OPEN

PRS GLOBAL OPEN

IDEAS AND INNOVATIONS

Special Topic

Enabling Remote Monitoring Using Free Apps and Smart Devices for a Free-Flap Adjunct Monitor

James C. Yuen, MD

Summary: Remote monitoring capability does not currently exist for Periflux (Perimed AB, Järfälla, Sweden) laser Doppler and other perfusion monitors. Two simple adaptations using free apps (applications) and smart devices can enable transmission of the perfusion readout to the surgeon's smartphone. A literature review was conducted to identify reports relating to remote free flap monitoring. In addition, 2 wireless methodologies are devised: One method uses a free app that converts a smart device into a camera, stationed next to the perfusion monitor, to stream live video of the laser Doppler readout to the surgeon's smartphone; a second method uses a free app installed on a bedside laptop computer, which is connected to the laser Doppler flowmeter via a data cord. A live feed of the computer's desktop as a teleconference host is transmitted to the surgeon's smart device over the Internet. These 2 methodologies were employed on 9 and 8 free flaps, respectively, as a pilot study. All free flaps were monitored remotely for 4–6 days with near 100% reliability. The Internet connectivity became disrupted only on several occasions, requiring simple Wi-Fi and software reset. Minor mechanical issues were encountered with the video streaming method. Literature review identified very few articles describing remote monitoring of free flaps. The 2 methodologies reported here provided reliable continuous transmission of quantitative data of flap perfusion to smart devices via Internet connection, which can revolutionize the microsurgeon's practice if his/her adjunctive perfusion monitor with display does not yet have Wi-Fi capability. *(Plast Reconstr Surg Glob Open 2017;5:e1507; doi: 10.1097/GOX.0000000000001507; Published online 21 September 2017.)*

Although the use of telemedicine has become widespread, little has been published describing real-time remote monitoring of free-flap perfusion. This article presents the currently available techniques in remote free-flap monitoring and describes 2 new modalities using adaptation of free applications (apps) on smart devices (SD). One modality uses the AtHome app (iChano, inc, Richmond, BC, Canada), which converts an SD into a wireless video camera, while its viewer app on a remote SD receives the continuous streaming via Wi-Fi or mobile broadband (3G, 4G, LTE network). The second modality uses the join.me app (LogMeIn, Boston, Mass.), which allows the computer desktop to be shared as a teleconference host, while the app on another SD allows the surgeon to join the meeting and view remotely any data displayed in real-time on the bedside computer. These Internet-based SD apps are employed in conjunction with the laser Doppler flowmeter (LDF) for routine adjunctive monitoring of free flaps.

From the Division of Surgical Oncology, Banner MD Anderson Cancer Center, Gilbert, Ariz.
Received for publication July 25, 2017; accepted July 31, 2017.
Selected for presentation at Plastic Surgery The Meeting 2017—American Society of Plastic Surgeons Annual Meeting, October 6–10, 2017, Orlando, Fla.

DOI: 10.1097/GOX.0000000000001507

METHODS AND MATERIALS

Method 1 (Video Streaming)

In setting up the SDs with the free AtHome app, the user downloads the free app in either the Android

Disclosure: *The author has no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the author.*

Supplemental digital content is available for this article. Clickable URL citations appear in the text.

Fig. 1. The smart device (mini-iPad) with Wi-Fi capability is positioned next to the laser Doppler flowmeter with its camera capturing the digital readout. An underpad "cradles" the 2 devices to prevent dislodgement of the camera angle.

