Telemedicine with Mobile Devices and Merged Reality for Early Postoperative Care

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Introduction

"Telemedicine" is a paradigm that digitally brings patients and providers together, allowing real time interaction across geographic distances [1]. Telemedicine is being increasingly used to enhance healthcare access to underserved and rural areas, while extending specialty care to these regions. However, telemedicine systems are diverse in its formats and capabilities. The usefulness of each system depends on the patient care circumstance being serviced. Circumstances that favor communication, such as history-taking or counseling, would require only two-way audiovisual interaction – whereas, physical examination and image review may require more advanced digital interaction techniques [3].

We have previously introduced a system, termed "virtual interactive presence" or (VIP), with augmented reality (AR). In this system, visual fields from both participants, are digitally merged into a common field, so that both participants see the same local image stream (e.g., the patient), while the remote participant (e.g., the provider) can virtually interact to provide complex visual instruction. The system has been previously used for an expert surgeon to virtually mentor a training surgeon [4] (telementoring), collaborate in complex microsurgical dissection (telecollaboration) [5] and orthopedic procedures [6].

After discharge from the hospital, the post-operative period is a critical time, when patients are vulnerable to surgical complications, but are outside the direct vision of the health care team. Moreover, postoperative care typically requires more physical interaction, such as wound dressing manipulations, and palpation, and other maneuvers. In a typical telemedicine system with only audiovisual interaction, the provider is limited to verbal communication and gesturing. However, VIP offers a paradigm in which the physician can virtually examine the patient, "as if he/she were there." In this paper, we describe a mobile VIP system, with AR features, that enable such interaction, and a clinical trial that explores its utility.

Methods

A. Core VIP Technology

VIP technology is a commercially available system, as a free mobile device. The basis of the paradigm is described in [4] and [5] (Fig. 1). In brief, bidirectional video feed is captured, using standard and commercially available cameras (e.g. mobile device camera) at the site of the provider (remote location) and the patient (field location). Video streams are stored into local data structures at each site. The foreground of the remote feed is segmented from the background layer, and then superimposed onto the field feed. Both participants see the same hybridized feed, allowing provider to interact virtually with the patient (Fig. 1).

B. Mobile Implementation

The application, is encoded in iOS (Apple, Cupertino, CA) for use on mobile devices (iPhone, iPad, iPad Mini). Encryption of health protected information was performed with use of the WebRTC framework (Google Inc., Mountainview, Ca), that includes the Advanced Encryption Standard (AES) 128-bit encryption. All encryption methodologies were approved by the University of Alabama at Birmingham Privacy and Security Offices for use in the study. Information exchange was delivered across a 3G/4G mobile network, or an available Wi-Fi network. The mobile application interface (Fig. 2) allows each user to configure the experience by selecting a mode of communication (e.g. "Receive Help", "Give Help", or "Face to Face").

References

1. L.S. Wilson and A.J. Meader, "Recent Direction in Telemedicine: Review of Trends in Research and Practice" *Healthc Inofrm Res.*, vol 21, no. 4 pp 213-222, Oct. 2015
2.M.N. Boulos, S. Wheeler, C. Tavares, "How smartphones are changing the face of mobile and participatory healthcare: an overview, with example from eCAALYX" *Biomed Eng Online,* pp. 10-24, 2011
3. M.J. Ackerman, R. Filart, L.P. Burgess, I Lee, R.K. Poropatich, "Developing next-generation telehealth tools and technologies" patient, systems, and data perspectives." *Telemed J E Health*, vol. 16, no. 1, pp. 93-95, Jan-Feb 2010
4. M.B. Shenai, M. Dillavou, C. Shum, D. Ross, R.S. Tubbs, A. Shih, B.L. Guthrie, "Virtual interactive presence and augmented reality (VIPAR) for remote surgical assistance." *Neurosurgery,* vol. 68 (1 Suppl Operative), pp. 200-207, March 2011
5. M.B. Shenai, R.S.Tubbs, B.L. Guthrie, A.A. Cohen-Gadol, "Virtual interactive presence for real-time, long-distance surgical collaboration during complex microsurgical procedures." *J Neurosurg.,* vol. 121, no.2, pp.277-284
6. B.A. Ponce, JK. Jennings, T.B. Clay, M.B. May, C. Huising, E.D. Sheppard, "Telementoring: use of augmented reality in orthopaedic education: AAOS exhibit selection.", *J Bone Joint Surg Am.,* vol. 96, no. 10, May 2014
7. V. Sathiayakumar, J.C. Apfeld, W.T. Obremskey, R.V. Thakore, M.K. Sethi, "Prospective randomized controlled trial using telemedicine for follow-ups in an orthopedic trauma population: a pilot study." *J Orthop. Trauma,* vol. 29, no. 3 pp. 139-145, March 2015
8.S.R. Aziz, V.B. Ziccardi, "Telemedicine using smartphones for oral and maxillofacial surgery consultation, communication, and treatment planning." *J. Oral Maxillofac Surg.,* vol. 67, no. 11, pp. 2505-2509
9. R.Wootton, S.E. Bloomer, R. Corbett, "Multicenter randomized control trial comparing real time teledermatology with conventional outpatient dermatological care: societal cost-benefit, analysis." *BMJ,* vol. 320, no. 7244, pp. 1252-1256, May 2000

