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Evaluation of a Mobile Wound Care Device for Assessment of Wounds: A Time Motion Study

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Abstract

Background: Comprehensive wound assessments are critical in identifying potential complications that affect wound healing and determining appropriate interventions for the patient. A wound care device (WCD) comprising a mobile device integrated with multi-spectral sensors that can capture stereoscopic and thermal images was recently introduced. A trial was conducted to assess potential productivity gains of the device.

Methods: A total of 30 inpatients who required wound care were recruited and assessed via a time motion study. For every patient recruited in this study, wound measurements and documentation steps were repeated twice for a total of 55 wounds, once using the WCD and the other using a conventional manual process, with the order of assessment determined using a random group assignment generator. A t-test was used for statistical analysis.

Results: The use of the WCD had a mean process time 4.86 minutes shorter than the conventional manual process ($P<0.001$). This constituted an increase in productivity by 44% for wound measurement, photography, and documentation. With estimated time savings of 5 minutes per patient, this amounts to 6,631 hours per year or a total of 3.42 nursing full-time equivalent savings per year based on an estimated load of 218 patients per day requiring wound care at an acute care institution in Singapore.

Conclusion: The adoption of a mobile WCD has potential to improve work productivity and result in full-time equivalent savings for wound care nurses. Most importantly, the WCD could provide clinically beneficial outcomes for the patient by enhancing the management and documentation of wound care.

Keywords: Wounds and injuries; Process assessment; Time and motion studies

Introduction

In countries with aging populations such as Singapore, the incidence rate of chronic wounds is expected to increase [1]. This leads to increasing costs and utilization of healthcare resources associated with treating chronic wounds, partially due to longer work time for nurses and increased use of wound care products [2]. The clinical and economic burdens of wound care is also rising, with an increase in inpatient wound episodes and an average gross charge of SGD $17,500 per wound episode [3].

The management of acute and chronic wounds is challenging and there are limited specialized wound care nurses for the assessment and treatment of complex wounds. Performing comprehensive wound assessments is critical in identifying potential complications that affect wound healing and determining appropriate interventions for the patient [4,5]. The current wound assessment process is manual, relying on the nurse's expertise for accurate measurements of wound size and visual inspection of wound condition. Subsequent documentation of these findings is also onerous as it

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requires time for the wound care nurse to upload photos of the wound to the patient's electronic medical records from local storage devices.

With more patients requiring wound care, there is a need to adopt more efficient and productive means of wound management to empower junior nurses and alleviate reliance on the limited pool of experts. Advancements in the technology of wound assessment devices have demonstrated accuracy in capturing wound images and measurements through various modalities [6].

The KroniKare Wound Scanner (KroniKare Pte Ltd, Singapore) is a medical device that comprises of a mobile device integrated with multi-spectral sensors that can capture stereoscopic and thermal images (Fig. 1). The captured wound images and data are analyzed by machine learning algorithms to measure the wound dimensions, perform tissue analysis, and detect potential complications including ischemia, infection, undermining, and inflammation for review by the nurse on an integrated dashboard. The technology has currently been approved by the Health Sciences Authority Singapore as a Class B diagnostic tool for AI (artificial intelligence)-based chronic wound assessment, providing 3-dimensional wound measurement, wound tissue type classification (all 7 medically assessed tissues) and complication detection. In a previous validated Proof of Value on 644 patients conducted by KroniKare, the KroniKare Wound Scanner was shown to be on-par with physical measurement of wounds (length, width, and depth) and detection of similar tissue types and complications (infections, undermining and ischemia) compared to expert assessment and opinion (see Supplementary Material).

Fig. 1. KroniKare Wound Scanner with mobile device and sensors. The figure shows both the front view of the mobile device and the back view with cameras and sensors.

The KroniKare Wound Scanner was also expected to save time in wound measurement and documentation, and hence a trial was conducted to assess potential productivity gains in this area. To understand the usability and potential productivity gains when using this mobile wound care device (WCD), an evaluation study was performed with the primary objective of comparing the time taken for wound assessment and update of assessment results using the KroniKare Wound Scanner against the conventional manual process (Fig. 2).

