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# Original Contributions

## WOUND CARE FOLLOW-UP FROM THE EMERGENCY DEPARTMENT USING A MOBILE APPLICATION: A PILOT STUDY

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☐ **Abstract—Background: Many patients presenting to emergency departments (EDs) do not have primary care and risk being lost to follow-up. Technology has been used successfully in surgical populations for wound care follow-up yet this is not well studied in ED populations. Objective: We aimed to conduct a pilot study demonstrating "smartphone" application-based follow-up after wound care in the ED. Methods: We enrolled participants in 2 urban EDs using a smartphone application called Mobile Post-Operative Wound Evaluator (mPOWEr) and defined participation as photographic submission at any time during the study period. We collected demographic data, frequency of use of mPOWEr, number of photographs uploaded, and timing of uploads. Results: We approached patients for study enrollment, and 67 patients (28%) were not enrolled because they had no access to a smartphone. Seventy-one patients (30%) declined to enroll, leaving 100 (42%) successfully enrolled. Smartphone ownership was more common among patients <40 years of age (81% vs. 64%, $p = 0.004$), more common among white patients than nonwhite patients (75% vs. 15%, $p = 0.046$), more common among patients approached at the university medical center than the trauma center (84% vs. 66%, $p = 0.003$), and among patients with commercial or other insurance than those with Medicare or Medicaid (92% vs. 54%, $p < 0.001$). Of those enrolled, 58% submitted a photograph. Conclusions: Patients presenting for wound care to the ED will participate in smartphone-based app communication for wound care follow-up and are satisfied with this option. Disparities in smartphone access must be considered when using this follow-up method.** © **2019 Elsevier Inc. All rights reserved.**

☐ **Keywords—emergency medicine; follow-up wound care; health care disparities; smartphone; telemedicine**

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### INTRODUCTION

Many patients presenting to urban emergency departments (EDs) lack primary care for follow-up visits after ED encounters (1,2). Nationally, an estimated 7.3 million visits for lacerations occurred annually to EDs between 1992 and 2002, and 3.5 million visits for skin and soft tissue infections in 2005, with most of these patients being discharged home (3,4). In a large prospective multicenter ED study, 2.6% of all traumatic lacerations became infected, while another study showed that ≤26% of patients had treatment failure within 7 days after incision and drainage of an abscess (5,6).

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More than 95% of these patients in the United States own or have access to computers, mobile devices, or "smartphones," defined as cellular phones that typically have internet access and are capable of running applications (apps); in 1 study in an urban ED population, 91% owned smartphones and 77% were comfortable using mobile devices (7,8). The opportunity to improve follow-up and open novel avenues of communication using this widespread and accessible technology is substantial.

Smartphone-based follow-up for wound care is not well described in emergency medicine populations. Despite participants expressing positive attitudes toward this follow-up mechanism, no patients actually sent a photograph in the sole previous feasibility study (7,9,10). Of note, this previous study used email-based follow-up rather than smartphone-based follow-up. While these previous results were discouraging, smartphone technology has advanced in prevalence, ease of use, and integration into the health care system, making further study timely and important (7).

While telemedicine is just beginning to be used in emergency medicine, app-based follow-up has been demonstrated successfully in postsurgical populations. Studies have demonstrated safety and efficiency of this follow-up mechanism, patient satisfaction, and cost savings (11–16). Telemedicine may be equally beneficial in a resource- and time-limited setting such as the ED.

We hypothesized that an app for smartphones that supported wound-care follow-up, added to standard practices in an ED population undergoing wound care, would be feasible for patients to use and would satisfy users. Our study aims included 1) demonstrating patient participation using a smartphone-based application for follow-up after receiving ED wound care and 2) describing patient satisfaction with this approach.

