cited in the literature for the high HCV infection rate in prisons including high rates of substance users, risk of infection while sharing needs, razors, and other materials, and testing programs within institutions. It is also worth noting that Canada has a lower incarceration rate (115 persons in custody per 100 000 population) as compared to the United States which has 666 persons in custody per 100 000. (22)

**Limitations and Strengths**

Study limitations included the generalizability of findings as the sample surveyed consisted of patients primarily from a tertiary care center based in an urban Canadian setting. However, it is important to note that our Community Liaison Program is very effective in engaging and retaining community-based HCV patients in care within our hospital-based clinic. The inclusion of patients from a community partner clinic, relatively large sample size, high participation rate, and the broadly representativeness of the sample, enhances the generalizability of our findings. Patients completed the surveys autonomously and separate from health care providers, which limit any influence of factors including social desirability bias. To further verify representation of diverse patient groups including those not engaged in hospital-based HCV care, future research drawing from community samples is warranted, with particular attention to patients with low literacy levels and/or who speak languages other than English.

**Conclusion**

As health care providers attempt to improve patient engagement and experience of care while at the same time reduce health care costs, teams are seeking to adopt innovative, integrated, community-oriented models of care delivery. Mobile applications may represent a useful tool for augmenting engagement, retention and successful HCV treatment among many different groups.

For instance, while higher income individuals may be interested in using mobile technology as a way of minimizing their clinic visits, such technology may provide the necessary bridge to connecting lower income individuals with HCV care. This study provides support for trialing mobile innovations in HCV care. Potential engagement obstacles as well as individual patient needs and preferences should be fully understood in an effort to provide optimal care.

**Acknowledgements**

Thank you to Dr. Richard Lester for providing access to survey questionnaires and approval to modify for use in our work.

**Disclosures**

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Kim Corace- Speaker Fees: Janssen, Vertex, AbbVie, Novo Nordisk

Mark Kaluzienski - Lundbeck, Sunovion, Otsuka

The following people have nothing to disclose: Julie Beaulac, Louise Balfour.

**References**


**Background:** Despite the prevalence of hepatitis C virus (HCV) and the availability of effective treatments, HCV screening remains suboptimal, in part due to primary care physicians’ (PCPs) unawareness of and discomfort discussing HCV risk factors. Patient-facing text message campaigns may overcome these barriers by empowering patients to initiate screening discussions with their PCPs.

**Aims:** The objectives were to evaluate a patient-facing text message campaign in terms of (1) feasibility, (2) acceptability, and (3) impact on patient-PCP discussions about HCV screening.

**Methods:** Primary care patients were recruited to receive either an HCV text message, which contained HCV information and a prompt to discuss HCV with their PCPs, or a calcium control text message. Forty minutes before their appointments, participants were sent their assigned text message. Participants were then called for an evaluation of the text message campaign.

**Results:** Of 185 patients called, 38 enrolled and completed the study. Participants who were sent an HCV text message (n=25) were significantly more likely to initiate a conversation with their PCPs about HCV screening than participants sent a calcium control text message (n=13) (p=0.008). Thirty-two (82%) participants liked receiving a health-related text message (88% in the HCV group; 70% in the control group).

**Conclusions:** A patient-facing HCV text message campaign shows promise as a novel method to activate primary care patients to initiate HCV screening discussions with their PCPs. This campaign may help educate patients about the importance of HCV screening, overcome physician barriers to screening, and, ultimately, help control the HCV epidemic.

**Keywords:** hepatitis C, text messaging, physician-patient relations, preventive health services, primary health care
**Introduction**

**Hepatitis C remains a hidden epidemic in at-risk populations**

Hepatitis C virus (HCV) afflicts approximately 3 million Americans and is the leading cause of liver disease in the United States. The U.S. Centers for Disease Control and Prevention (CDC) and the U.S. Preventive Services Task Force (USPSTF) recommend HCV screening for many at-risk populations, including the 1945 to 1965 birth cohort (“baby boomers”). Despite longstanding HCV screening recommendations and the success of oral direct acting antivirals (DAAs), which can reverse the natural progression of HCV, 45-85% of people with HCV are unaware of their infection because they are asymptomatic and/or untested. Among baby boomers, who make up 75% of those infected with HCV only 13.8% have been screened.

**Primary care physicians are not routinely screening for HCV and face barriers to do so**

While primary care physicians (PCPs) are seen as critical facilitators to increasing HCV screening rates, they are struggling to make screening routine. Few PCPs conduct regular assessments of HCV risk factors, and, of those who do, even fewer screen these at-risk patients. One barrier to screening is a lack of time necessary to assess HCV risk factors. Another barrier is knowledge of risk factors; some PCPs are unclear about the at-risk populations needing HCV screening and uncomfortable asking patients about their risk factors.

**Text messages may empower patients to overcome PCP HCV screening barriers**

According to the Pew Research Center, 95% of Americans own a mobile phone and over three-quarters of them send and receive text messages. Text messaging is the most used mobile phone feature, and health interventions can take advantage of this inexpensive, broad access to patients. Furthermore, text messages can be personalized to enhance effectiveness. Studies have found that patients are receptive to receiving health reminders by text message and that text messages can be effective for disease prevention interventions. For HCV in particular, Levine et al. reported 96% of patients at their clinic would be receptive to receiving a text message encouraging HCV screening. Moreover, 71% of PCPs surveyed by Thomson et al. thought HCV screening would improve if patients were provided education on HCV; thus, patient-centered text messages could help PCPs improve their HCV screening practices by educating patients about HCV. Text messages may also empower patients to ask for the HCV test. According to our previously published health campaign push-pull model, personalized text messages that contain information on disease prevention and recommend further action may “push” patients to “pull” their physician into a health discussion. For PCPs who are uncomfortable discussing HCV screening, or who are unfamiliar with risk factors and screening guidelines, a patient-facing, personalized text message campaign may help overcome physician-level barriers.

**Study Objective**

Although several studies have evaluated physician knowledge and perspectives on HCV screening, studies on patient-centered HCV screening campaigns are limited. The aims of our pilot study were to (1) determine the feasibility of recruiting patients for a mobile health text message campaign, (2) gauge the acceptability of health-related text messages and (3) assess the impact of a campaign on empowering patients to discuss HCV screening with their PCP.

**Methods**

**Study Design**

**Text Message Content Development**

In spring 2017, research staff approached community members at local venues (e.g., grocery stores, cafeterias, etc.) to assess their HCV knowledge and to ask for suggestions on content for an HCV screening campaign. Based on these discussions, the research staff drafted text messages with HCV information and again approached community members to rank their preference of message content. The themes of the highest-ranked text messages were selected by the research staff to be incorporated into the final text message content for the present study (see Table 1).

Each finalized text message began with the participant’s name, included HCV information according to one of the three HCV themes, and ended with a prompt to ask the PCP about HCV screening. To further personalize the text message, the name of the participant’s PCP was included. The research team also created a control text message, which similarly included the participant’s name and PCP’s name, but instead contained information about calcium supplementation.
Participant Recruitment & Enrollment

Patients were recruited from an academic private practice primary care clinic that serves predominately insured patients in Houston, TX. Staff from the study clinic provided the research team with a list of patients who had primary care appointments within the upcoming week. This list included the patient’s name, phone number, PCP’s name, and appointment date and time. From July 7 to August 16, 2017, the research staff called patients at least two business days before their appointment date, with a second call at least one business day before their appointment if they did not answer the initial recruitment call. Patients were provided with a brief description of the study, outlining that participants would receive a text message before their appointment, as well as a phone call after their appointment for a post-text message evaluation survey. The research staff then provided interested patients with more details of the study and screened for eligibility. The eligibility criteria were (1) over the age of 18, (2) English-speaking, (3) own a cell phone and read text messages, and (4) plan to attend their upcoming appointment. The research staff read the consent form to interested and eligible patients; patients that provided verbal consent were then enrolled. To reduce the likelihood of patients failing to answer a post-message follow-up call from an unfamiliar number, we provided the study cell phone number and elicited a preferred date and time to call back. To assess the feasibility of recruitment and retention for this text message campaign study, the research team maintained records of patient recruitment, enrollment, and completion of the study. This study protocol (H35157) was approved by the Baylor College of Medicine Institutional Review Board; participants gave informed consent before taking part.

Text Message Campaign Delivery

Study participants born between 1945 and 1965 were assigned, in order of enrollment, to receive either HCV1, HCV2, HCV3, or calcium control (see Table 1). All other study participants (those not born between 1945 and 1965) were assigned, in order of enrollment, to receive either HCV1, HCV2, or calcium control. These participants were never assigned the HCV3 text message that contained message content targeting the 1945-1965 birth cohort. Forty minutes before a participant’s appointment, the research staff sent the participant his/her assigned text message, substituting in the participant’s name and PCP’s name. Messages were individually typed and sent from the study cell phone.

Post-Text Message Evaluation Surveys

After their appointments, participants were called to determine the acceptability of the text message, as well as its impact on patients initiating HCV discussions with their PCPs. The research staff called participants at a preferred time specified in the initial recruitment call, or two hours after their appointment, if they did not indicate a preference. If participants did not answer this first call, a second call was made within that same day. If this second call was not answered, the research staff left participants a voicemail that provided contact information to return the call. Participants who did not attend their appointments were considered ineligible to complete the post-text message evaluation survey. Regardless of text message type sent, all participants were asked if they talked to their PCP about HCV and then, using an open-ended question, were asked why.

Statistical Analysis

Standard descriptive statistics were used to summarize participant demographics and responses to the post-text message evaluation survey. Participant initiation of HCV discussions between text message groups were compared using a Fisher’s exact test at a 95% confidence interval. Data analysis was conducted with R (version 3.1.2; R Core Team; Vienna, Austria).

Table 1: Text Message Themes

<table>
<thead>
<tr>
<th>Text Message Type</th>
<th>Text Message Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCV1</td>
<td>HCV is asymptomatic; routine bloodwork may not include an HCV test.</td>
</tr>
<tr>
<td>HCV2</td>
<td>Many HCV-positive patients do not know they are infected.</td>
</tr>
<tr>
<td>HCV3</td>
<td>Adults in the birth cohort of 1945-1965 should be tested for HCV.</td>
</tr>
<tr>
<td>Calcium Control</td>
<td>Adults need 1,000 milligrams of calcium per day.</td>
</tr>
</tbody>
</table>
Results

Patient Recruitment & Enrollment

A total of 185 patients were called. One hundred nine (59%) answered, of whom 47 (43%) enrolled. Of these 47 participants, 25 (53%) were in the birth cohort. Within the 22 non-birth cohort participants, 18 (82%) were born after 1965, and 4 (18%) were born before 1945. See Figure 1 for all recruitment and enrollment outcomes.

Post-Text Message Campaign Evaluation

Acceptability of Text Message Campaign

Of the 47 enrolled participants, 39 (83%) completed the post-text message evaluation survey. Of the 34 participants who were sent an HCV-themed text message, 26 (76%) completed the post-text message evaluation survey, while all 13 participants who were sent the calcium control text message completed the post-text message evaluation survey.

Thirty-two (82%) of the 39 participants surveyed liked receiving a health-related text message (88% in the HCV group and 70% in the calcium control group), and 25 (64%) found the message useful (76% in the HCV group and 46% in the calcium control group).

