An Evolution of Communication in Postoperative Free Flap Monitoring: Using a Smartphone and Mobile Messenger Application

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Summary: For more precise and rapid notification of free flap status between staff members after surgery, the authors used a smartphone and mobile messenger application including multimedia during the initial postoperative period and analyzed the influence of this method for the re-exploration time and survival rate of the flap before and after use. From April of 2010 to September of 2011, 123 consecutive free flaps were reviewed. The authors increased the flap survival rate from 96.2 to 100 percent and increased the threatened flap salvage rate from 50 to 100 percent with this method. The time interval between the first notification of flap compromise and the start of re-exploration was significantly shortened (4.0 versus 1.4 hours). This method not only provided better communication and comprehensive information but also allowed early diagnosis of flap compromise to be actualized at early re-exploration, ultimately increasing flap survival. (*Plast. Reconstr. Surg.* 130: 125, 2012.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, III.

THERAPEUTIC 3

Postoperative free flap monitoring is crucial to enable the early detection of vascular compromise of the flap to maximize salvage rates.[1] Primary observers of the flap are different, depending on the circumstances of each hospital, but are usually nurses or residents in training programs.[2,3] These primary observers are universally given two important missions to be carried out: the first is assessing the flap condition accurately, and the second is sharing the information of the flap examination quickly and precisely with their seniors or surgeon.

For flap assessment, clinical evaluation traditionally includes examination of flap color, temperature, capillary refill, and skin turgor.[2–5] Ascertaining the status of the flap circulation simply by its clinical characteristics, however, is difficult for even the experienced observer. Thus, numerous sophisticated monitoring techniques have been developed constantly with advances in technology, despite concerns about their reliability and cost efficiency.[4,5]

For communication between members, perhaps the most frequently used method is a verbal report via telephones since the inception of free-tissue transfer. Telephone communication can be rapid but not objective and precise. To add more accurate information to the verbal report, clinical photographs of the flaps taken by a digital camera were transmitted as a downloadable file between computers of distant staff members through a modem and telephone link, as telemedicine had gained popularity in the late 1990s.[6] With advances in Internet access in the late 2000s, flap images were transferred through Internet lines by commonly used Internet mail portals accessed by personal computers or personal digital assistant telephones.[7] More recently, photographic images taken by a smartphone are transferred to another's smartphone.[8]

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What are the next tools for better communication between staff in postoperative free flap monitoring beyond a verbal report and simple image transfer? In this study, we described our communication method reflecting the latest mobile environment using a smartphone and mobile messenger application. In addition, we analyzed the influence of this method on the survival rate of the flap and re-exploration time before and after use in microsurgical free flap monitoring.

PATIENTS AND METHODS

In the authors' department, the microsurgical team was composed of one professor, one fellow, and one junior and senior resident. All patients undergoing free flap transfer went to their original bed at the general ward and were monitored primarily by a junior resident and an assigned nurse. Free flap monitoring included clinical assessment of flap status and a handheld Doppler examination every 2 hours for the first 12 hours, every 3 hours for the next 24 hours, and then every 4 hours up to 72 hours after the surgery. Laser Doppler flowmetry (Perimed AB, Järfälla, Sweden) was also applied for continuous monitoring of the flap status. If there were any signs of flap compromise checked by the junior resident or nurse, they notified the senior resident or fellow, and then a final decision for intervention was sought from the surgeon by telephone consultation.

From January of 2011, the communication system among microsurgical team members was totally changed, whereas the monitoring method and time schedule for the examination were not. Whenever the junior resident went to the patient's bed to check the flap, the resident simultaneously shared all flap information with team members using a smartphone with a mobile messenger application (Fig. 1). All members were in the connecting-on state, and the chatting window was activated immediately whenever someone typed or uploaded information, so that near real-time communication between members was possible (Fig. 2). The smartphones used in this study included

Fig. 1. Smartphones are equipped with megapixel cameras so that high-quality images of the flaps can be obtained with good color reproducibility through wide liquid crystal display or light emitting diode screens (*left*). Taking a new photograph and distributing it to team members is performed simply and within seconds so that a kind of photoconference can be held immediately. Comparing serial photographs is fast and convenient because there is no need to download every single image. In addition, photographs can be saved either into a joint photographic experts group (.jpeg) file over 2560 × 1920 pixels (1.55 megabites) for patients' visual records or printing it (*right*).