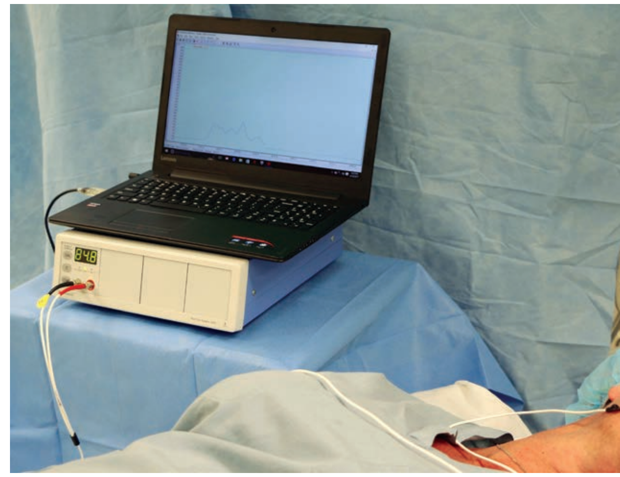

Fig. 2. A laptop computer is connected to the laser Doppler flowmeter using a data cord and software provided by the laser Doppler company. The laptop's desktop is configured using the free join.me app to become a teleconference host for screen sharing.

(Google, Mountain View, Calif.) or iOS (Apple, Inc., Cupertion, Calif.) platform. The app is designed to convert an SD into a security camera. In this report, the mini-iPad was converted into a continuous video camera, connected to the Internet via hospital Wi-Fi and positioned next to the LDF (Fig. 1). Transmission of real-time video of the laser Doppler reading must never include any patient identifier; therefore, the camera must capture the LDF's display in close-up, away from any patient identifiable part with sound capability deactivated. The Periflux 5000 (Perimed AB, Järfälla, Sweden) LDF, as a routine practice, was employed for free-flap monitoring with its surface probe sutured to the skin of each flap. The entire set-up (table and devices) is positioned to avoid any chance for transmission of patient identifiers.

Method 2 (Teleconferencing)

This method uses the free join.me app, which allows the computer desktop to serve as a teleconference host. This adaptation requires a Perimed data cord connecting the LDF to the computer. By bedside, a Wi-Fi-enabled dedicated laptop computer is required for transmitting data over the Internet (Fig. 2). The Perimed Data Acquisition and Analysis Software is used to display the LDF recording onto the computer's screen. The join.me app is then launched, generating a security code. On the SD, such as an iPhone (Apple, inc., Cupertion, Calif.), the join.me app is launched with code entered. The LDF recording is then transmitted to the smartphone's display in real-time.

To confirm that no publication exists to date in the English literature describing these 2 free-flap remote monitoring methodologies, a MEDLINE search was conducted using PubMed (Bethesda, Md.) and OVID (New York, N.Y.) databases, including EBM Reviews and using the following Mesh terms: [(free or microvascular) AND flap] AND [(remote and monitoring) OR telemedicine)].

With Institutional Review Board (IRB) approval, a retrospective review of free-flap remote monitoring was conducted on 9 and 7 consecutive cases using the AtHome and join.me apps, respectively. Accuracy in clinical performance of LDF has previously been reported.[1]

RESULTS

There were 13 total articles identified in the English literature to be related to telemedicine in plastic surgery or monitoring free flaps with remote methodologies and/or smartphone technologies. Only 9 articles are related to remote free-flap monitoring in the Internet era.[2–10] Table 1 summarizes the methodologies and/or technologies that can be employed for remote monitoring of free flaps.

Method 1

Using the AtHome app on the mini iPad (Apple, inc., Cupertion, Calif.) and iPhone 6S, live streaming of LDF digital readout was completed on 9 patients for 5–6 days. Only on 3 occasions did the AtHome app spontaneously quit or became disconnected from Wi-Fi, which required simple reset. Otherwise, the app and Internet connectivity were reliable for the duration. Positional issues with the camera angle were prevented by cradling the iPad and LDF with an underpad and tape (Fig. 1).

Method 2

The second methodology uses a data cord to transmit the LDF recording onto the computer monitor. The Perimed data transfer software was 100% reliable for all 7 patients during the entire monitoring period. The Internet connectivity was interrupted on 4 occasions, requiring Wi-Fi and software reset.

No microvascular complication was encountered during either methodology.