Impact of Text Message Campaign on Participant-PCP HCV Discussions

Of the 39 participants who completed the post-text message evaluation survey, one participant did not read the text message prior to the clinic appointment and was excluded, leaving 38 for analysis. Of these, 25 participants received an HCV-themed text message, and 15 (60%) reported having an HCV-related discussion with their PCP, 10 of whom (40% of all 25) reported initiating this discussion because of the text message. Of the 13 participants who received the calcium control message, none initiated a discussion about HCV with their PCP. Participants who were sent an HCV-themed text message were more likely to initiate discussions with their PCPs about HCV than participants sent the calcium control text message (p=0.008). Of those in the birth cohort, 7 of the 14 (50%) participants who received an HCV-themed text message reported initiating an HCV-related discussion with their PCP because of the text message, while 3 of the 11 (27%) non-birth cohort participants did so. See Figure 2 for overall results of the text message campaign and see Table 2 for results by text message type.

Discussion

Recruitment Feasibility Outcomes

Our pilot study demonstrated the feasibility of recruiting patients into an HCV text message campaign for the healthcare setting. Using cold call recruitment, nearly 60% of patients answered the phone – an answer prevalence comparable to that achieved in a government-led national survey.\(^\text{21}\) Once patients answered the phone, nearly half enrolled. This enrollment success may have been because our study required a one-time only intervention and follow-up survey, since time commitment is a critical factor in research study participation.\(^\text{22,23}\) Also, some patients were pleased to learn of a research partnership between Baylor College of Medicine and their clinic, and patients are more likely to enroll in studies run by persons

\[\text{Figure 1: Patient Recruitment and Enrollment.}\]

*Four patients were ineligible because a mutually convenient time for the screening could not be arranged. The other eight ineligible patients were disqualified for the previously stated eligibility criteria.*
they trust.\textsuperscript{24,25} Finally, of those enrolled, over 80% completed all steps of the study. This high retention rate may have resulted from the research staff eliciting participants’ preferred time for the post-text message phone call, implementing flexible strategies that accommodated participants’ needs.\textsuperscript{26}

**Acceptability Outcomes**

Our HCV text message campaign was found to be acceptable; 82% of participants liked receiving a health-related text message, and, specifically, 88% liked receiving a message with HCV content. As McGuire noted, “liking” a campaign is an “index of persuasive effectiveness.”\textsuperscript{27} The formative research that we conducted with members of the target audience to guide HCV text message content likely enhanced our message’s acceptability, as pretesting has been shown to do.\textsuperscript{28} As for utility, about three-fourths of participants who received an HCV text message found it useful. The messages may have

---

Table 2: Impact of Text Message Campaign on HCV Discussions by Text Message Type.

<table>
<thead>
<tr>
<th></th>
<th>HCV1 Text</th>
<th>HCV2 Text</th>
<th>HCV3 Text</th>
<th>Any HCV Text (HCV1, 2, or 3)</th>
<th>Calcium Control Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of participants who were sent each text message type</td>
<td>15</td>
<td>13</td>
<td>6</td>
<td>34</td>
<td>13</td>
</tr>
<tr>
<td>Number of participants who answered the post-text message evaluation phone call</td>
<td>13</td>
<td>11</td>
<td>6</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>Number of participants who completed the post-text message evaluation survey*</td>
<td>11*</td>
<td>9</td>
<td>5</td>
<td>25</td>
<td>13</td>
</tr>
<tr>
<td>Number of HCV discussions with PCP that occurred</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>Number of HCV discussions that were initiated by participant</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Number of HCV discussions that were initiated by participant because of text message</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>% HCV discussions initiated by participant because of text message, out of those who completed post-text message evaluation survey</td>
<td>45%</td>
<td>33%</td>
<td>40%</td>
<td>40%</td>
<td>0%</td>
</tr>
</tbody>
</table>

\*Participants who did not attend their appointments were ineligible to complete the post-text message evaluation survey.

\*Twelve participants completed the post-text message evaluation, but one participant did not read the text message prior to the appointment, and therefore was excluded from the analysis.

---

Figure 2: Impact of Text Message Campaign on HCV Discussions.

\*Out of 26 participants who received an HCV-themed text message and completed the post-text message evaluation survey, one participant did not read the text message prior to the clinic appointment and was therefore excluded from further analysis; thus, the evaluable number of participants who received an HCV-themed text message was 25.
been particularly practical because they addressed previously identified gaps in patient knowledge, such as HCV’s routes of transmission and asymptomatic nature.29

Impact of the HCV Text Message Campaign on Patient-Physician HCV Discussions

This pilot study demonstrated preliminary effectiveness of an HCV text message campaign to empower patients to discuss HCV screening with their physicians. While no participant in the control text message group initiated an HCV discussion with their physician, 40% of participants receiving an HCV text message initiated this discussion. This success could be attributable to several features of our campaign. First, personalization, which is used in most successful text message interventions,30 was a key feature of the text message content. As noted by Hawkins et al., “personalization attempts to increase attention or motivation to process messages by conveying, explicitly or implicitly, that the communication is designed specifically for ‘you.’”31 In our study, each message included the participant’s name and his/her physician’s name, thereby making the message more salient to the receiver. Second, our HCV text message content included a specific cue to action – a key component for stimulating behavior change according to the health belief model.32 Each HCV text message encouraged patients to talk to their physician about HCV screening at the upcoming clinic visit, thereby providing the cue about “when and where” the health action should be done.33 Finally, the messages were delivered at an opportune moment – just before the participant’s appointment – when the health action needed to occur, and optimizing exposure to a campaign’s message is a critical determinant of campaign success.27

Overall, text message campaigns for health promotion and disease prevention have numerous advantages over other types of health-related mass media campaigns. A 2004 review on health communications campaigns reminds campaign planners that messages should be “kept simple, because complicated messages are more likely to be misunderstood and misremembered.”34 Because text messages are limited to 160 characters, messages must be shorter and less complex. Additionally, campaign exposure is a mediator of success that campaign designers struggle to achieve.30,34 However, a text message campaign can be delivered to a specific person at a specific – and even preferred – time, to increase exposure. In the case of text message campaigns for healthcare settings, some electronic medical record (EMR) systems have the capability to send text messages to mobile phones and the advantage of being able to extract personalization and health data (e.g. prior HCV screening results) to deliver relevant and timely messages near clinic visits.

Limitations

There are limitations to our study. This study was conducted in an academic private practice clinic, which serves a socioeconomically advantaged, predominately white patient population. Therefore, our results may not be generalized to other healthcare settings – such as those serving low-income, minority patients, who are often harder to recruit for research and have poorer communication with their physicians.35–37 Additionally, our patient population likely had higher health literacy than racial and ethnic minorities,38 and therefore may have been more comfortable initiating a discussion with a physician.39 Indeed, patients from disadvantaged populations (e.g. lower income, racial/ethnic minorities) are less active in discussions with their physicians,40 and it remains to be seen whether a text message campaign would be equally effective at prompting these patients to have an HCV discussion with their physicians. Finally, while 40% of participants reported discussing HCV screening with their physicians, this result may have been subject to social desirability bias, though the research staff did emphasize to each participant during the post-text message survey that there were no right or wrong answers.

In short, our study was conducted in a relatively homogenous population. Further research is needed to determine the translation of our results to more diverse patient populations. Despite these limitations, this study provides critical proof-of-concept that a patient-facing text message campaign can stimulate HCV discussions in healthcare encounters. Building upon previous work which has shown that minorities are amenable to receiving healthcare reminders, our proof-of-concept study takes the next step towards a larger health campaign focusing on minorities.41

Conclusions

Despite national recommendations for HCV screening,2,3 HCV screening remains suboptimal,4,6 because physicians face barriers to ordering the test, and patients are unaware of their need to be tested.7–10 Our study suggests that a patient-facing HCV screening campaign, based on the push-pull model, could help overcome these barriers. Further research is
needed to determine how to optimize recruitment and retention strategies for a health center-based text message campaign study, and a larger study may help confirm our preliminary and promising results. Additionally, the impact of a patient-facing HCV text message campaign on physician orders of HCV tests – the ultimate metric of an HCV screening campaign’s success – needs to be determined.

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Conflict of Interest Statement
None of the authors have a conflict of interest or funding source related to this work to report. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the U.S. Department of Veterans Affairs or the United States government.

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References


Background: There is incredible potential for telemedicine to advance postoperative care. Work in high-income nations shows the potential to use mobile phones to monitor postoperative recovery progress. However, there is little information about the attitudes of people in low resource countries, like Myanmar, toward the adoption of mHealth in postoperative care.

Aims: This study presents survey results collected in Myanmar to better understand cultural attitudes of this population towards adopting mHealth technologies to improve postoperative patient care.

Methods: A thirteen-question survey was developed, focused on demographic questions and attitudes towards physicians, the internet, and willingness to perform tasks on their mobile phones. Respondents were selected in a sample of convenience in urban and rural public spaces.

Results: Of the 125 people approached, 112 agreed to participate in the survey. A wide range of ages (18-78), genders (55.4% female), locations (22.3% rural, 77.7% urban) and ethnicities (67% Burmese) were represented. 85.7% were willing to make contact with a surgeon in a hypothetical postoperative setting via mobile phone. 83.0% were willing to fill out a survey about their postoperative state and 69.6% were willing to send a picture of their wound with their surgeon via mobile phone. A majority of respondents had a very high level of trust in physicians in general, most already owned a mobile phone with access to the internet and used it to look up health information.

Conclusion: Our results indicate that Myanmar could provide a promising location for the implementation of mHealth technologies to improve post-operative care.

Keywords: mobile health, telecare, health information on the Web, ehealth, assistive technologies
Introduction:
The role of mobile technology to augment and improve postoperative care is immense. Mobile health applications offer promising avenues for physicians and patients to exchange critical health information for improved convenience, cost reduction and efficiency. This is particularly valuable in the developing world, where such increases could greatly affect access to care, patient outcomes and management of complications. Thus far, mobile health (mHealth) applications in low resource countries like Myanmar have focused mainly on primary care, maternal health and management of chronic diseases. However, developing new mHealth applications for postoperative monitoring of patients could have a major impact. This technology could enable early identification of complications and aid in efficiently evaluating overall patient outcomes which would ultimately decrease length of hospital stay and facilitate patient recovery.

Emerging work in Western and developed nations is beginning to show widespread patient support for using mobile phones to monitor postoperative recovery. For instance, Abelson et al. recently found in a population based survey of New York State residents that 60-70% of patients were willing or very willing to fill out surveys and send pictures by mobile phones in order to document their postoperative course to physicians. Likewise, multiple investigators have revealed enthusiasm in public and patient populations for using mHealth applications to augment postoperative care. However, investigations have also documented some hesitancy to use mobile phones to convey medical information to physicians due to lack of privacy, familiarity and/or access to technology.

There are significant differences in the delivery of postoperative care in Western and developing countries, including Myanmar. Care is often limited by scarce resources and a limited medical workforce. Patients often live long distances from health care facilities, particularly if their conditions require advanced surgical procedures. In addition, there may be unexplored cultural differences that influence the attitudes of patients in Myanmar towards both sharing information and their overall relationships with their healthcare providers.