Results

Figure 1.

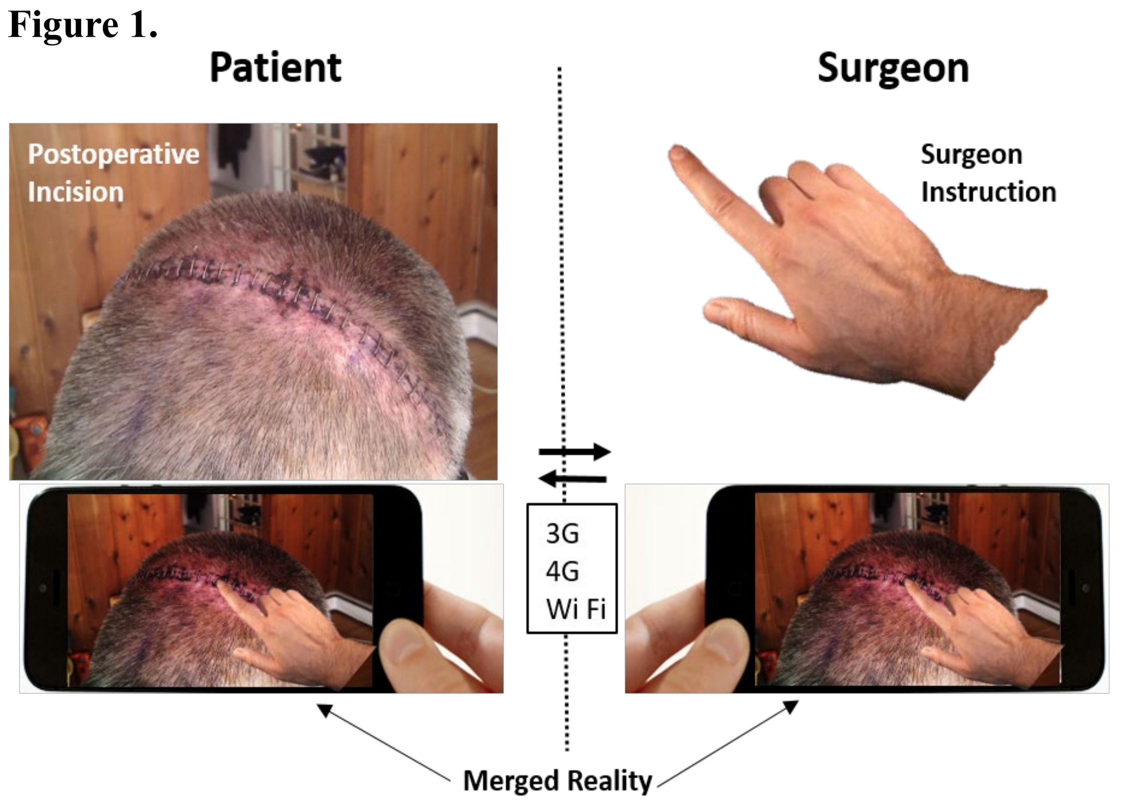

Figure 2.