## MATERIALS AND METHODS

### *Setting*

We conducted a prospective cohort study of patients undergoing wound care at 2 urban EDs, including a level 1 trauma center and a university medical center. We selected these sites to allow for the sampling of 2 different patient populations using ED care within the same health care system. We enrolled patients from February to October 2017 with a target of 100 participants. We chose this sample size because it was logistically feasible to accomplish in a 12-month study period based on the historical volume of eligible patients at our centers, would be double the size of the only similar study in an emergency department population, and would provide a reasonable level of precision for the data analysis (9). Specifically, this sample size provides a worst-case margin of error of $\pm 10\%$ (95% confidence interval width) for estimates of proportions. Study approval was obtained from the institutional review board, including both enrollment sites.

### *Patient Population*

We included patients undergoing laceration repair or incision and drainage of an abscess. The research assistant (RA) reviewed the chief complaints listed for incoming ED patients. These were a convenience sample identified primarily during varying days of the week, including weekends, most often in afternoon and evenings. We selected these times because patient density was known to be highest during this time with more potential patients for inclusion. The RA screened patients for eligibility by their chief complaint, including "laceration," "motorcycle crash," "motor vehicle collision," "fall," "abscess," "wound re-evaluation," and "dressing change," among others. Eligibility criteria included: >18 years of age, not incarcerated, English-speaking, with access to a smartphone, and not admitted to the hospital at the conclusion of the ED visit.

### *Smartphone Application Platform*

The platform we chose to study, Mobile Post-operative Wound Evaluator (mPOWEr), is a smartphone application developed initially for follow-up of surgical wounds following discharge home (17). This application was previously approved by our institutional review board. It is not commercially available, and this study received no financial support from mPOWEr. It can be accessed via a secure password-protected portal by patients and designated providers to review text-based symptoms and wound photographs submitted by patients and allows messages to be sent between provider and patient. Screenshots of mPOWEr are shown in Supplemental Appendix 1.

### *Enrollment Procedures*

An RA was trained in screening and approaching eligible patients and obtaining informed consent. Eligible persons were approached by the RA and asked if they had a smartphone at any point during their ED care. Patients who had access to a smartphone were offered enrollment in the study. For all approached patients, whether enrolled, declined, or with no access to smartphone, basic demographics were collected via the electronic medical record including age, sex, race, ethnicity, site of approach, and insurance status.

The RA was trained by the application developers to register subjects and teach them how to use the

application. After enrollment and consent, with the assistance of the RA, subjects proceeded to create their mPOWEr account, and usage of the application was demonstrated on their personal devices or on a study device (iPad), which took approximately 10–15 min. All participants received a brochure with instructions to use the app for reference at home. All enrolled participants were given a $10 Starbucks gift certificate for their participation at enrollment. As part of the enrollment procedure, the RA explained to participants that no part of this study, including communication, pictures, or texts, should replace their care plan as provided by their ED care team. Specifically, the participants were instructed that while an RA would review their images and communications, no provider would be reviewing them for clinical purposes, and if they have any concerns to communicate with their established care team or return to the emergency department as instructed by their ED providers.

*Data Collection*

The RA asked the participants, and thereafter prompted them via email, to send an image of their wound on days 1, 3, 7, and 14 after their initial ED visit. We collected data for each participant on frequency of use of mPOWEr and communication between the RA and participants, including emails and text-based symptoms submitted via mPOWEr. We recorded dates of photograph submission and grouped photographs into the requested deadline date following the actual date of submission.

On day 14, each participant received an email with a survey regarding their experience with mPOWEr, with up to 2 reminder emails. The survey tool included 8 questions that requested a response on a 4-point scale with 1 corresponding to the lowest rating (e.g., poor quality) and 4 corresponding to the highest rating (e.g., excellent quality), and 1 open-ended question for feedback. It was designed to capture subject satisfaction with mPOWEr, its ease of use, and whether they would use this platform in a similar clinical setting in the future to achieve wound care follow-up. This survey was based on a previously validated and standardized measure of patient satisfaction and adapted to our use, the Client Satisfaction Questionnaire 8 (18–21). The survey with questions and allowed responses is included in Supplemental Appendix 2.