The use of mHealth to enhance postoperative healthcare delivery in Myanmar offers great potential in alleviating some of these obstacles. Despite the relatively low per capital GDP, the penetration of mobile phones, especially internet enabled phones, is high in Myanmar- 92.7% of urban households and 65.9% of rural households own a mobile telephone. However, there are no studies about the willingness and general attitudes of people in Myanmar to use mobile phones for communicating with their physicians and medical professionals. Here, we present survey results taken in Myanmar to better understand the cultural attitudes and willingness of this population towards adopting mHealth technologies to improve postoperative patient care.

Methods
Survey development
Drawing from prior surveys performed in other populations, a thirteen question survey was developed. Seven of the questions seek to obtain patient demographic and background information in order to form a frame of reference and better understanding of the participant. Two questions evaluate the individual overall trust of physicians in general, and whether or not the internet is a major source for obtaining medical information. Four questions related to a theoretical situation whereby individuals are questioned about their willingness to perform multiple tasks on their mobile phones if they were to undergo surgery in the future.

The survey questions were first reviewed by two Myanmar natives to ensure cultural sensitivity and clarity. The full survey is available in the Supplementary Materials. All non-demographic questions have closed-ended answers, although extraneous information volunteered by participants during explaining their answers was also recorded.

Sampling
The survey was translated into Burmese and administered orally to individuals in busy public areas throughout Myanmar in July 2017. Eligibility included all volunteers agreeing to participate who were at least 18 years old or older, and without prior knowledge of their surgical history. Before administering the survey, it was explained to the participants that the purpose of this survey was to better understand how people in Myanmar use mobile phones to communicate their medical needs to healthcare providers.

After agreeing to participate, the survey was administered to each subject by a native Burmese speaker, and the answers were then translated in real time to English for data recording. Out of consideration for
the subject’s cultural comfort level, audio recordings were not made of their responses. None of the subjects agreeing to participate declined to either complete the survey or to answer any of the survey questions, so there were no missing responses. The complete administration of each survey took approximately 2-3 minutes per participant.

Of note, although we asked survey respondents specifically about their ethnicity, the concept on ethnicity for those in Myanmar is often conflated with their religious identity, thus, many responded with religious identifiers when asked about their ethnic background, although this does not represent true ethnicity. We reported here what respondents stated when asked about their ethnicity and did not attempt to correct/clarify if respondents answered with a religion when asked about ethnicity.

Analysis

The primary outcome of our survey was to determine if respondents wished to have their physician contact them after surgery. Secondary outcomes included information about patients’ current trust in their physicians and current engagement with online sources for health information. We also collected information regarding patient to participate in mobile health applications in a theoretical postoperative scenario. Although not part of the original survey design, we also made notes of comments by patients who spontaneously volunteered information while taking the survey, to better understand the motivation for their answers. None of the respondents refused to answer any questions, so there were no missing responses.

Microsoft Excel and R v3.4.1 were used for data analysis. P values were calculated for continuous variables with students t test. For categorical variables, the Fisher’s test was used for cell sizes <5, otherwise the Chi test was used.

Results

Of the 125 people asked to participate in the survey, 112 (89.6%) agreed to participate. The average age of respondents was 36.6 years (standard deviation 16.7 years, with a minimum age of 18 and maximum age of 78). Of the respondents, 55.4% were female. 77.7% of survey respondents were from urban areas and 22.3% were from rural areas. A map of the survey locations around Myanmar is included in Figure 1. Individuals came from a range of self-identified religious/ethnic groups and professions (Table 1). The majority of respondents, 67.0%, identified as Burmese (Bamar). The next most common self-identified religious/ethnic groups were Muslim (6.3%), Chinese (4.5%) and Karen (3.8%). The most common occupations were sales (20.5%) and other non-manual labor requiring less than a university degree (21.4%). 12.5% of respondents were retired, 11.6% worked at home and 3.8% were unemployed.

In terms of their medical background, the majority (67.0%) had no surgical history. However, of the 33.0% with a prior surgical history, the majority (81.1%) had some sort of follow-up care.

Figure 1: Location of survey administration throughout Myanmar with purple icons representing rural areas and green icons representing urban areas.
Mobile phone with internet capability was widespread in our sample population, with most people (90.2%) owning their own phone, which included a phone owned jointly by their families. 88.1% of these phones had internet capabilities. In the population of respondents who owned phones without internet capabilities, most respondents (83.3%) reported that they primarily used their phones to contact friends and family. In those with internet capabilities to their mobile phones, the most common primary usage of their mobile phones was for Facebook (48.3%), calling friends and family (24.7%) and work-related applications (13.5%). Only 25% of respondent reported any contact of any kind with a physician on their mobile phone.

Most respondents (61.2%) had used internet resources in some form to look up health information. Of those that did look up online information about their health, 50.7% trusted this information “a little”, 44.9% trusted this information “a lot” and 7.7% did not trust the information. This contrasted with respondents’ trust for physicians, which was almost uniformly qualitatively assessed as “a lot” for 84.8% of people, and 13.4% trusted physicians “a little”. Only 1.8% of respondents reported that they did not trust physicians.

Most were very open with their health information, with 83.9% noting a willingness to share their health information with friends and family (Figure 2). A willingness to share their health information was not associated with gender, age or ownership of a mobile phone, as seen in Table 3.

The majority of respondents, 85.7%, expressed a desire for physicians to contact them via mobile phone for postoperative care, irrespective of whether they had previously used mobile phone technology to interface with their physicians (Figure 2). Of note, even in people who did not own a phone, 72.2% were in favor of the theoretical idea of being contacted by phone by their physicians. When presented with a theoretical situation in which they required postoperative monitoring, a majority of respondents, 83.0%, stated that they would be willing to fill out regular surveys to provide information about their recovery to their surgeon. Relatively fewer people, although still a majority at 69.6% were willing to send a picture of their wound to their surgeon. The only variable associated with a decreased willingness to send a picture of a postsurgical wound via mobile phone to a surgeon was female gender, with an odds ratio of 0.40 when using male gender as a reference, 95% confidence interval (0.48, 0.93).

People who had previously contacted a physician with their mobile phone, were more likely to wish to contact a surgeon for postoperative care and send a picture of their wound to their surgeon, as seen in Table 3. Otherwise, there were no significant predictors for increased willingness in the aspect of mHealth we inquired about. A majority of patients were open to contacting their surgeon via mobile phone in a hypothetical postoperative setting, regardless of age, gender, ethnicity, occupation, mobile phone ownership, prior contact with a physician via mobile phone and mobile phone ownership (Table 2).

Some qualitative information was collected from patients as a majority of respondents did not restrict their answers to single word responses, but instead preferred to elaborate responses at length. Many favored contact with their physician via mobile phone, but only if this was in addition to seeing their physicians in person, and especially in cases of postoperative monitoring. Some expressed a willingness...
Figure 2: Attitudes of people in Myanmar regarding engagement with mHealth for various aspects of postoperative care.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Willing (N = 96) n (%)</th>
<th>Not willing (N=16) n (%)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age-category, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24</td>
<td>27 (28.1%)</td>
<td>2 (12.5%)</td>
<td>0.35</td>
</tr>
<tr>
<td>24-39</td>
<td>35 (36.4%)</td>
<td>5 (31.3%)</td>
<td></td>
</tr>
<tr>
<td>40-64</td>
<td>25 (26.0%)</td>
<td>7 (43.8%)</td>
<td></td>
</tr>
<tr>
<td>≥65</td>
<td>9 (9.3%)</td>
<td>2 (12.5%)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>54 (56.3%)</td>
<td>8 (50%)</td>
<td>0.85</td>
</tr>
<tr>
<td>Male</td>
<td>42 (43.8%)</td>
<td>8 (50%)</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>73 (76.0%)</td>
<td>14 (87.5%)</td>
<td>0.52</td>
</tr>
<tr>
<td>Rural</td>
<td>23 (24.0%)</td>
<td>2 (12.5%)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burmese</td>
<td>66 (68.8%)</td>
<td>9 (56.3%)</td>
<td>0.49</td>
</tr>
<tr>
<td>Non-Burmese</td>
<td>30 (31.3%)</td>
<td>7 (43.8%)</td>
<td></td>
</tr>
<tr>
<td>Occupation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student</td>
<td>7 (7.3%)</td>
<td>2 (12.5%)</td>
<td></td>
</tr>
<tr>
<td>Sales</td>
<td>20 (20.8%)</td>
<td>3 (18.8%)</td>
<td></td>
</tr>
<tr>
<td>Business Owner</td>
<td>4 (4.2%)</td>
<td>2 (12.5%)</td>
<td></td>
</tr>
<tr>
<td>Driver (transport/taxi)</td>
<td>4 (4.2%)</td>
<td>1 (6.3%)</td>
<td></td>
</tr>
<tr>
<td>Housework/childcare</td>
<td>12 (12.5%)</td>
<td>1 (6.3%)</td>
<td></td>
</tr>
<tr>
<td>Other non manual labor requiring less than college education</td>
<td>24 (25.0%)</td>
<td>1 (6.3%)</td>
<td>0.19</td>
</tr>
<tr>
<td>Other non manual labor requiring more than a college education</td>
<td>7 (7.3%)</td>
<td>1 (6.3%)</td>
<td></td>
</tr>
<tr>
<td>Manual labor</td>
<td>5 (5.2%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Retired</td>
<td>9 (9.4%)</td>
<td>5 (31.3%)</td>
<td></td>
</tr>
<tr>
<td>Unemployed</td>
<td>4 (4.2%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Mobile phone ownership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Have internet enabled mobile phone</td>
<td>80 (83.3%)</td>
<td>9 (56.3%)</td>
<td>0.03</td>
</tr>
<tr>
<td>Have non-internet enable mobile phone</td>
<td>8 (8.3%)</td>
<td>4 (25.0%)</td>
<td></td>
</tr>
<tr>
<td>Do not own mobile phone</td>
<td>8 (8.3%)</td>
<td>3 (18.8%)</td>
<td></td>
</tr>
<tr>
<td>History of prior surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, prior surgery</td>
<td>64 (66.7%)</td>
<td>11 (68.8%)</td>
<td>1.0</td>
</tr>
<tr>
<td>No history of prior surgery</td>
<td>32 (33.3%)</td>
<td>5 (31.3%)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Demographics of survey respondents and willingness to make contact with a surgeon via mobile phone in a hypothetical future postsurgical care scenario.
to fill out questionnaires and take pictures of their wound, but only if requested by their physician.

The most frequent reason cited by participants for their unwillingness to share information with a physician via mobile phone in a theoretical setting was their concern about eroding the patient-physician relationship. Almost all patients who felt that they would not like to contact their surgeons in the postoperative setting cited this as the reason. A majority felt that it was easier for physicians to acquire information and review their condition more thoroughly in-person as compared to by phone. In several cases, respondents stated that their physicians were relatively available, so they did not see the need for mobile phone communication as a significant convenience factor. A few individuals expressed hesitancy to use mobile phones for privacy reasons.