DISCUSSION

Remote methodologies of free-flap monitoring have not been widely published. As for continuous monitoring using objective parameter, there is 1 report quali-

Table 1. Free-Flap Telemonitoring Methodologies

Reference (Year), Country	Methodology	Continuous (Real-Time) Monitoring Capability	Wi-Fi and Mobile Broadband Enabled	Tissue Type Applicability	Reported Clinical Utilization	Comments
Present article (2017), United States	AtHome app (iChano, Inc., Richmond, Canada) converts a smart device into video camera in sync with laser Doppler flowemeter to provide streaming of the perfusion readout to other smart device(s)	Yes	Yes	All tissue types (skin, muscle, fascia, intestine, periosteum)	9 Flaps (pilot study)	Preliminary report showed reliability of internet/wireless connectivity, monitor-to-smart device interface, and app software.
Present article (2017), United States	Join.me app (LogMeIn, Boston, Mass.) allows a portable computer, registering readout from the laser Doppler flowmeter, to host a teleconference and share its screen with remote smart devices.	Yes	Yes	All tissue types	8 Flaps in 7 patients (pilot study)	Preliminary report showed reliability of internet/wireless connectivity, computer-laser Doppler interface, and software [both join.me app and Perimed (Perimed AB, Järfälla, Sweden)].
Alemi et al.[2] (2017), United States	Use of a telehealth movable tower, TelePresence (Cisco Systems, San Jose, Calif.), free flaps were monitored. remotely on a computer or smart device.	Yes	Yes	All types viewable by camera using toggle	29 Flaps	First study to show efficiency (reduced time spent) and clinical applicability of remote telehealth free-flap monitoring.
Ricci et al.[3] (2016), United States	Program feature added to TOx Tissue Oximeter (ViOptix, Inc. Fremont, Calif.) to send text message alerts instantly of any change in oximetry levels.	Yes	Yes	Skin only	286 Flaps for breast reconstruction	First report enhancing monitoring capability with text support.
Goodson et al.[4] (2014), United Kingdom	Using hospital Wi-Fi and remote desktop software, data from adjunct monitor O2C (LEA Medizintechnik, Germany) is transmitted to smart devices via Internet.	Yes	Yes	All tissue types	No patients presented. Thumb was used as a test.	First reported model in configuring an adjunct monitor without built-in Wi-Fi to send quantitative data via Wi-Fi/Internet to smart devices.
Chandawarkar et al.[5] (2015), United States	Using Eulerian Video Magnification algorithm with Android-based smartphone app, skin perfusion of flaps was analyzed in real-time.	Yes	Yes	Skin only	Number of cases not presented in abstract (pilot study)	Proof-of-concept for real-time, noninvasive monitoring of free flaps with a smartphone.
Kiranantawat et al.[6] (2014), Thailand	Using a smartphone app developed by the authors analyzing color changes on images of skin, software can diagnose between venous versus and arterial occlusion	No	Yes	Skin only	1 Flap reported (pilot study)	Steps require observer to take each photograph through a folded white paper box. Concept for telemonitoring is posited by author Yuen.
Hwang and Mun[7] (2012), South Korea	Using mobile messenger app and smartphones—photos, audio files, videos, and chats were reported instantaneously to the entire team.	No	Yes	Any tissue type viewable with camera	62 Flaps	Single center experience eliminating redundant steps of vertical reporting from junior resident to senior resident, fellow, and then attending.
Chen et al.[8] (2012), Taiwan	Telecommunication by nurse to surgeon using digital photos/videos sent over intranet or Internet.	No	Yes	Ileocolon and jejunum (exteriorized loop)	112 Flaps	Authors claimed 1 hour is saved each time they had a take-back because they used telecommunication.
Engel et al.[9] (2011), Taiwan	Use of smartphone to provide immediate communication between nurse or house staff and attending.	No	Yes	Any tissue type viewable with camera	103 Flaps (100 cases)	Remote, real-time monitoring of free flaps via smartphone photography is feasible, reliable, and safe.
Varkey et al.[10] (2008), Taiwan	Serial digital photos were taken at standardized intervals, and video clips of dermal scratch test were sent to surgeon when flap perfusion was in question (via e-mail), which were viewed on computer.	No	No	Any tissue type viewable with camera	67 Flaps	This study was conducted before higher generation mobile broadband (3G or higher) network became available to authors.