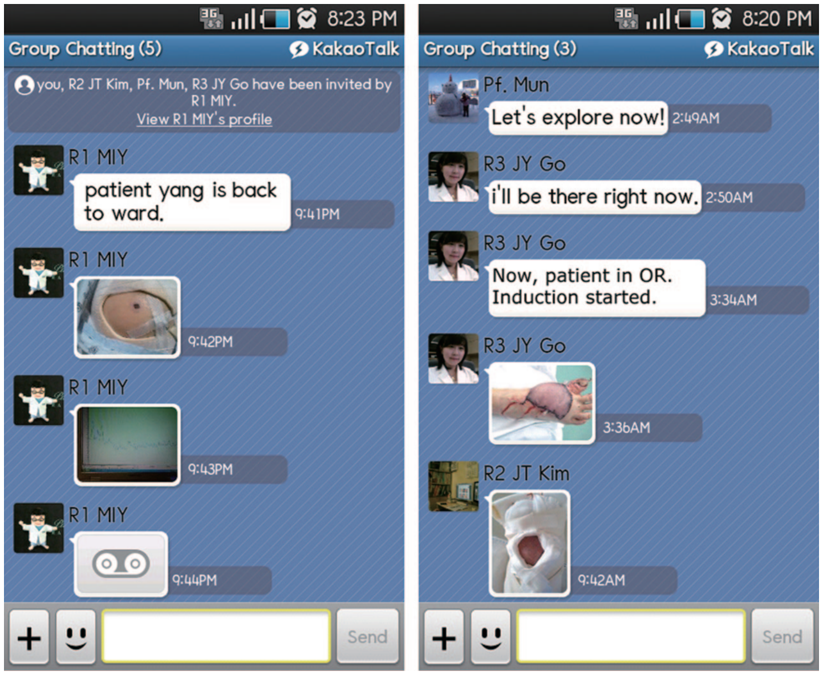
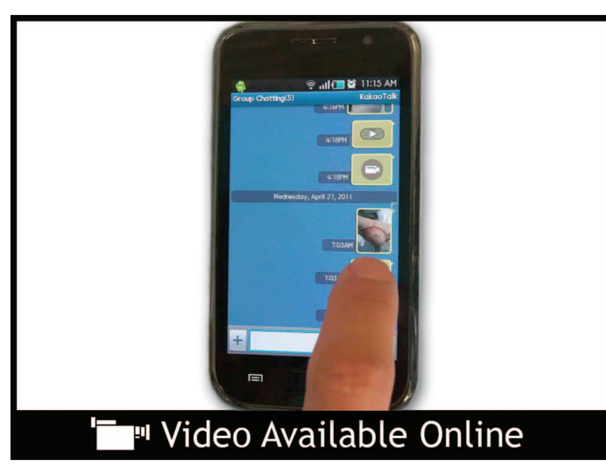


Fig. 2. Images captured on the smartphone screen during group chatting are shown. By using a multiuser chat application, stepwise notification system from primary observer to operator changed into roundtable conferencing between members. It automatically links the users on the contact list as chatting members to as many people they want, without registration or log-in. Thus, very quickly and conveniently, consulting, discussing flap status, and deciding the necessity of re-exploration was possible at any time and place.

iPhones (Apple Inc., Cupertino, Calif.), and the Galaxy S (Samsung Electronics Co., Seoul, Korea). All telephones were installed with a free mobile messenger application, Kakao Talk (Kakao Corp., Seoul, Korea). **See Video, Supplemental Digital Content 1,** demonstrating the practical use of a smartphone and mobile messenger application for flap monitoring, ***http://links.lww.com/PRS/A510***.

In a 9-month period beginning January of 2011, every patient who underwent free flap surgery was included in the smartphone group as a study group. To compare this group with the conventional method, all patients undergoing free flap surgery during a matching period in 2010 were included in the conventional group as a control. Patient demographics, operative details, and flap complications were collected by chart review. Chi-square and Fisher's exact tests were used as applicable for statistical comparison of flap complication rate. The Mann-Whitney U test was used for threatened flap analysis. All analyses were performed with SPSS, version 16.0 (SPSS, Inc., Chicago, Ill.). Significance was defined at p less than 0.05.



Video. Supplemental Digital Content 1 demonstrates the practical use of a smartphone and mobile messenger application for free flap monitoring, ***http://links.lww.com/PRS/A510***. Handheld Doppler sounds can be uploaded and shared with the others immediately as an audio clip or video clip while hearing the sound at bedside. Video recording using smartphones is also useful in demonstrating capillary refill time or a pinprick test. These multimedia can give us more comprehensive information complementing simple photographs so that a more objective judgment of the flap status can be obtained. Waves of capillary perfusion demonstrated by the laser Doppler monitoring device can be captured as images or video clips so that the staff can evaluate flap perfusion together with the result.

RESULTS

There were a total of 123 free flaps performed from April of 2010 to September of 2011, 61 flaps in conventional group and 62 flaps in smartphone group. There was no significant difference between the groups regarding patient age or flap types (Table 1). Total survival rate was higher in smartphone group, but it was not statistically significant (96.7 versus 100 percent; $p = 0.244$).