### Table 3: Univariate analysis for willingness to engage in various aspects of mHealth postoperative care by user status by respondent demographics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Would like to contact physician via mobile phone Odds Ratio (95% CI) N=112</th>
<th>Fill out survey on mobile phone Odds Ratio (95% CI) N=109</th>
<th>Send pictures on mobile phone Odds Ratio (95% CI) N=110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age-category, years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-24</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>25-39</td>
<td>0.52 (0.07, 2.6)</td>
<td>0.88 (0.17, 3.91)</td>
<td>1.09 (0.39, 3.01)</td>
</tr>
<tr>
<td>40-64</td>
<td>0.26 (0.03, 1.22)</td>
<td>0.65 (0.12, 2.94)</td>
<td>2.19 (0.69, 7.47)</td>
</tr>
<tr>
<td>≥65</td>
<td>0.33 (0.04, 3.10)</td>
<td>0.33 (0.05, 2.11)</td>
<td>1.23 (0.27, 6.66)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>Female</td>
<td>0.78 (0.27, 2.28)</td>
<td>0.43 (0.13, 1.27)</td>
<td>0.40 (0.17, 0.93)</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>Rural</td>
<td>2.21 (0.56, 14.71)</td>
<td>2.17 (0.55, 14.49)</td>
<td>1.30 (0.48, 3.92)</td>
</tr>
<tr>
<td>Mobile phone ownership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do not own mobile phone</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>Have non-internet enable mobile phone</td>
<td>0.75 (0.11, 4.51)</td>
<td>0.75 (0.08, 5.69)</td>
<td>1.29 (0.19, 8.98)</td>
</tr>
<tr>
<td>Have internet enabled mobile phone</td>
<td>3.33 (0.64, 14.10)</td>
<td>1.73 (0.24, 8.07)</td>
<td>1.02 (0.21, 3.99)</td>
</tr>
<tr>
<td>History of prior surgery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No history of prior surgery</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>Yes, prior surgery</td>
<td>1.10 (0.36, 3.74)</td>
<td>0.58 (0.20, 1.77)</td>
<td>0.61 (0.26, 1.46)</td>
</tr>
<tr>
<td>Previously contacted physician via mobile phone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>Yes</td>
<td>5.87 (2.7, 8.35)</td>
<td>0.72 (0.24, 2.49)</td>
<td>2.12 (1.32, 3.33)</td>
</tr>
<tr>
<td>Use internet to lookup health information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>Yes</td>
<td>1.74 (0.59, 5.13)</td>
<td>0.99 (0.31, 2.91)</td>
<td>1.16 (1.18, 4.44)</td>
</tr>
<tr>
<td>Trust of internet health information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Not at all”</td>
<td>Ref.</td>
<td>Ref.</td>
<td>Ref.</td>
</tr>
<tr>
<td>“A little”</td>
<td>2.96 (0.82, 14.08)</td>
<td>0.88 (0.26, 3.02)</td>
<td>1.20 (0.46, 3.21)</td>
</tr>
<tr>
<td>“A lot”</td>
<td>2.59 (0.71, 12.38)</td>
<td>1.76 (0.44, 8.75)</td>
<td>1.71 (0.61, 5.11)</td>
</tr>
</tbody>
</table>

Three patients were unsure if they would fill out a survey about their postoperative state and two patients were unsure if they would be willing to send their surgical team a picture of their postoperative wound via mobile phone. These patients were removed from the univariate analysis for these outcomes.
particularly with regard to sending pictures of injuries of certain body parts, but would be willing to send photos of “non sensitive” areas. Finally, one respondent felt that mobile phone contact with physicians would only increase physician workload, thus, it would be best to handle all medical needs in person.

Conclusion/Discussion

The potential of mobile phone technology to increase the efficiency and availability of postoperative care in Myanmar is vast. Our survey results suggest that many in Myanmar are receptive to adopting mobile health technologies, with over 85% reporting that they would like their physician to contact them via phone in a hypothetical postoperative situation. Furthermore, based on a theoretical survey question, a majority would be willing to supply regular postoperative information via surveys and provide pictures of postoperative wounds to their healthcare providers. Both patients with prior surgeries and those with no history of surgery showed similar willingness to engage in postoperative mHealth. The application of mHealth technology in developing nations such as Myanmar has the potential to aid in early identification of postoperative complications, promote continuity of care, and allow for better assessment of overall patient outcomes.

Our survey results also shed interesting light on the culture of patient-physician relationships and mobile phone usage in Myanmar. An overwhelming majority of respondents had a high level of trust for physicians, and many patients used the internet to search for healthcare information. This highlights the need to engage patients with trusted medical providers and curate accurate internet sources in Burmese for health related topics.

There were some limitations of our results and methods. First, despite an effort to include both rural and urban respondents, the majority of patients came from Yangon, one of the most highly educated and wealthy cities in the country. It was also a survey of convenience of people in public areas, without the advantages of random administration, so there is likely selection bias towards people with more familiarity with mobile phones and higher health literacy. Thus, we would expect that our survey respondents would be more familiar with the concept of physician contact through their phone as compared to more remote, low income populations in rural communities. In the future, we would like to specifically investigate the more remote areas of Myanmar, since these people might potentially benefit the most from advancements in mHealth.

Overall, the results of this survey indicate that many in Myanmar are enthusiastic about mHealth in the postoperative care setting. However, this survey indicates that successful adoption of mobile phone applications will rely heavily on understanding and strengthening the physician-patient relationship, given the high regard for patients have for their physicians. As in other countries, people in Myanmar show a willingness to answer survey questions about their health and send in pictures of their wound in a postoperative care setting. Our results support a bright future for mHealth for postoperative monitoring in Myanmar to improve access to health information and physicians.

Acknowledgements

N/A.

References


7. Hmone, M. P., Li, M., Alam, A. & Dibley, M. J. Mobile Phone Short Messages to Improve Exclusive Breastfeeding and Reduce Adverse Infant Feeding


A MOBILE ELECTRONIC RECORD FOR LIFESTYLE COACHES IN GESTATIONAL DIABETES PREVENTION

David Simmons FRACP MD¹, Tosin Daniels BSc (Hons)², Daniel J Simmons BEng³, Mireille NM van Poppel⁴, Jürgen Harreiter MD⁵

¹Western Sydney University, NSW, Australia and Cambridge University Hospitals, Cambridge, England
²Cambridge University Hospitals, Cambridge, England
³Techtonic Software, Norfolk, England
⁴Department of Public and Occupational Health, EMGO+-Institute for Health and Care Research, VU University Medical Centre, 1081 BT Amsterdam, the Netherlands and Institute of Sport Science, University of Graz, 8010 Graz, Austria
⁵Department of Medicine III, Division of Endocrinology, Gender Medicine Unit Medical University of Vienna

On behalf of the DALI core investigators group (see Appendix)
Corresponding author: da.simmons@westernsydney.edu.au

Background: Lifestyle programmes require a structured approach to be effective. Maintaining fidelity of coach-based interventions is challenging. Mobile devices may assist by supporting the use of an algorithm based approach.

Aims: To describe the development and challenges associated with a mobile technology approach to supporting a coach-based lifestyle programme for the prevention of gestational diabetes mellitus (GDM) in pregnancy.

Methods: Narrative approach to system design, with a survey of 12 lifestyle coaches involved in the pan-European multicentre DALI (Randomised controlled trial for the prevention of gestational diabetes mellitus (GDM) with vitamin D And Lifestyle Intervention) study.

Results: A mobile device based programme was associated with more technical issues than a web-based approach, particularly in relation to upgrades to improve usability and utility. Even after multiple upgrades, a paper approach was preferred by some coaches, and by most for aspects of the intervention that required greater coach-participant interaction (eg goal setting). Coaches generally preferred the mobile device approach for obtaining pre-existing data, structured data entry and for intervention prompts.

Conclusion: Mobile technology can facilitate coach-delivered lifestyle interventions. However, more work is required to minimise intrusion into the behavioural intervention.

Introduction

Type 2 diabetes (T2DM) has now been shown to be preventable through weight loss, increased physical activity and appropriate dietary change (1). Successful randomised controlled trials (RCTs) for preventing T2DM included coaching interventions provided within a curriculum (2), with the major studies being ‘classroom’ or clinic based (2-3). It has been a challenge to create widespread diabetes prevention services (4) translated from such intensive interventions, applied by a small number of ‘coaches’, to RCT participants within a single country. Besides the difficulty of obtaining funding for such programmes, a major issue is the fidelity (ie the degree to which the intervention is correctly implemented) of any intervention implemented by non-research staff, outside of the rigour of an RCT. The Diabetes Prevention Program (DPP) showed that the more of the lifestyle messages that were taken up, the lower the probability of incident T2DM (2), and hence any reduction in fidelity could reduce the effectiveness of the intervention.

Elsewhere in health services, the need to improve the quality of interventions is an area that is addressed by quality assurance programmes. In diabetes, there has been a range of strategies trialled with varying effectiveness, including improvements in documentation (5). Diabetes electronic records continue to progress, but uptake has been varied (6,7). Mobile computing has been seen as one way of improving care (8,9). The potential benefits were identified as: (i) faster, real time access to and recording of health data, (ii) provision of decision support, and (iii) translation of knowledge into practice (7). However a range of challenges remain in introducing such systems into healthcare (6-9).

DALI (Randomised controlled trial for the prevention of gestational diabetes mellitus (GDM) with vitamin D And Lifestyle Intervention) included a range of lifestyle interventions for the prevention of GDM across 9 European countries (10). The lifestyle programme was based upon a series of 12 messages (7 Healthy Eating (HE) and 5 Physical Activity (PA)) delivered following Motivational Interviewing principles, and was associated with significant reductions in gestational weight gain (11,12). Rather than a curriculum based approach, a key component involved the woman prioritising interventions and working with the support of a coach to set and achieve goals. The approach was based upon prior work in New Zealand (13), where Maori Community Health Workers used a structured electronic record on a personal digital assistant (PDA) to support a lifestyle programme among adult Maori. The intervention used data collected at baseline, from self-monitoring and from prior coaching sessions. There was a need to be able to review which messages had been covered and to be able to review progress (eg, weight change) for each participant. In view of these needs, it was decided to incorporate a handheld computing device. The data collected were to be part of a process evaluation of intervention implementation in the trials. We now describe the development and usability of the DALI lifestyle coaching e-support programme, including the development and usability of the DALI lifestyle coaching e-support programme, including how these were overcome.