*Outcomes*

Our primary outcome was participation, measured by photograph submission at any time and during the time periods defined above. Our secondary outcomes were: 1) any communication prompted by mPOWEr, including photographs, text-based symptoms, and emails, as a proxy for future bidirectional communication between providers and patients and 2) participant satisfaction with the platform.

*Statistical Analysis*

We summarized participant demographics and outcome measures of mPOWEr utilization as mean ± standard deviation (SD), median (range), or number (percentage). Independent groups of participants were compared using the *t* test (continuous variables) or Fisher exact test (categorical variables). Multivariate logistic regression was used to further assess differences between groups after adjusting for other demographics. Ratings from the user survey were dichotomized from a 4-point scale into positive (3,4) and negative ratings (1,2) for analysis. All statistical calculations were conducted with the statistical computing language R (version 3.1.1; R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was defined as $p < 0.05$ (two-sided) without any adjustment for the number of comparisons.

## RESULTS

*Patient Demographics and Factors Related to Enrollment*

During the enrollment period, we approached 238 patients who met the preliminary eligibility criteria. Of these, 67 (28%) were not enrolled because of a lack of access to a smartphone, and 71 (30%) declined to enroll, leaving 100 (42%) successfully enrolled (Figure 1). Demographics of the enrolled patients, patients who declined, and patients without a smartphone are summarized in Table 1.

Of the 238 patients approached, 171 (72%) owned a smartphone. Smartphone ownership was more common among patients <40 years of age (81% vs. 64%, $p = 0.004$), white patients than nonwhite patients (75% vs. 15%, $p = 0.046$), patients approached at the university medical center than the trauma center (84% vs. 66%, $p = 0.003$), and patients with commercial or other

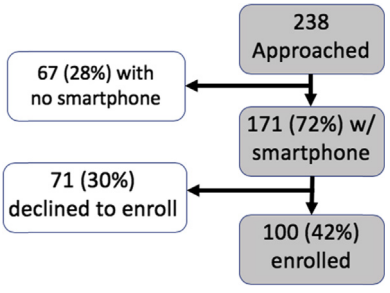


**Figure 1. Enrollment of subjects.**

**Table 1. Patient Demographics in Each Cohort**

| Variable | Cohort | | |
|---|---|---|---|
| | Successfully Enrolled (N = 100) | Eligible but Declined (N = 71) | Approached but No Smartphone (N = 67) |
| Female sex, n (%) | 25 (25.0) | 19 (26.8) | 15 (22.4) |
| Median age, y (IQR) | 37 (27–52) | 40 (29–49) | 47 (32–59) |
| Site, n (%) | | | |
| Trauma center | 59 (59.0) | 47 (66.2) | 55 (82.1) |
| University medical center | 41 (41.0) | 24 (33.8) | 12 (17.9) |
| Race,*n (%) | | | |
| White | 78 (82.1) | 46 (71.9) | 41 (62.1) |
| African American or Black | 10 (10.5) | 11 (17.2) | 13 (19.7) |
| Other | 7 (7.4) | 7 (10.9) | 12 (18.2) |
| Ethnicity,†n (%) | | | |
| Hispanic or Latino | 5 (5.1) | 6 (9.4) | 6 (9.1) |
| Not Hispanic or Latino | 94 (94.9) | 58 (90.6) | 60 (90.9) |
| Insurance status,‡n (%) | | | |
| Commercial | 36 (38.3) | 18 (28.6) | 3 (4.7) |
| Medicare | 5 (5.3) | 10 (15.9) | 11 (17.2) |
| Medicaid | 32 (34.0) | 18 (28.6) | 45 (70.3) |
| Labor and industry workers' compensation | 19 (20.2) | 11 (17.5) | 3 (4.7) |
| Charity/self | 2 (2.1) | 6 (9.5) | 2 (3.1) |