The analysis of threatened flaps is shown in Table 2. The same number of threatened flaps ($n = 4$) occurred after surgery in each group. Although half of them were salvaged in the conventional group, all threatened flaps survived in the smartphone group. Onset time of abnormal signs for a threatened flap after the initial surgery was not significant between groups (25.3 versus 14.8 hours; $p = 0.564$). The time interval, however, between when signs of flap compromise were first noticed and when re-exploration was initiated in the operating room was significantly shorter in the smartphone group than in the conventional group (4.0 versus 1.4 hours; $p < 0.05$).

Table 1. Patient Demographics and Flap Survival Rates

	Conventional Group	Smartphone Group	*p*
No. of patients	61	62	
No. of flaps	61	62	
Mean age, yr (range)	44.7 (9–84)	44.5 (9–77)	0.959*
Flap type			
DIEP	31	28	0.590†
TDAP	20	27	0.267†
msTRAM	3	0	0.244‡
LD nm	5	1	0.114‡
ALT	2	3	1.000‡
Gracilis nm	0	2	0.496‡
SCIP	0	1	1.000‡
No. of threatened flaps (%)	4 (6.6%)	4 (6.5%)	1.000‡
Threatened flap survival rate (%)	2/4 (50%)	4/4 (100%)	0.429‡
No. of flap survival (%)	59 (96.7%)	62 (100%)	0.244†

DIEP, deep inferior epigastric artery perforator; TDAP, thoracodorsal artery perforator; msTRAM, muscle-sparing transverse rectus abdominis myocutaneous; LD nm, latissimus dorsi neuromuscular; ALT, anterolateral thigh; gracilis nm, gracilis neuromuscular; SCIP, superficial circumflex iliac artery perforator.
**t* test.
†Chi square test.
‡Fisher's exact test.

DISCUSSION

The timing of the presentation of the first signs of vascular compromise was known to dictate the salvage outcome of free flap transfers.[1] Actual early detection of flap compromise is worthy, however, when earlier exploration is guaranteed. Our method ultimately reduced the time interval between first recognition of flap compromise and the beginning of the exploration operation significantly from 4 to 1.4 hours. The redundant steps of a vertical reporting system were eliminated by interactive real-time mobile messenger communication. The diagnostic accuracy of flap compromise was improved, and the decision was promptly made by the senior operator based on accurate, high-quality information: all-inclusive photographs, audios, videos, and chats. The vertical report system and verbal presentation of flap status had no competitive power any longer in comparison with comprehensive mobile messenger communication using the smartphone. Our method actualized quick detection for early exploration and therefore influenced flap survival rate. Moreover, this improvement did not add costs to either the patient or surgeon.

In centers in which the clinical assessor varies from nurse, resident, or fellow, our communication method using a smartphone and mobile mes-

Table 2. Threatened Flap Analysis

	Vascular Compromise	Clinical Recognition of Flap Compromise (hr)*	Re-Exploration (hr)†	Time Interval (hr)	Flap Salvage
Conventional group					
Patient 1	Venous	13.3	15.9	2.6	Fail
Patient 2	Venous	8.4	14.0	5.6	Success
Patient 3	Venous	67.4	71.2	3.8	Success
Patient 4	Arterial	12.0	No		Fail
	Average	25.3		4.0	
Smartphone group					
Patient 5	Venous	8.1	9.4	1.3	Success
Patient 6	Venous	13.1	14.3	1.2	Success
Patient 7	Venous	10.9	12.5	1.6	Success
Patient 8	Venous	26.9	No (medical leech)		Success
	Average	14.7		1.4	
p		0.564‡		0.0495‡	

*Clinical recognition of flap compromise means postoperative time when any abnormal sign of flap compromise was detected.
†Re-exploration means postoperative time when the re-exploration was started at operation room.
‡Mann-Whitney *U* test.

senger application is recommended for the postoperative routine of microsurgical free flap surgery. Recently, Wi-Fi–enabled monitoring devices were introduced capable of wireless transmission of data from the console directly to the surgeon but not through the observer.[9] We agree, however, that the decision finally comes down to what the surgeon's eye sees.[10] We think that the clinical observation of free flap by the surgeon or nurse is irreplaceable beyond the results of a monitoring device, until the ideal monitoring device is developed. Until then, enhancement of communication between the bedside observer and other surgical members should be considered, and our method suggests a practical alternative reflecting the latest mobile technology.

CONCLUSIONS

For more precise and rapid notification of the free flap status after surgery between staff members, we used a smartphone and communication application including multimedia during the initial postoperative period. Ultimately, this allows the early diagnosis of flap compromise to be actualized for early re-exploration to improve the flap salvage rate in free flap surgery.

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