Methods

DALI study design overview

Interventions to prevent gestational diabetes mellitus (GDM) remain unproven (14). DALI developed 3 lifestyle interventions: HE, PA and HE+PA (10). The 3 interventions were piloted (11), and then used in one RCT of HE, PA, HE+PA vs controls (13) and one RCT of Vitamin D tablets (VDT)+HE+PA vs VDT+no lifestyle intervention vs placebo+HE+PA vs no intervention (10). The trials invited pregnant women at risk of GDM (BMI≥29 (kg/m²) from 9 European countries to have a 75g oral glucose tolerance test before 20 weeks gestation. Those without GDM (15) were randomized to an intervention group, pre-stratified for each site. Women received 5 face-to-face, and 4 telephone coaching sessions from consent to 35 weeks, based on motivational interviewing principles, supported by a bespoke record system using a handheld electronic device (HTC HD7, HTC Corporation, Taiwan), or similarly structured paper methodology. An optimal gestational weight gain (GWG) target of <5kg was emphasized. Coaches were health workers recruited locally (eg midwives, nurses, pharmacy technician, health coaches, doctor) and attended 3 training and standardisation workshops through the trials. All coaches were required to be able to be fluent in English. Trial data (questionnaire, OGTT, measurements) were collected at baseline, 24-28 weeks, 35-37 weeks and at birth and entered directly into a bespoke database using MySQL with unique identifier and separate tabs for each time point. Data were entered by research staff who were kept separate from the coaches to maintain integrity of the randomisation.
DALI lifestyle coaching e-support programme development

The architecture was developed from experience gained with the use of a personal digital assistant (PDA) to help structure, guide and record coach-participant interactions in Te Wai o Rona: Diabetes Prevention Strategy (13). Steps taken were design of the algorithm, architecture, hardware and software choices, screen development, software development including security, navigation approaches, linkage with the server and server development. The original DALI design involved a PDA holding an electronic coach record (the application front-end), with an anonymised data back up synchronised with the DALI database after each coaching session. Data on the database was then to be used for feedback to the coach, using the study ID, and reporting progress to the wider project group (Figure 1). The server was expected to periodically create data backups stored on a separate drive.

Key:
Physical activity interventions (n=5): “Be active every day”; “Sit less”; “Build your strength”; “Take more steps”; “Be more active at weekends”
Healthy Eating interventions (n=7): “Replace sugary drinks”; “Eat more non-starchy vegetables”; “Increase fibre consumption”; “Watch portion size”; “Eat protein”; “Reduce fat intake”; “Eat less carbohydrates”
Stages of change (1-5): Precontemplative; Contemplative; Preparation; Action; Maintenance

Figure 1: System Algorithm.
Advances in mobile technology allowed the upgrading of the PDA to a mobile phone, and the HTC HD7 (HTC Corporation, Taiwan) was selected for its large screen and Windows operating system (the system used in Te Wai o Rona: Diabetes Prevention Strategy). However, the newer Windows 7 operating system (Microsoft, USA) required a complete rewrite of the intervention application. Coaches had varying experience with information technology and implemented the system at varying rates. A default paper system was designed to incorporate the stages in the algorithm for times when the electronic system was not able to be used.

Screens were developed for each stage in the algorithm, designed to streamline the coach-participant interaction and ensure that each aspect of the intervention was either completed, or an active bypassing decision made (eg. for time reasons). Screens were structured for easy use, with large buttons for touchscreen completion. Writing into the programme was minimised, and completed through the on-screen keyboard. A traffic light system was used to indicate where the participant reported to the coach the uptake of a given message and whether it had progressed (green), regressed (red) or was intermediate (orange). Navigation was developed based upon the flow of the expected coaching interview. The key navigation screen provided 6 buttons to the measurements section, 7 HE messages, HE tools provided, 5 PA messages, PA tools provided and adverse events. Data saving was possible at key points through the screens.

Security features included 256 bit AES encryption and separation of any identifying information from actual research data. All coaches had their own identifier and password. Data entered into the handheld programme could be saved and used as the basis for creating appointments on the phone. Any programme updates, were downloaded from the Microsoft App store.

The original plan of linking to the DALI trial database was abandoned after the trial database was built, for security reasons, without an outward facing functionality that prevented receipt of mobile phone data. The repercussions of this were:

- The need to procure a separate server for the mobile computing with new software development
- The need for a separate office PC-based bespoke programme (called the ‘PC to PDA programme’), written in C# (Microsoft, USA), for blinded research staff to re-enter baseline questionnaire data to allow direct upload to the PDA through a cradle. Direct uploading was decided upon for security reasons. Zune client software (Microsoft, USA) was selected as the programme for linking the ‘PC to PDA programme’ with the PDA.

The server-side of this new system proved difficult to implement, and was ridged when changes needed to be made to the database (either with results or the data itself). The system on the client side had a number of minor problems mostly revolving around the international nature of the project, making debugging the application and giving support to coaches difficult through a phone application. The client application required local data to be stored on the mobile phone, which made it volatile due to the nature of the Windows Phone 7 Operating system, storing data in isolated storage (which is deleted if the application was uninstalled) and the data not being sent to the server as soon as an appointment/intervention was completed. Distance was an issue, there being no direct way of accessing data stored by the application. Storing data in a usable format on the phone was also a challenge due to the Windows phone still being in semi-early development.

The server side system was eventually replaced by a direct MYSQL approach (Oracle Corporation, USA) with all data being created and stored instantly on the main database via the use of a PC Client application which connected to the main database via the internet. During this period, the paper PDA was used by the coaches, rather than the mobile phone application itself. This meant that no data was stored locally and removed the potential for data loss or corruption either through program fault/malfunction or human error. This was soon followed by a scaled-down PDA/phone client application that acted more as a portable intervention creator that was then sent to the server and viewed through the PC client. In this way, the risk of data loss on the client side was significantly minimized to the scope of about one or two appointments.

Reporting system

The ongoing need to identify the causes of difficulties with the system (user issues, international site internet issues, software issues, server issues) delayed the development of the reporting system which needed a foundation of a stable, operating architecture. This was not achieved until the MYSQL based system was
developed and too late to be used in the trials themselves. The system commenced with 4 reports:

- **Report 1**: % of women receiving all 3 of introduction, GDM explanation, blood result explanation
- **Report 2**: % of women with no weight taken
- **Report 3**: % of women with weight taken whose current weight minus baseline weight is less than or equal to 5kg
- **Report 4**: % of messages covered for each woman in the intervention group

**Training programme**

Coaches were provided with the Manufacturer User Guide for the mobile device, and a manual for the coach e-support system that covered each stage in the algorithm. The manual also covered the ‘authorised user’ policy, security aspects, who to contact should problems arise and general issues relating to the phone. Coaches were required to practice on a simulation system before commencing, and to describe the positive and negative aspects of the system. Online updates were provided including a user video. Updates were provided via email. A ‘clinic’ was provided at the end of the pilot and midway through the first Lifestyle RCT.

**Evaluation**

The uptake of the system was continuously monitored either by email or reviewing the use of the database. At the end of the pilot study and after the migration to the PC client system, questionnaires (shown in Tables 4-6) were used as way to gather the coaches opinions on issues surrounding technology options, the usability of the PDA device and wider applicability of the PDA for delivering the DALI messages. The short questionnaire was distributed to the 12 coaches by email. A thematic analysis was used to list the issues identified. The monitoring system was not completed until after the completion of the PC client system and was not used for feedback. The DALI studies received ethics approval across all local ethics committees.

**Results**

Ultimately, of the 12 coaches trained in the use of the system, 3 used the system in the intervention fully. Table 1 lists the number of coaches using different components of the system. At least one survey was received from each coach within the lifestyle RCT. Table 2 describes the advantages and disadvantages reported by the coaches in using the system. Advantages related largely to accessibility of data and some design aspects. Disadvantages were largely technical, although there were unexpected difficulties due to international differences in the way punctuation is used (eg full stop (UK) vs comma (Europe) for the decimal point). Table 3 describes the technical issues encountered by the coaches. All were eventually resolved, but took time impacted on the attitudes of the users to the new technology. Table 4 shows that the users reported that most of the features worked well. The main areas of difficulty related to connecting to the internet and the inability to correct errors. Approximately 50% of the coaches reported the training was adequate. Table 5 shows the user ratings for different aspects of the system. Overall, among users, the HTC HD7 was rated 5/10, the DALI PDA programme 4.3/10, the DALI PC to PDA programme 6/10, the PC client programme 6.9/10 and the paper PDA 7.6/10. All coaches used the PC client and Paper PDA. Table 6 shows the preferred methodologies were largely electronic for administrative items, but paper for more complex issues relating to the behavioural intervention.

**Discussion**

**Effectiveness**

We have described the development, experience and evaluation of a mobile electronic record for lifestyle coaches involved in the prevention of GDM through lifestyle change. The experience was gained within randomised trials across 9 European countries over 3-4 years between 2010 and 2014. While many lifestyle applications now exist (16), the DALI application was tailored to the work undertaken by the DALI coaches for an intervention based upon the Health Action Process Approach (HAPA) model (10) for behavioural change, across 12 key lifestyle messages including goal setting and review. As the
delivery to all trial participants was managed using the algorithm developed, either through the ‘paper’ or electronic ‘PDA’, our evaluation is unable to state whether the paper or electronic approach was more effective, just that the DALI intervention itself was effective in limiting gestational weight gain (11,12).

Preference
The electronic forms (PDA/PC client) was preferred for recording data (eg. type of appointment, measurements) and obtaining prior data (eg. personal details). Similar preference was stated between electronic forms and the paper PDA for explaining results and discussing interventions including choice of tools and recording adverse events. The paper PDA was preferred for goal setting, which requires more free text. There were occasional strong preferences for and against the use of the electronic PDA, generally based upon the ease of the technology with a capability to incorporate the technology, versus a concern over the intrusion of the technology into the flow of the coach-participant motivational interviewing.

Usability and utility
There remains evolving debate over how to define usability and utility. In his 1994 text, Nielson

Table 2a

Benefits and Positive aspect of the system

- Quick way to summarise the coach sessions.
- Good form of having all the information together.
- App very understandable
- Ability to upload data from baseline questionnaire onto the PDA
- Ability to present and show participants the baseline data and blood result during the first coach visit
- Ability to access data from previous coach session
- Data entry reasonably easy and quick to input.
- Easy overview
- Using the PDA during the coach session, helps with remembering all the information
- The PDA is easy and fast to handle.
- It is at hand
- The touch screen capacity is good
- App is easy to install
- Great technical support from the DALI programmer

Table 2b

Difficulties and Negative aspect of the system

- Sometimes data loss is experienced after updating the new versions of the DALI App.
- The App crashes very easy especially when adding accents to the name of the participants on the PC to PDA programme
- Needing to synch so many times until the synch was successful
- Not able to use PDA during coaching because of the size of the screen being too small.
- Inability to synchronise information (real time) with server on hospital site.
- Unable to correct data once input, in particular date, time and spelling errors in goals.
- The PDA was very difficult to install
- There were many updates and many things could go wrong when updated
- Difficult to use in a hospital, where there are many security barriers.
- Internet connection
- Not having access to data from previous sessions
- Language differences. For example the Dutch vs English (especially the difference between dot (.) and comma (,) installation on one of the coaches computer. This caused the program to crash on their PDA.