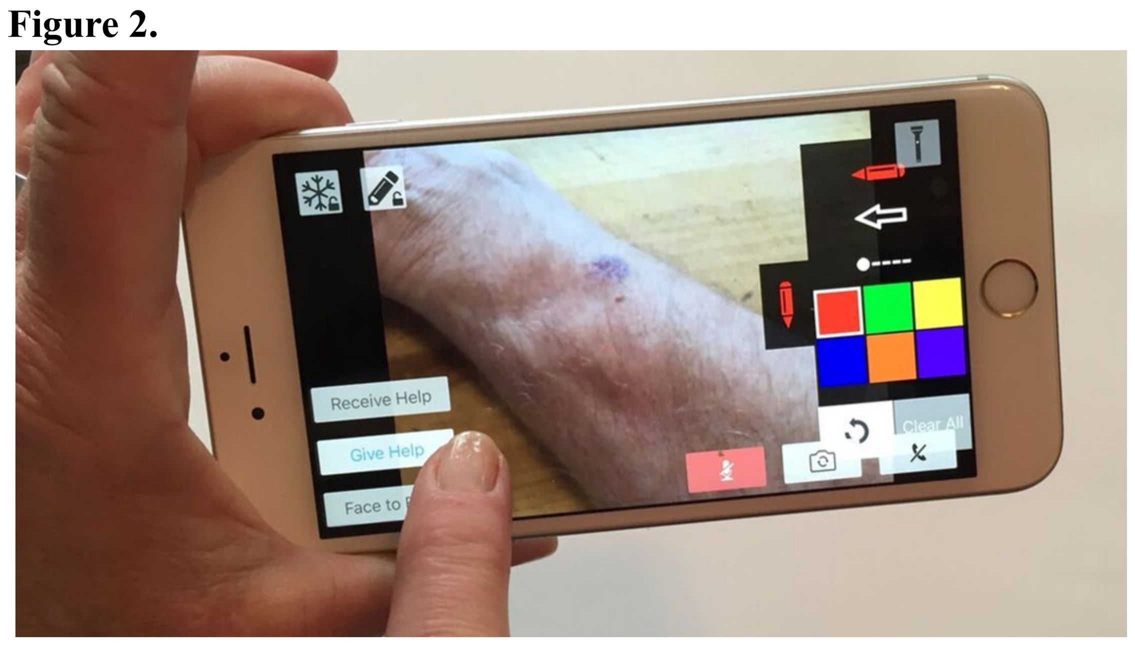

Figure 3.

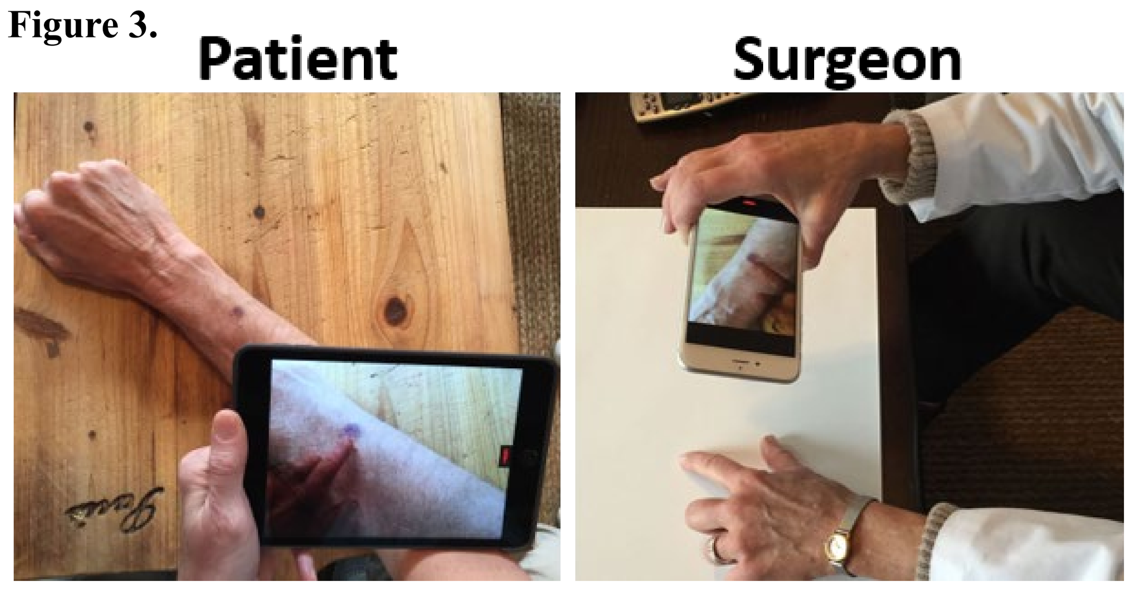

Table 1. Patient vs. Surgeon Survey Responses

	Survey Question	*Patient Score*	*Surgeon Score*
1	… provided reassurance	4.8±0.5	4.6±0.5
2	… useful for wound instruction	4.7±0.5	4.5±0.5
3	… useful for instruction on durable medical equipment	4.8±0.5	4.7±0.5
4	… superior to phone call	4.8±0.5	4.5±0.6
5	…superior to text/e-mail ($P<0.05$)	4.7±0.5	4.4±0.8
6	… rate overall experience ($P<0.05$)	4.6±0.5	4.2±0.5