Methods

Selection criteria

This was a prospective time motion study involving ward patients who received wound care management during the period of May 1, 2019, to June 30, 2019, from the wound care management nursing specialty team in a local institution. Types of wounds were not recorded, although all general wound types seen by the wound care nurse such as pressure injuries, vascular wounds, diabetic wounds, and dermatological wounds were included in the study (excluding plastic reconstructive and other surgical wounds). Based on current protocol, this study did not require institutional review board approval as (1) it did not affect the current standard of care for patients, (2) it was non-invasive in nature, involving only documentation and capturing of images by nurses under standard wound care practice, (3) no patient identifiers were collected.

To reduce bias due to variation of technical competency of wound care nurses, only nurses having at least 2 years of specialized wound care experience participated in this study. Additionally, wound care nurses go through a standardized training checklist to assess their competency in providing the same quality of care for patients. The conventional manual process for wound measurements involves the use of a wound measuring tape and sterile swab to measure the greatest length, breadth, and depth of the wound. Technical training on use of the WCD was conducted prior to the study. For wound measurements using the WCD, the nurse captures an image of the wound with the WCD (Fig. 3), and the length, width and depth measurements are generated automatically.

For every patient recruited in this study, wound measure-

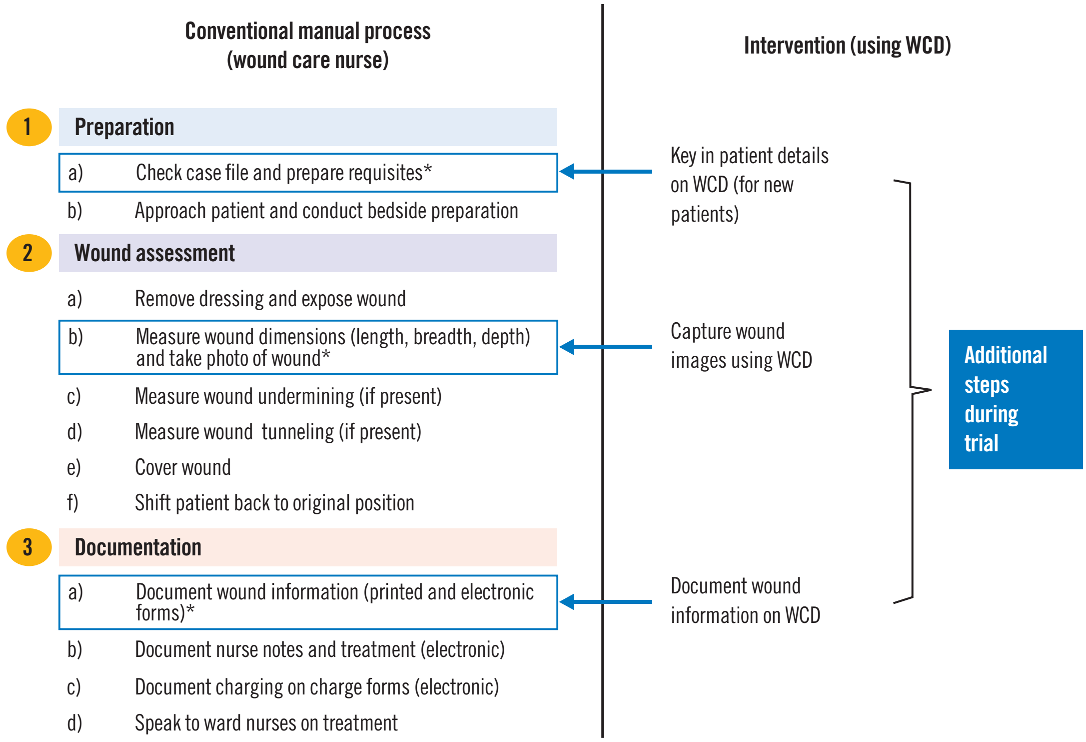

Fig. 2. Schematic diagram representing the conventional and WCD process. Additional steps required when using the WCD are shown in the diagram (marked with asterisks) compared to the conventional manual process. WCD, wound care device.