Table 2: Advantages and disadvantages of the system reported by the coaches
included a broad and deep definition to include “Efficiency (Resources expended in relation to the accuracy and completeness with which users achieve goals), Satisfaction (Freedom from discomfort, and positive attitudes towards the use of the product), Learnability (The system should be easy to learn so that the user can rapidly start getting work done with the system), Memorability (The system should be easy to remember so that the casual user is able to return to the system after some period of not having used it without having to learn everything all over again), Errors (The system should have a low error rate, so that users make few errors during the use of the system and that if they do make errors they can easily recover from them and further, catastrophic errors must not occur) and Utility (the ability of a system to meet the needs of the user).” (17 as summarised in 18). Others have narrowed this down to effectiveness, efficiency and satisfaction (18). A range of applications have been reviewed using the System Usability Scale (19), covering a range of features. Our coach survey revealed a range of issues impacting on usability, but we suspect that these were heavily influenced by the prior perspective of the coach on technology and technology use during a motivational interviewing encounter. Whether clients feel that when their coach uses a PDA or another screen based device interferes with rapport and quality counselling would be of interest to study further in other settings. One issue that was

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### Technical issues encountered

<table>
<thead>
<tr>
<th>Issues</th>
<th>Responses/Actions</th>
</tr>
</thead>
</table>
| Handheld device/software issues | • Use of Windows Phone7 operating system with isolated meant that all data was deleted with the application making the data extremely vulnerable.  
• The lack of a library that connected the phone directly to an SQL database meant the phone had to store data in a text file based format.  
• Data had to be stored locally on the phone due to discontinuous connection with the internet. This mean that other steps, such as synchronising the phone and setting up passwords, had to be put into place which created unnecessary steps for the user.  
• The configuration and security settings of the local network for each of the coaches often varied and with some sites blocked the PDA establishing a connection to the main server.  
• The phone system was designed to streamline and direct coaches during appointments which they did not like. Coaches often made mistakes and would want to go back and edit them later |
| International/ Multisite issues | • Due to distance of the running applications, it was often very difficult to debug the application from another country.  
• Issue with the local and some countries using a comma(,) instead of a decimal point (.) which caused extra fields to be created when results were put into comma separated variable format  
• The configuration and security settings of the local network for each of the coaches often varied and with some sites blocked the PDA establishing a connection to the main server. |
| User Issues | • Coach antagonistic to the use of hand held devices: disrupted initial training and ongoing programme – non participation in handheld device.  
• Coach did not use the phone during the Motivational Interviewing due to appearance that they were texting during appointments.  
• Coaches decided to manually write down the appointments which sometimes did not get entered into the PDA and synched.  
• Coaches forgot to synch or rarely did this and had to be prompted often to do so.  
• The phone system was designed to streamline and direct coaches during appointments which they did not like. Coaches often made mistakes and would want to go back and edit them later |
| Other Issues encountered | • Programme failure  
• Application shut down  
• Error synching  
• Server connectivity error  
• Firewall issue  
• The resolution of technical issues fell in the domain of the DALI programmer |

Table 3: Technical issues encountered.
not initially expected in the programming arose from the international nature of the study with the different uses of commas, full stops and accents. This was addressed, but such events, as ‘developer errors’ reduced confidence in the system, and this itself appeared to be influenced by the pre-existing attitude to the technology. The workshops and rapid feedback, addressing issues as they arose, were used to improve confidence, but with some coaches, confidence remained low as the issues occurred on top

<table>
<thead>
<tr>
<th>Question A</th>
<th>Number of Respondent</th>
<th>Not used</th>
<th>STRONGLY AGREE</th>
<th>AGREE</th>
<th>NEITHER AGREE NOR DISAGREE</th>
<th>DISAGREE</th>
<th>STRONGLY DISAGREE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a Size of screen is just right</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2a Size of buttons for typing in data is just right</td>
<td>12</td>
<td>4</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>3a The touch screen capability is just right</td>
<td>12</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4a The time taken to move from one screen to the next is just right</td>
<td>12</td>
<td>4</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5a Connecting to the internet/synchronising was just right</td>
<td>12</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6a The programme is intuitive, that is, it is easy to follow</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7a Navigation from one screen to the next is just right</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8a Navigation to a previous screen is just right</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9a The ability to correct errors is just right</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>10a Data entry is easy on all screens</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11a All screens are easy to read</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12a There is easy access to data from the baseline questionnaire</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>13a There is easy access to data from previous sessions</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>14a The initial PDA training was just right</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>15a The PDA user guide was just right</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>16a The training videos and other training were just right</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>17a The upgrade process and programmer help was just right</td>
<td>12</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>2</td>
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</tr>
</tbody>
</table>

Table 4: PDA USER-EVALUATION QUESTIONNAIRE – Programme/Physical issues.
### Table 5: PDA USER- EVALUATION QUESTIONNAIRE –Experience rating

<table>
<thead>
<tr>
<th>Questions B</th>
<th>Number of Respondents (n)</th>
<th>Not used</th>
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<th>Very Positive (10)</th>
<th>Mean rating among users /10</th>
</tr>
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<tr>
<td>1b</td>
<td>12</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>0</td>
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<td>2b</td>
<td>12</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3b</td>
<td>12</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4b</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>5b</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
</tbody>
</table>

### Table 6: PDA USER- EVALUATION QUESTIONNAIRE –Preferred methodology

<table>
<thead>
<tr>
<th>Question C</th>
<th>Number of Respondent (n)</th>
<th>Not used</th>
<th>Paper PDA</th>
<th>PDA</th>
<th>PC</th>
<th>PC client</th>
<th>PC client &amp; paper PDA</th>
</tr>
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<tbody>
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<td>1c</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td>4</td>
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<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3c</td>
<td>12</td>
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<td>2</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4c</td>
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<td>4</td>
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</tr>
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<tr>
<td>8c</td>
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<td>3</td>
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<td></td>
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<tr>
<td>9c</td>
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<td>3</td>
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<td>1</td>
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<tr>
<td>10c</td>
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<td>0</td>
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<td>3</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>11c</td>
<td>12</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12c</td>
<td>12</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>2</td>
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<td>0</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>
of some of the other barriers that were outside of the control of the developers (e.g., the firewall issues).

**Privacy and security**

The electronic PDA and the PC to PDA programme held identifiable data. The former was used with the participant and had significant security as a password protected handheld device. The latter was within a password protected personal computer, within the firewall of the health service site. The server never held personal data, and was linked via a participant identifier. As a result, the personal details were protected within the limits of sensible password use.

**Technical issues**

This work involved a stream of technical issues from the beginning with the requirement to operate independently from the trial database, to the need to upgrade the operating system, to the difficulties with operating the PC to PDA system within the intranet of the health service site. Many of the ‘user’ requests related to the local intranet/internet administration, and not the DALI programmes. Nevertheless, each time there was a problem with the local information technology, it undermined the credibility of the DALI system. Most of the difficulties hinged on two issues (1) the underdeveloped Windows Phone 7 system which had no official support for sequel databases at the time; and (2) the lack of a live connection to the database as well as the absence of a guarantee of standard of network facilities or access to internet.

**Conclusion**

The DALI system through the PC client/web based approach ended up as the preferred electronic system, albeit with some caveats over longer text entry associated with goal setting. Further field trials are warranted should similar lifestyle interventions be undertaken. Besides testing the effectiveness of the approach, whether such mobile technology will improve the fidelity of interventions would be worthwhile investigating.

**Funding:** The project described has received funding from the European Community’s 7th Framework Programme (FP7/2007-2013) under grant agreement no 242187. In the Netherlands, additional funding was provided by the Netherlands Organisation for Health Research and Development (ZonMw) (Grant nr. 200310013). In Poland, additional funding was obtained from Polish Ministry of Science (Grant nr 2203/7.PR/2011/2). In Denmark, additional funding was provided by Odense University Free Research Fund. In the UK, The DALI team acknowledge the support received from the NIHR Clinical Research Network: Eastern, especially the local diabetes clinical & research teams based in Cambridge. In Spain, additional funding was provided by CAIBER 1527-B-226. The funders had no role in any aspect of the study beyond funding.
Conflict of interest: DJS was paid as the software and system developer for the DALI systems, but was not involved in the evaluation of the software.

References


Appendix

The DALI core investigators group


Gernot Desoye, PhD. Department of Obstetrics and Gynecology, Medizinische Universitat Graz, Graz, Austria. E: gernot.desoye@medunigraz.at

David Simmons, MD (Cantab) Institute of Metabolic Science, Addenbrookes Hospital, Cambridge, England and Macarthur Clinical School, Western Sydney University, Sydney, Australia. E: Da.simmons@westernsydney.edu.au

Rosa Corcoy, PhD. Department of Obstetrics and Gynecology, Medizinische Universitat Graz, Graz, Austria. Institut de Recerca de l’Hospital de la Santa Creu i Sant Pau, Barcelona, Spain. E: RCorcoy@santpau.cat

Juan M Adelantado, PhD Institut de Recerca de l’Hospital de la Santa Creu i Sant Pau, Barcelona, Spain. CIBER Bioengineering, Biomaterials and Nanotechnology, Instituto de Salud Carlos III, Zaragoza, Spain. E: JAdelantado@santpau.cat

Roland Devlieger, PhD KU Leuven Department of Development and Regeneration: Pregnancy, Fetus and Neonate. Gynaecology and Obstetrics, University Hospitals Leuven, Belgium. E: roland.devlieger@uzleuven.be

Andre van Assche, PhD KU Leuven Department of Development and Regeneration: Pregnancy, Fetus and Neonate. Gynaecology and Obstetrics, University Hospitals Leuven, Belgium. E: andre.vanassche@med.kuleuven.be

Peter Damm, DMSc. Center for Pregnant Women with Diabetes, Departments of Endocrinology and Obstetrics, Rigshospitalet, Institute of Clinical Medicine, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark. E: pdamm@dahlnet.dk

Elizabeth Rheinhardt Mathiesen, DMSc. Center for Pregnant Women with Diabetes, Departments of Endocrinology and Obstetrics, Rigshospitalet, Institute of Clinical Medicine, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark. E: elisabeth.reinhardt.mathiesen@regionh.dk

Dorte Moeller Jensen, PhD. Department of Endocrinology and Department of Gynaecology and Obstetrics, Odense University Hospital, Department of Clinical Research, Faculty of Health Science, University of Southern Denmark, Odense, Denmark. E: Dorte.Moeller.Jensen@rsyd.dk

Lise Lotte T. Anderson, MD. Department of Endocrinology and Department of Gynaecology and Obstetrics, Odense University Hospital, Department of Clinical Research, Faculty of Health Science, University of Southern Denmark, Odense, Denmark. E: lise.lotte.andersen@rsyd.dk

Annunziata Lapolla, MD. DPT Medicine, Universita Degli Studi di Padova, Padua, Italy. E: annunziata.lapolla@unipd.it

Maria G Dalfrà, MD. DPT Medicine, Universita Degli Studi di Padova, Padua, Italy. E: u053734@sanita.padova.it

Alessandra Bertolotto, PhD. Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy. E: alessandrabortolotto1959@yahoo.it

Ewa Wender-Ozegowska, PhD. Medical Faculty I, Poznan University of Medical Sciences, Poznan, Poland. E: ewaoz@post.pl

Agnieszka Zawiejska, PhD Medical Faculty I, Poznan University of Medical Sciences, Poznan, Poland. E: agazaw@post.home.pl

David Hill, DPhil. Recherche en Santé Lawson SA, St. Gallen, Switzerland. E: davidhill473@gmail.com

Frank J Snoek, PhD. Department of Medical Psychology, EMGO+-Institute for Health and Care Research, VU University Medical Centre and Medical Psychology AMC, Amsterdam, the Netherlands. E: fj.snoek@vumc.nl

Mireille N.M. van Poppel, PhD. Department of Public and Occupational Health, EMGO+-Institute for Health and Care Research, VU University
Medical Centre, Amsterdam, the Netherlands. E: mnm.vanpoppel@vumc.nl

Alexandra Kautzky-Willer, MD.\textsuperscript{2} Gender Medicine Unit, Division of Endocrinology and Metabolism, Department of Medicine III, Medical University of Vienna, Vienna, Austria. E: alexandra.kautzky-willer@meduniwien.ac.at

Fidelma Dunne, PhD.\textsuperscript{1} National University of Ireland, Galway, Ireland. E: fidelma.dunne@nuigalway.ie
Evaluating Artificial Intelligence and Telemedicine-based Care Models in Dermatology

Rose Liu
1
1School of Medicine, Nursing and Health Sciences, Monash University, Clayton VIC, Australia
Corresponding Author: roseliu378@gmail.com

Introduction
Artificial Intelligence (AI) and telemedicine have the potential to play a significant role in dermatology given the visual nature of most dermatological conditions. This is particularly in rural or remote areas where access to specialists is limited. Clinical images or histopathological images of sufficient quality may be utilised in various platforms to obtain a diagnosis either via consultation with a dermatologist, dermatopathologist, or artificial intelligence algorithms.