Video Graphic 1. See video, Supplemental Digital Content 1, which shows 3 apps (ViOptix, AtHome, and join.me) in action for remote free-flap monitoring. This video is available in the "Related Videos" section of the Full-Text article on PRSGlobalOpen.com or available at ***http://links.lww.com/PRSGO/A540***.

fying the wireless capability of the ViOptix device.[3] Since 2009, the ViOptix device offers built-in Wi-Fi, allowing its continuous oximetry recording to be sent to the provider's SD. Other technologies, such as the Perimed LDF, do not yet have this telemonitoring capability built-in. The concept of free-flap continuous telemonitoring on the surgeon's handheld device using laser Doppler/spectrophotometry and computer desktop Wi-Fi transmission was posited in 2014.[4] The general idea of remote monitoring on SDs, therefore, is not new. However, the concept of configuring SDs and free apps with established adjunct continuous, real-time monitoring is novel, and this descriptive report and pilot study serve as proof-of-concept [**see video, Supplemental Digital Content 1**, which shows 3 apps (ViOptix, AtHome, and join.me) in action for remote free flap monitoring, ***http://links.lww.com/PRSGO/A540***]. Whether remote continuous monitoring during vascular compromise will translate into faster return to the operating room or improved salvage rate will require large prospective and randomized comparative studies.

Since the transmission of information is restricted to the laser Doppler recording (no identifiers), there is no violation of the Health Insurance Portability and Accountability Act (HIPPA). As in day-to-day handling of medical records, the surgeon must remain vigilant in safeguarding protected health information and conform to regulatory guidelines within one's institution.

SUMMARY

Both methods, using the video streamer/viewer app and teleconference app, in conjunction with the LDF, proved to be reliable and practical in continuous remote monitoring of free flaps. The ability to remotely look at the flap's perfusion recording on demand in real-time can be provided by relatively simple and inexpensive adaptations of apps and SDs when using adjunct monitors that do not have built-in Wi-Fi capability.

James C. Yuen, MD
Division of Surgical Oncology
Banner MD Anderson Cancer Center
2940 E Banner Gateway Drive
Suite 450
Gilbert, AZ 85234-2168
E-mail: YuenJamesC@gmail.com

REFERENCES

1. Yuen JC, Feng Z. Monitoring free flaps using the laser Doppler flowmeter: five-year experience. *Plast Reconstr Surg.* 2000;105:55–61.
2. Alemi AS, Seth R, Heaton C, et al. Comparison of video and in-person free flap assessment following head and neck free tissue transfer. *Otolaryngol Head Neck Surg.* 2017;156:1035–1040.
3. Ricci JA, Vargas CR, Lin SJ, et al. A novel free flap monitoring system using tissue oximetry with text message alerts. *J Reconstr Microsurg.* 2016;32:415–420.
4. Goodson AM, Payne KF, Simmons J, et al. Free-flap telemonitoring to the surgeon's handheld device: proof of concept. *Microsurgery.* 2014;34:413–414.
5. Chandawarkar A, Unukovych D, Sartori A, et al. Real-time visualization of blood flow for free flap monitoring using a smartphone application. *Plast Reconstr Surg.* 2015;136:68–69.
6. Kiranantawat K, Sitpahul N, Taeprasartsit P, et al. The first smartphone application for microsurgery monitoring: SilpaRamanitor. *Plast Reconstr Surg.* 2014;134:130–139.
7. Hwang JH, Mun GH. An evolution of communication in postoperative free flap monitoring using a smartphone and mobile messenger application. *Plast Reconst Surg.* 2012;130:125–129.
8. Chen HC, Kuo HC, Chung KP, et al. Quality improvement of microsurgery through telecommunication—the postoperative care after microvascular transfer of intestine. *Microsurgery.* 2012;32:96–102.
9. Engel H, Huang JJ, Tsao CK, et al. Remote real-time monitoring of free flaps via smartphone photography and 3G wireless Internet: a prospective study evidencing diagnostic accuracy. *Microsurgery.* 2011;31:589–595.
10. Varkey P, Tan NC, Girotto R, et al. A picture speaks a thousand words: the use of digital photography and the Internet as a cost-effective tool in monitoring free flaps. *Ann Plast Surg.* 2008;60:45–48.