Fig. 3. Use of wound care device to capture a wound image. Figure showing the actual use of the wound care device in a clinical setting.

ments and documentation steps were repeated twice, once using the WCD and the other by the conventional manual process (measurements and recording without the use of any automated device). Every recruited patient was randomized to have wound measurements and documentation steps completed first using either the conventional manual process or the new workflow involving the WCD, with random group assignment determined using R version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria) before the commencement of this study. The randomization outcome was only made known to the wound care nurses shortly before beginning each wound measurement and documentation process for each patient. Times required for measurement and documentation were collected by an assigned research assistant allocated for this study. Repeat time measurements were done for steps in the wound care process where the WCD is hypothesized to save time (i.e., wound measurement, photography and documentation). Time measurements were also collected for other steps that occurred during wound care to determine the observed time spent on each step of the wound care process (Fig. 2). Baseline demographic details (age, race, sex) at the time of enrollment were collected. Other data such as whether the patient was a new or follow-up case, bed bound status, and total number of wounds were also collected.

Assuming the conventional manual process takes 45 minutes (with a standard deviation [SD] of 10 minutes) based on nurses' estimations of the time required during standard care

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and a corresponding 20% time decrease when using the WCD, with alpha=0.05 and power of 80%, and enrollment ratio of 1:1, the sample size required was calculated to be 38. However, as measurements are repeated twice, once using the conventional manual process and once using the WCD on the same patient, the number of patients required would therefore be 19.

Statistical analyses

Statistical analysis was performed using Stata for Windows version 15 (StataCorp, College Station, TX, USA). The results were expressed as mean±SD or percentages (%). A t-test was used to test for statistical significance of difference in time between intervention (WCD) and conventional manual process. Subgroup analysis was performed to assess time savings for components of the wound care analysis where the WCD is posited to increase efficiency in the wound care process. For statistical tests performed, a value of $P<0.05$ was considered statistically significant.

Results

A total of 30 inpatients who required wound care were recruited in this study (Fig. 4). For case type categorization, 19 patients (63.3%) were new cases while 11 were follow-up patients. There was an equal distribution for sex with 15 male (50.0%) patients and 15 female (50.0%) patients, respectively. For race, 15 patients (50.0%) were Chinese, 13 (43.3%) Malay, and 2 (6.7%) belonging to other races. Thirteen patients (43.3%) were randomized to undergo the time motion study beginning with the conventional manual process first, whereas 17 patients (56.7%) underwent the time motion study beginning with the WCD first. A total of 55 wounds were assessed across the 30 patients included in this study, of which 13 patients presented with one wound (43.3%), 11 patients with two wounds (36.7%), 4 patients with three wounds (13.3%), and 2 patients with four wounds (6.7%). There was an equal distribution in the number of nurses involved in the wound care procedure with 15 patients (50.0%) having one nurse and 15 patients (50.0%) having two nurses, respectively. The summary of the demographic profiles for these patients can be found in Table 1.

Table 2 depicts the 12 distinct chronic wound care processes in order of sequence involved in the ward setting, which include checking patient files and preparing items necessary for wound assessment and care, approaching patient and completing bed side preparations, removing dressing and exposing wound, measuring wound dimensions (length, breadth, depth) and taking wound photos, measuring wound undermining, measuring wound tunneling, covering wound, shifting patient back to original position, documenting wound information (printed and electronic forms), documenting nursing notes (electronic), documenting charges and fees (elec-