This perspective piece seeks to examine the implications and potential impact of AI and telemedicine, and to evaluate where these have been implemented around the world as shown in case studies.

Mobile Applications
The proliferation of mobile applications (apps) for dermatology has faced minimal regulation with over 225 new dermatology mobile applications created since 2012 [1]. As mobile smartphone functions become more integrated to include voice, text, audio recording, images, and geographic information services (GIS) tracking [2], they have the capacity to screen and improve management of cancers and chronic diseases by facilitating specialist assessments and consultations, and providing patients with greater access to information related to their condition [3].

Artificial Intelligence in Dermatology
Artificial Intelligence (AI) refers to the capacity for computers to perform tasks attributed to human intelligence. AI has garnered interest amongst researchers due its potential to assist doctors and complement clinical decision-making with larger quantities of data and evidence [4]. In 2017, researchers at Stanford University developed an algorithm to diagnose skin malignancy with the same accuracy as board-certified dermatologists. The team trained a convolutional neural network with a large dataset of 129,450 clinical images with 2032 different diseases. The team used the Google Inception v3 CNN architecture, which was trained using 1.28 million
specialist-graded images. When the performance of this CNN was tested against 21 board certified dermatologists the CNN was found to classify the cancer at a similar level to the trained dermatologists [5].

Australia has the highest incidence of non-melanoma skin cancer (basal cell carcinoma and squamous cell carcinoma) in the world [6]. Australia also has one of the highest rates of melanoma and melanoma mortality in the world [7]. In 2016 approximately 2000 Australians died from melanoma and other malignant neoplasms of skin [8]. This is largely due to the country’s high proximity to the equator and high levels of ultraviolet (UV) light exposure. An AI screening tool for skin cancer has the potential to improve patient care outcomes by being able to provide fast and accurate diagnosis for patients who would otherwise be unable to access specialist care due to long wait times or geographical location.

Telmedicine in Dermatology

Telmedicine is the remote provision of healthcare using telecommunications and information technology to improve access to care in regions with specialist shortages, and encourage continuity of care by allowing the primary care physician to drive patient care.

Broadly there are 2 service models implemented for teledermatology: Live Interactive (LI) and Store and Forward (SAF). The LI model provides two-way interaction between the patient, primary care physician (PCP) and dermatologist simultaneously. This model allows the dermatologist to directly converse with the PCP and patient to provide live diagnosis and input for complex cases. This model is limited by expense as all parties must have access to video conference equipment, and an additional logistical barrier of time scheduling for all parties involved.

The SAF model requires the PCP to obtain images of the lesion, relevant patient data and history to send to the consulting dermatologist. This is a more common service model than LI model as barriers to setup are lower and less expensive. The dermatologist can review the case at his convenience, and high bandwidth is not required. The SAF model lacks capacity for the specialist to ask the patient and doctor questions for clarification, or to revise images captured that are unsuitable or of poor quality. The low cost and simplicity of the store and forward model, with nurses and technicians being able to assist doctors with image acquisition, also makes it highly suitable for implementation in dermatology. SAF models also mitigate medico-legal risk as written notes and images can be easily referenced and recorded [9].

Cost effectiveness of the store and forward model

An analysis of the costs of implementing the various forms of teledermatology also support SAF service model the most scalable and hence preferred form for large scale implementation. The capital costs for SAF model generally include a digital camera for photography and dermatoscope. It is foreseeable that improvements in smartphone camera resolution will reduce the capital costs and barriers associated with SAF teledermatology.

A systematic review on the cost effectiveness of SAF teledermatology found the model to be cost-effective when used to triage patients, particularly in instances where patients were required to travel significantly long distances to see a specialist dermatologist [10]. Furthermore a prospective analysis of teledermatology consultations in The Netherlands found that SAF resulted an 18% reduction in healthcare expenditure and prevented 74% of in-person referrals [11].

An Australian case study: Tele-Derm

In Australia dermatology practices are more concentrated in metropolitan areas which presents challenges for rural and remote patients seeking specialist care, which is of significant concern considering approximately 30% of Australian live in rural and remote areas [12].

Tele-Derm is a free online consultation service that aims to assist clinicians in geographically and professionally isolated locations in the management of dermatological presentations. Tele-Derm was established in 2004 by the Australian College of Rural and Remote Medicine (ACRRM) in collaboration with the Queensland Divisions of General Practice. This service employs the SAF model where the PCP uploads a patient’s clinical notes with a photographed image of the lesion, and a dermatologist provides the patient with advice typically within 24 hours. In order for Tele-Derm to be effective it is essential that primary care physicians provide an image of sufficient quality. In a 12 month period, 73% of the 406 cases submitted to Telederm included clinical photos of sufficient quality for dermatologists to provide advice [13]. There has been Australia-wide utilisation of Tele-Derm
National, with even some Australian doctors working overseas in the Pacific Islands, New Zealand and South East Asia utilising the service. Tele-Derm is an example of how telemedicine can reduce the impact of geography on patient access to specialist advice.

**Australian Barriers to Teledermatology Implementation**

In rural and remote Australia the primary barriers to telemedicine implementation include funding, lack of time or incentives for PCP to set up teleconsultations, and lack of required infrastructure, equipment or training [14]. A study of clinicians’ attitudes towards the Tele-Derm project found that 15% of doctors cited lack of remuneration as a negative aspect of using the service [15]. Additional consultation time spent taking and uploading the photograph and relevant data is not billable in the present MBS. The same survey found 38% of doctors felt Tele-Derm increased their workload and 45% felt it was too time consuming in comparison to regular in person consultations. Whilst teledermatology services such as Tele-Derm may provide significant savings for patients in terms of cost savings in travel time and productivity loss, it is clear that sufficient incentives for specialists and PCPs are required for successful implementation.

**Conclusions**

Artificial Intelligence and telemedicine have the potential to improve access to specialist advice and reduce healthcare costs, particularly when used in tandem and applied to the contexts of rural and remote areas with reduced access to dermatologists and dermatopathologists. Greater awareness, incentives and the barriers to adoption for primary care physicians and specialists should be explored in order to implement these technologies, together with the careful validation and software regulation to ensure the ongoing provision of accurate and high standard of care.

**REFERENCES**


AN AFFORDABLE SMART PHONE COMMUNICATION SYSTEM FROM HIGHWAY TO HELIPAD: A CASE SERIES

Jordan Koll1, Douglas Martin MD FRCP(C)2,3, Gregory Hansen MD FRCP(C) MPH MSc4

1Public Health Agency of Canada, Winnipeg, Manitoba, Canada; 2Department of Emergency Medicine, University of Manitoba, Health Sciences Centre, Winnipeg, Manitoba, Canada; 3Shock Trauma Air Rescue Society (STARS), Winnipeg, Manitoba, Canada; 4Division of Pediatric Critical Care, University of Saskatchewan, Royal University Hospital, Saskatoon, Saskatchewan, Canada.

Corresponding Author: gregory.hansen@usask.ca

Introduction: Improving communication between all providers involved with rural trauma and urgent care patients may be beneficial. In our proof of concept study, we examine the potential of an open architecture and flexible smart phone system, utilizing an affordable, off-the-shelf and secure application called Wickr.

Methods: Two patient scenarios were constructed to test the capabilities of the Wickr application for data transfer. Roles were distributed between three players: one represented the transport medical doctor, another played the air medical crew, and the final assumed all the other roles. As the two scenarios unfolded simultaneously, phone conversations, text messages, pictures, and imaging files were conducted between the players by smart phones via downloaded Wickr applications. Upon completion, players answered nine questions on a 5-point Likert scale that focused on the quality of the videos, texts and pictures shared, as well as indicators that we deemed essential to transport communication systems from our experience.

Results: Scores on video, picture and sound quality ranged from good to excellent. Scores on user friendliness, task suitability, speed, information discretion and customizable data retention ranges from somewhat agree to agree.

Conclusion: Wickr was quick, user friendly, and well suited for the clinical communication during simultaneous patient scenarios. Whether it is a capable system for a busy helicopter emergency medical service has not been evaluated.

Key Words: emergency medical services, mhealth, rural health, telemedicine, emergency care, Prehospital

Introduction
Over 46 million American and 7 million Canadian residents do not have access within 1-hour following injury to level I or level II trauma centers.1,2 Many others have medical conditions that require emergent and time-sensitive access to specialized treatment or diagnostics (i.e. acute ischemic stroke or myocardial infarction) available only at distant tertiary centers. Typically these patients are initially managed in rural, remote or isolated health centers, which may not have appropriate medical expertise or trauma resources. As poorer outcomes have been observed...
with rural trauma\(^3\), acute myocardial infarction\(^5-7\), and prolonged time to definitive stroke treatment,\(^8\) improvements to pre trauma/tertiary hospital care should be considered.

Rural trauma and urgent care systems coordinate the initial emergency medical services (EMS) response, organize rapid transfers to smaller health centers, and quickly refer to trauma or tertiary centers when appropriate.\(^2\) Specialized retrieval teams within these systems have evolved over the past few decades,\(^9\) with the goal to improve care and expedite both scene and interfacility transports to the trauma or tertiary center. Evidence from recent military conflicts suggested that specialized trauma retrieval teams are effective and achieve improved survival outcomes.\(^10,11\) Data from the civilian context suggests similar benefits.\(^12\) While the optimal composition of the transport crew has not been established, improved outcomes may be further related to enhanced critical care training and experience.\(^13\)

Rural trauma and urgent care systems have also utilized telecommunication technologies to improve patient care.\(^14\) In closed centralized models, medical control originates from a hub and is delivered to spoke rural centers or transport assets.\(^15,16\) This approach has facilitated management recommendations and improved interfacility care\(^17\) and clinical quality.\(^19\) However, significant limitations exist, including considerable expenses, vendor dependency, inability to involve non-spoke care providers, and inability for conference communication.\(^15,20\)

A telecommunication model for which trauma and urgent care expertise is available for all rural, EMS and transport crew providers may be beneficial. In our proof of concept study, we examine the potential of an open architecture and flexible smart phone system, utilizing an off-the-shelf application, with an emergency physician acting as the medical lead.