IQR = interquartile range.
* Race was unavailable in 5 enrolled patients, 7 patients who declined, and 1 patient without a smartphone.
† Ethnicity was unavailable in 1 enrolled patient, 7 patients who declined, and 1 patient without a smartphone.
‡ Insurance status was unavailable in 6 enrolled patients, 8 patients who declined, and 3 patients without a smartphone.

insurance than those with Medicare or Medicaid (92% vs. 54%, $p < 0.001$). These differences remained statistically significant after adjusting for all demographics except racial differences, which became marginally nonsignificant ($p = 0.062$). Similar to the differences between those with and without smartphones, the enrolled cohort was somewhat younger (age <40 years: 55% vs. 41%, $p = 0.035$), more often approached at the university medical center (41% vs. 26%, $p = 0.017$), more often white (82% vs. 67%, $p = 0.039$), and less likely to have Medicare or Medicaid than commercial or other insurance (39% vs. 66%, $p < 0.001$) than those approached but not enrolled. Of those with a smartphone, there were no statistically significant differences in these demographics between those who enrolled or declined ($p > 0.11$ for each).

Of the 100 enrolled patients, 59 were recruited from the trauma center and 41 from the university medical center. There were no statistically significant differences in sex ($p = 0.48$), age ($p = 0.74$), race ($p = 0.92$), or ethnicity ($p > 0.99$) between enrolled patients from the two sites, but insurance status differed between the groups ($p = 0.010$). The trauma center had fewer patients with commercial insurance (22% vs. 54%) and more patients on Medicaid (41% vs. 15%).

*Participation*

Of the 100 enrolled successfully, 58% submitted a photograph at any time after enrollment, 27% sent a text message through mPOWEr, and 59% communicated either way via mPOWEr. Sixty-nine percent communicated in any way with the research team, including through mPOWEr, phone-based text, or email. There were no statistically significant differences in these participation rates between the level 1 trauma center and academic medical center sites ($p > 0.063$ for all), between males and females ($p > 0.60$ for all), or older (≥40 years of age) and younger (<40 years of age) participants ($p > 0.31$ for all).

Of the 58 patients who submitted ≥1 photograph over the study period, the median number of photographs submitted per participant was 3 (range 1–17 photographs). The median time until a participant submitted a photograph was 3.5 days. Forty-six of 100 participants submitted a photograph between days 1 and 2, 44% between days 3 and 6, 36% between days 7 and 13, and 20% between days 14 and 19 (Figure 2). One participant submitted a photograph after day 20. Overall, 13% of participants submitted a photograph during each range of days 1–2, 3–6, 7–13, and 14–19, as requested. Participants ≥40 years of age (n = 45) were more likely than participants <40 years of age (n = 55) to submit a photograph on days 7–13 (53% vs. 22%, $p = 0.002$) and on days 14–19 (31% vs. 11%, $p = 0.022$) (Figure 2). Eleven (24%) of those participants ≥40 years of age submitted a photograph during each range of days 1–2, 3–6, 7–13, and 14–19, as requested, compared with 2 (4%) of those <40 years of age ($p = 0.003$). Participants ≥40 years of age tended to submit their initial photograph earlier (median time to first photograph: 2 vs. 5 days, $p = 0.20$), submit more photographs (median: 3 vs. 1 photographs, $p = 0.038$), and, of those who submitted any