A. Patient Experience

- 96% of patients agreed experience was "useful"
- 100% of patients receiving wound instruction rated experience as "useful"
- 90% of patients were "overall satisfied" with experience, with 93% and 97% rating it superior to phone or text messaging, respectively.

B. Surgeon Experience

- 89.6% of surgeons agreed that experience was useful for wound inspection
- 100% of surgeons were satisfied with experience on wound care instruction
- 86.6 % of surgeons voiced "overall satisfaction", with 93% and 86.6% rating it superior to phone or text messaging, respectively.

C. Patient-Surgeon Comparisons

- Both patients and surgeons agreed that interaction was reassuring, but patients were more likely to strongly agree.
- Patients and surgeons felt similarly that dressing changes and equipment management interactions were useful, but patients were more likely to strongly agree.
- Patients were more likely than surgeons to find virtual interaction more useful than text or email ($P<0.05$)
- Patients were generally more satisfied with the interaction overall ($P<0.05$)

Methods (cont.)

C. Prospective Clinical Trial

Patients scheduled to undergo neurosurgical or orthopedic procedures with one of three suregons (BAP, EWR, BLG) were screened pre-operatively. Inclusion criteria were: 1) at least 18 years of age, 2) scheduled for an elective surgical procedure requiring post-operative wound evaluation, 3) capable of carrying out the protocol, 4) access to an iOS mobile device capable of video transmission via a 3G/4G or Wi-Fi network. Exclusion criteria were 1) inability to give informed consent, 2) anticipation of a complex postoperative course, 3) no access to an iOS device with mobile capability, or 4) postoperative scheduling conflicts. The clinical protocol was approved by the University of Alabama at Birmingham Institutional Review Board.

All enrolled patients were assisted with the download of the mobile application, or given a hard copy of the installation process. A virtual session was scheduled within several days of patient discharge, prior to the patient's first in-person follow-up with the primary surgeon or a local provider. The session typically included verbal interaction regarding subjective clinical course, a virtual visual inspection of the wound, and virtual interaction with the surgeon if required. During the session, the patient or designate (e.g. spouse) could follow the surgeon's hands or instruments to accomplish the task).

After the session, patients and surgeons were required to complete questionnaires regarding their respective experiences. Each questionnaire consisted of 15 questions with Likert scale responses of 1 (strongly disagree) to 5 (strongly agree), and the option to provide free text comments. "Overall agreement" was calculated as the total number of "4" or "5" ratings. Questionnaires were administered in-person if direct follow-up was available, or by email or phone. Questions clustered around areas of "usefulness", "usability", and "overall experience" Six questions of the patient and surgeon questionnaires were similar, and allowed study of concordance. Descriptive statistics were performed, and a paired student's t-test was used to compute significance. All patient study information was stored on a secure database (REDCapTM, Version 6.9.3, Vanderbilt University).

Discussion/Conclusions

The results of this clinical trial indicate that the VIP application is useful in clinical assessment, therapeutic instructions, and subjective reassurance. From the patient's perspective, a post-operative evaluation is a relatively rare event, with few points for comparison. Therefore, the use of a new technology is likely to enhance patients' experiences. For surgeons, the post-operative visit is routine. Therefore, an acceptable substitute will be seen more positively by patients.

There were two instances in which the protocol led to undesirable experiences. In the first case, a patient that had incisional bleeding unsuccessfully attempted to contact the surgeon via the application, delaying the decision to go the emergency department by 6 hours. In the second case, a patient had a seizure, and the family also attempted to use the application for help unsuccessfully. Both patients were ultimately managed without complication or long-term effect. These instances of "overreliance" highlight the need for expectation management with this paradigm.

The use of telemedicine and augmented reality adds significant value to remote post-operative interaction, with both patients and surgeons endorsing overall satisfaction. Patients, however, had a stronger positive reaction, highlighting the value of mobile telemedicine to the patient experience, and overall satisfaction. Implementation, patient education, and expectation management are key areas of future focus for advanced telemedicine paradigms.