**Methods**

**Wickr**

Wickr Professional (Wickr Inc., San Francisco, USA) is an app (Figure 1) that enables participants using iOS and Android-based smart devices, MS Windows, and Mac OS computers to exchange end-to-end encrypted and content-expiring messages, photos, videos, and enable encrypted voice and video conferences (Figure 2). Wickr is an Internet-accessible electronic platform for exchanging personal health information that satisfies data sharing requirements in accordance with the Health Insurance Portability and Accountability Act (HIPAA) (Figure 3).\(^21\) It protects users of its network by storing a minimal quantity of identifiers in an encrypted, unrecoverable format, and data by utilizing advanced encryption algorithms and Perfect Forward Security to protect against compromises of message keys. For additional security - or if an organization requires it - Wickr can be hosted as an ‘on premise’ solution, installed and configured by an organization’s IT team.

Wickr was selected as it has several advantages over telehealth and mobile communication systems tested or utilized by EMS organizations.\(^22-26\) These systems can have significant security issues that may not be accepted by current privacy regulatory standards.

![Figure 1: Wickr secure login.](image)
For this reason, by selecting Wickr our approach was to prioritize data security and privacy up front, with the understanding it is difficult to architect data security into solutions after the fact. Furthermore, their focus has been on software development and not processes, for the evolving pre-hospital patient. In contrast, our strategy has been to emphasize an open, interoperable communication platform to engage our team, and iterate our processes quickly versus waiting for software development resources to be available.

One of the authors (JK) had previously used Wickr Messenger, and a request for information led to an invite to participate in a private beta test of the enhanced professional version. For this proof of concept, we utilized Wickr’s Internet-accessible infrastructure and an early preview (alpha release) of Wickr Professional, as a smart phone communication system for sharing evolving patient information during two trauma transport scenarios.

**Rural Trauma and Urgent Care System**

Rural trauma within a 275 km concentric of Winnipeg, Canada are initially triaged through a provincial call center. The centre rapidly and simultaneously notifies both rural ground EMS and the specialized trauma helicopter EMS (HEMS) crew if the reported patient acuity is high. Depending on scene location, actual patient acuity and clinical trajectory, HEMS may be stood down, land at the scene, or retrieve the patient at a rural health center. The HEMS air medical crew (AMC) consists of a
specialized registered nurse and an advanced care paramedic. A transport MD (medical doctor) provides online (real time) medical control from a central location if the team is utilized.

**Trauma and Urgent Care Scenarios**

Two scenarios (Figure 4) were created that included a 45-year old male with severe traumatic brain injury secondarily to a high speed motor vehicular collision, and a 55-year old male with acute onset of severe chest pain. Scenarios were constructed to model “real world” situations, which might test the capabilities of the Wickr application for data transfer using several different modalities and file sizes. Scenarios are not intended to be representative of ideal medical care.

Roles were distributed between the three authors: one represented the transport MD (DM), another played the AMC (GH), and the final (JK) assumed all the other roles. Communication between the players was conducted by Apple iPhones and downloaded Wickr applications in an area with...
3G/LTE coverage. Dialogue consisted of conversations, text messages, pictures, and imaging files. The two scenarios unfolded simultaneously via separate initiating calls from the mock provincial call centre, followed by sequential actions coordinated by the transport MD. The electrocardiogram, chest roentgenogram, and head computed tomography images were found in the public domain (Creative Commons CCO 1.0 Universal Public Domain Dedication, Wikimedia Commons). The shared focused assessment with sonography in trauma was an author’s (DM) personal scan for this project, and the monitor image came from our simulation lab.

**Metrics**

All three authors answered nine questions on a 5-point Likert scale (1 “disagree” to “unacceptable” to 5 “agree” or “excellent”) upon completion of the scenarios. The questions focused on the quality of the videos, texts and pictures shared, as well as indicators that we deemed essential to transport communication systems from our experience. This included whether the system, 1) was intelligible to the new user (“User Friendliness”); 2) was well matched to the situational requirements of clinical communication (“Task Suitability”); 3) allowed the required communication to occur without fault or interruption (“Reliability”); 4) allowed for timely communication (“Speed”); 5) allowed the user to discriminate which information is shared with other parties; (“Information Discretion”) and, 6) could preferentially archive, erase or export all aspects of the communication (“Customizable Data Retention”). Due to the small sample size, raw data was documented only.

**Results**

Likert scores between the three authors varied by one or less for all indicators (Table 1). Video, picture and sound quality ranged from good to excellent (Likert 4 and 5). The Wickr system also received Likert 4 and 5 scores (somewhat agree to agree) on user friendliness, task suitability, speed, information discretion and customizable data retention. Reliability received the lowest scores (2,3,3).

**Discussion**

The purpose of this proof of concept study was to examine the potential of an off-the-shelf smart phone app as a medical telecommunication system for a HEMS program. By activating two simultaneous and scripted trauma team scenarios, we found that Wickr was quick, user friendly, provided appropriate discretion and control over health information, and was well suited for the clinical communication and archiving requirements of a trauma transport program. Its advantages over centralized hub and spoke models may include cost, customizability, ability to add consultants to a call, and mobility of the transport MD. Its major disadvantage includes potentially suboptimal telecommunication coverage maps.

The Wickr system was intelligible to the authors who were all novices with the app. A very brief orientation to the system was provided at the onset of the scenarios, but its interface resembled a default iPhone or Android messaging app and consequently became quickly familiar. Capturing images and videos, making voice and video calls, and attaching media to messages were analogous to how smart devices are used for personal communication.

The Wickr system was well suited for the clinical communication requirements of a HEMS program. First, the transport MD had complete control over who received information, and for how long secure messaging could be accessed prior to deletion. This is an important asset to quality reviews, as the system can archive aspects of a patient transport that may otherwise be undocumentable. Just as importantly, the information technology (IT) team or administrator can control how long (by policy) recipients have access to any message by specifying a time to “live”. For example, if a snapshot of a patient’s roentgenogram was shared, the transport MD’s Wickr app can destroy the keys required for decryption, allowing for deletion from the device, and ensuring the image cannot be recovered. Second, the transport MD was not constrained to a

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Raw Likert Scores</th>
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<tbody>
<tr>
<td>Video Quality(^a)</td>
<td>4,4,4</td>
</tr>
<tr>
<td>Picture Quality(^a)</td>
<td>5,5,5</td>
</tr>
<tr>
<td>Sound Quality(^a)</td>
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<tr>
<td>User Friendliness(^b)</td>
<td>4,4,5</td>
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<td>Task Suitability(^b)</td>
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<td>Reliability(^b)</td>
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<td>Speed(^b)</td>
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<tr>
<td>Information Discretion(^b)</td>
<td>4,4,5</td>
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<tr>
<td>Customizable Data Retention(^b)</td>
<td>4,5,5</td>
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\(^a\)Likert scores 1 “unacceptable” to 5 “excellent”;\(^b\)Likert Scores 1 “disagree” to 5 “agree”.

Table 1: Wickr Pilot Evaluation
It is important to note that while Wickr’s level of data security safeguards Personal Health Information, untangling the web of policy and legislation that health jurisdictions may require to implement such a system may nonetheless be challenging. Constraints placed on the in-flight operation of Personal Electronic Devices (PEDs) by aviation regulatory bodies may represent a second source of challenge to a smartphone based medical communication system.

The strength of centralized hub and spoke models has been their reliance on a series of fixed, leased telecommunication lines that guarantee with a degree of certainty the quality and availability of connections. Wickr or BYOD solutions however, offer a trade-off of this certainty in return for flexibility and mobility.

Perhaps Wickr’s greatest advantage over centralized vendor solutions is cost. Although the tested Wickr Professional is not publicly available, our understanding is that it will be offered at around $25 US/seat for the software as a service (SaaS) model, with the benefit of decoupling licenses from devices (accessed on multiple devices by the licensed user), and avoiding capital costs of licensing and hardware refreshing. Improvement in technology and features also occur on an annual basis for the same price (i.e. a wireless and data plan). Although BYOD offers similar advantages to Wickr from the standpoint of costs, built in messaging apps should always be considered insecure. This not only pertains to the transmission of data, but also because there is no segregation between personal and confidential patient data on the smart device itself. Regardless, BYODs with a multitude of apps continue to be employed as ad hoc communication platforms, despite the awareness of potential security concerns. It is important to note that while Wickr’s level of data security safeguards Personal Health Information, untangling the web of policy and legislation that health jurisdictions may require to implement such a system may nonetheless be challenging. Constraints placed on the in-flight operation of Personal Electronic Devices (PEDs) by aviation regulatory bodies may represent a second source of challenge to a smartphone based medical communication system.

In our testing we initially experienced some challenges, as one of the author’s device’s intermittently ‘froze’ when connecting to the Wickr network. However, we were unable to determine whether this was a device issue (iPhone 5 versus 6s) or with the pre-production software release. It is understood that encryption adds some overhead to communication, and Wickr is currently addressing this matter. Furthermore, by relying on cellular wireless data networks, Wickr’s reliability and speed of data transmission can be predicted on the coverage map of telecommunication providers operating in a jurisdiction. With the assistance from Wickr, we conducted a basic network test to capture network provider, network and signal strength in a representative rural service area within the HEMS catchment. While connected to a high speed (LTE) network with the weakest (-118 dBa) to the strongest (-90 dBa) being recorded, we were able to consistently send and receive secure communications from Wickr on the other end. LTE network coverage was available from the helipad or parking areas of rural health facilities, although rural highways were a mix of LTE and slower, 3G connections. In areas where LTE was not available, future testing may consider the use of portable cellular signal boosters to improve connectivity.

Practically, Wickr should not be viewed as a substitute for a bedside evaluation. Critical elements of the patient exam (i.e. heart and lung sounds) obviously cannot be appreciated with the app, and must be assimilated into the context of the patient’s clinical trajectory. With hyperacute patient presentations requiring immediate attention, the use of Wickr during these stressful times may not be intuitive or safe. On the surface, utilizing Wickr may appear superior to standard phone discussions, through its ability to provide real time visual information that can be safely and easily shared with multiple health providers. However, communication patterns with several consultants in a private chat room have to yet be clearly defined, and are a fascinating area of research. How to manage competing interests, membership to the chat room (inclusion/exclusion) and leadership of the discussion, are only a few of the potential hot spots that may require deft navigation.

Our study had several limitations. First, to reflect typically HEMS volume, the Wickr system was trialed with two simultaneous trauma team scenarios. However, given its ease of use, it is unlikely that more scenarios or other acute presentations i.e. acute respiratory failure, toxidrome, would have
added further layers of complexity. Second, the sample size of three evaluations was very small, and consequently carried a high bias risk. Nevertheless, we are confident that our proof of concept study was able to demonstrate Wickr’s telecommunication potential for a larger scale assessment.

Conclusions
Effective telecommunication technologies for HEMS programs managing rural trauma are vital for optimal patient management. Our proof of concept study was able to demonstrate that Wickr, an open architecture, flexible and HIPAA compliant smart phone communication system, was quick, user friendly, and well suited for the clinical communication during simultaneous mock trauma scenarios. Whether it is effective on a large scale has yet to be established.

Compliance with Ethical standards
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Authors have not received any funding nor financial incentives for this study.

Conflict of Interest
All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure. pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical Approval
This article does not contain any studies with human participants or animals performed by any of the authors.

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