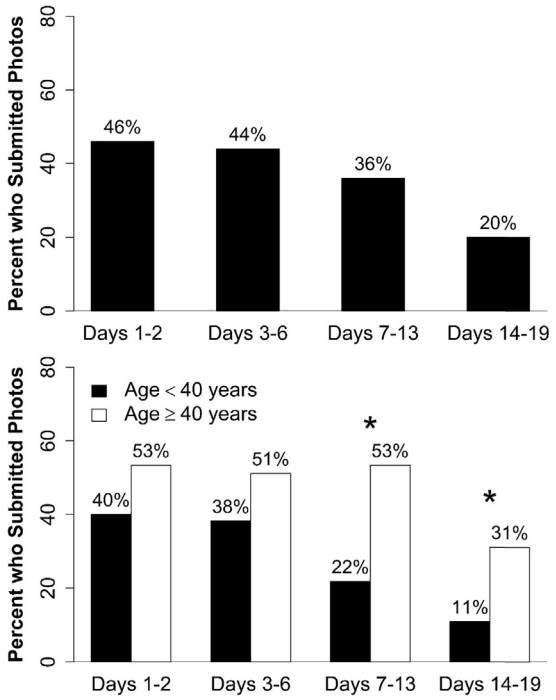


**Figure 2. Photograph submission rates over time among all enrolled subjects (top) and by age. Asterisks represent statistically significant differences between age groups ($p < 0.05$).**

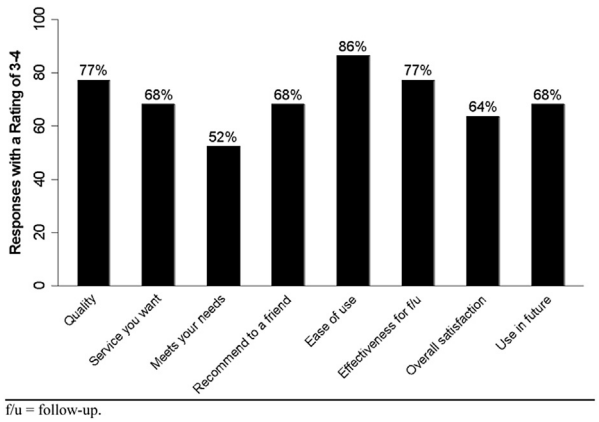


**Figure 3. Responses to the user survey regarding their experience with mPOWEr from the 22 participants who responded to the survey. Each item was rated on a 4-point scale, with 1 corresponding to the lowest rating (e.g., poor quality) and 4 corresponding to the highest rating (e.g., excellent quality). One participant did not respond to the "meets your needs" question and was excluded from the summary of that question.**

photographs (n = 29 of each age group), submit photographs over a longer period (median interval between the first and last photo: 8 vs. 3 days, $p = 0.053$).

*Satisfaction*

Twenty-two of all enrolled patients submitted satisfaction surveys (overall response rate 22%). Relative to survey nonresponders, responders were older (mean age: 48 vs. 39, $p = 0.031$), female (41% vs. 21%, $p = 0.091$), and more likely enrolled at the level 1 trauma center site (73% vs. 55%, $p = 0.15$). In addition, those who submitted ≥1 photograph during the last 2 time points (days 7–19) were more likely to respond to the satisfaction survey than patients who did not submit a photograph during that time period (38 [39%] vs. 62 [11%], $p = 0.002$). Responders and nonresponders had similar race ($p = 0.90$) and ethnicity ($p > 0.99$) distributions. Most surveys (77%) indicated that this method of communication was good or excellent and that most were satisfied with the ease of use of mPOWEr (Figure 3).

## DISCUSSION

We performed a prospective cohort study of urban ED patients participating in smartphone-based wound care follow-up. In our study, 72% of approached patients had smartphones, fewer than previous studies (7,8). Patients without smartphones were older, more often from minority groups, and more often had Medicare or Medicaid than commercial or other insurance compared with patients with smartphones. Similarly, we also found those patients presenting to our level 1 trauma center were less likely to have smartphone access, more likely to have Medicaid insurance, and less likely to have commercial insurance than those presenting to our university medical center. These results suggest that there is a disparity in access to smartphones that may be related to socioeconomic status. Of those with smartphone access, we found no statistically significant differences in ethnicity, race, site, age, sex, and insurance status between those who enrolled or declined.

Participation in this study was significantly higher than in the only previous ED-based study on this subject, with a majority (60%) of enrolled patients communicating via the app compared with 0% in the previous study (10). Participation did not vary significantly by site of enrollment, sex, or age. Participation decreased over the follow-up period, from 46% on days 1–2 to just 20% on days 14–19. Because this was a pilot study and data collected were not used as part of clinical care, participants did not receive direct feedback on their photograph submissions and we suspect this led to a loss of interest and decreased participation as the study period progressed. Despite this, 13% of participants submitted during all date ranges as requested. Our results compared with those of previous studies likely represent the increased integration of smartphones into the general population's daily activities and the cross-generational comfort with a smartphone interface.

Interestingly, participants ≥40 years of age were more likely to submit on days 7–13 and days 14–19 than participants <40 years of age. This was unexpected given that younger generations tend to have higher utilization of smartphone technology. However, this may have been related to the lack of feedback after submissions. While older patients may have followed instructions without feedback, younger participants may be more accustomed to an interactive and back-and-forth experience with apps and smartphone technology, and the absence of this dynamic may have led to a loss of interest.

Only 22% of participants submitted satisfaction surveys, limiting our interpretation of patient satisfaction results. Similar to the participation trend, participants who submitted a survey were more likely to be older. Despite the low submission rate, among participants who completed the survey, there was overall satisfaction with the platform.

### *Limitations*

Because this was a pilot study that aimed only to provide data surrounding willingness to participate and patient utilization of this smartphone-based app platform, no clinical feedback was provided to participants after photograph submission. This lack of feedback may have led to decreased participation, especially as the study period progressed. This would have skewed the results toward decreased participation, and theoretically one could assume that if implemented with consistent clinical feedback, this platform would achieve higher participation rates. In addition, we did not consider the quality of the photographs. For the purpose of assessing participation, the quality of the photographs was less important, but when considering implementing this technology in clinical care, the quality and utility of these photographs in evaluating wounds will need to be taken into consideration. In addition, this study did not assess economic implications of smartphone-based follow up for wound care.

Our ability to draw conclusions regarding patient satisfaction is limited because of the low proportion of participants who submitted a satisfaction survey. It is possible that the lower photograph submissions rates among younger participants reflect a lack of satisfaction with our application within that demographic group which could not be captured in the satisfaction survey because of the overall low response rate, with younger participants even less likely to respond.

## CONCLUSIONS

To our knowledge, our study is the first that shows the utilization of a smartphone-based application for wound photograph submission postdischarge in an urban ED population, with most enrolled subjects participating. Smartphone technology has advanced in prevalence, ease of use, and integration into the health care system in the past 5 years, likely contributing to the increased participation in the current study (8). This technology, with its ubiquity and evolving capability, holds real potential to contribute to ED patient follow-up, especially for those patients with limited primary care and those at risk for being lost to follow-up. Future work in this area should investigate a more interactive platform between clinicians and patients, as well as assess the quality of pictorial and text communications to understand the necessary details for clinical decision making based on these types of smartphone-based applications.

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## ARTICLE SUMMARY

**1. Why is this topic important?**

Patients are at risk for wound complications after emergency department care without adequate follow-up. Utilizing app-based communication allows for emergency departments to provide wound care follow-up, as previously demonstrated in post- surgical populations.

**2. What does this study attempt to show?**

This study aims to assess the feasibility, demonstrated by patient participation and satisfaction, of app-based communication for wound care follow-up after an emergency department visit.

**3. What are the key findings?**

59% of enrolled patients participated through app-based communication, suggesting this avenue for follow up is feasible in this population. We discovered disparities in access to smartphones, with smartphone access being more prevalent in younger patients, in white compared to non-white patients, and in those with commercial insurance as compared to Medicare or Medicaid.

**4. How is patient care impacted?**

Our results are the first to suggest that this technology-based approach for wound care follow-up is feasible in an ED population, but that disparities in smartphone access must be considered. This platform holds potential to increase safe discharge plans for an at- risk population.