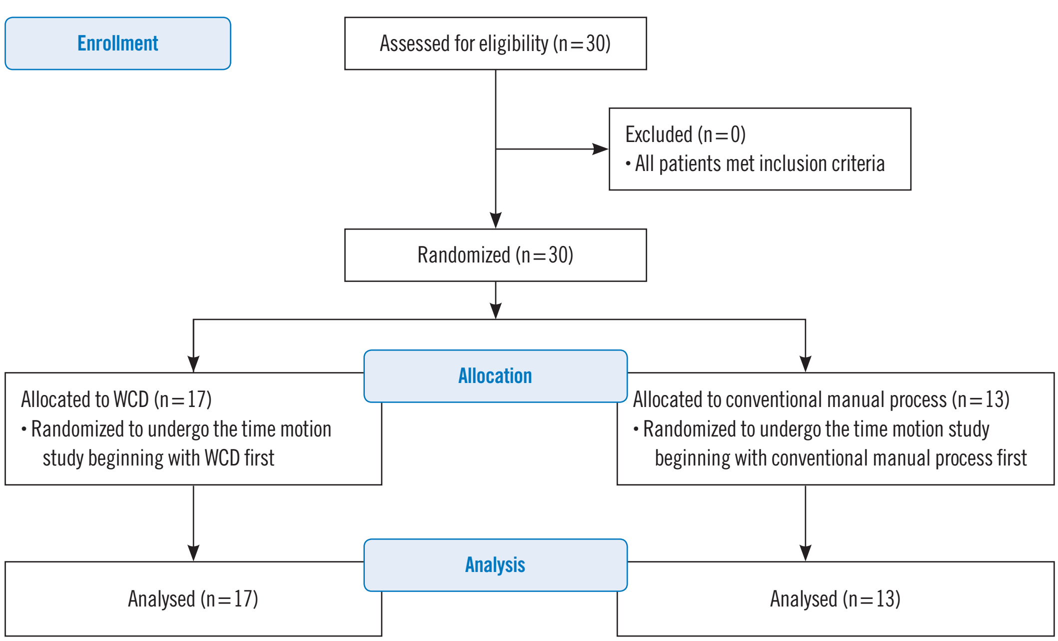

Fig. 4. CONSORT flow diagram of study participation. Flow diagram indicating number of patients allocated into the conventional manual process-first and wound care device (WCD)-first groups.

Table 1. Summary of patient demographic and characteristics (n=30)

Characteristics	No. (%)
Case type	
New	19 (63.3)
Follow-up	11 (36.7)
Sex	
Male	15 (50.0)
Female	15 (50.0)
Race	
Chinese	15 (50.0)
Malay	13 (43.3)
Others	2 (6.7)
Randomized to start with	
Conventional manual process	13 (43.3)
Wound care device	17 (56.7)
No. of wounds	
1	13 (43.3)
2	11 (36.7)
3	4 (13.3)
4	2 (6.7)
No. of nurses	
1	15 (50.0)
2	15 (50.0)

tronic), and speaking to ward nurses about the overall treatment plan. Two of these processes (wound measurement and wound documentation) are marked with asterisks for direct comparison between the conventional manual and WCD intervention processes. Each of the main wound care steps are represented by the corresponding mean time spent in minutes and percentage of total time spent on each step.

Keying in details to the WCD constitutes an additional step for new patients that does not occur under the conventional manual process, with a mean additional timing of 0.9 minutes (SD=0.7) expected. These details include brief information about the patient such as age, sex, and comorbidities. Measurement of wound dimensions (length, breadth, and depth) plus photography and documentation of wound information (printed and electronic forms) through the conventional manual process took a mean of 11.0 minutes (36.3% of total time spent on wound care). There were the areas where the WCD was expected to save time and enhance productivity.

Fig. 5 presents the t-test results with mean and SD differences between the conventional manual process and WCD in wound measurement and photography. The mean time taken for the conventional manual process and WCD was 1.95 minutes (SD=1.72) and 2.69 minutes (SD=1.79), respectively, indicating that the conventional manual process was 0.74 min-

Table 2. Mean time spent on each wound care step during conventional manual process and WCD

Process	Wound care steps	Time spent on conventional manual process (min)	Time spent on WCD (min)	Time spent on wound care using conventional manual process (%)
1. Preparation	(a) Checking patient files and preparing items necessary for wound assessment and care	7.1±3.5	NA	23.4
	Keying in details to WCD application[a]	NA	0.9±0.7	-
	(b) Approaching patient and completing bed side preparations	2.1±2.1	NA	7.1
2. Wound assessment	(a) Removing dressing and exposing wound	2.4±2.2	NA	7.8
	(b) *Measuring wound dimensions (length, breadth, depth) and taking wound photos[a]	2.0±1.7	2.7±1.8	6.5
	(c) Measuring wound undermining (if present)	0.4±0.6	NA	1.2
	(d) Measuring wound tunneling (if present)	0.3±1.5	NA	0.9
	(e) Covering wound	1.5±1.5	NA	4.9
	(f) Shifting patient back to original position	1.6±1.6	NA	5.3
3. Documentation	(a) *Documenting wound information (printed and electronic forms)[a]	9.0±4.8	2.5±1.3	29.8
	(b) Documenting nurse notes and treatment (electronic)	2.1±1.4	NA	6.8
	(c) Documenting charges and fees (electronic)	0.7±0.5	NA	2.2
	(d) Speaking to ward nurses about treatment	1.3±1.3	NA	4.2

Values are presented as mean±standard deviation. Asterisks are shown for comparison between conventional manual and WCD process.
WCD, wound care device; NA, not available.
[a]The portions WCD is involved under the intervention.

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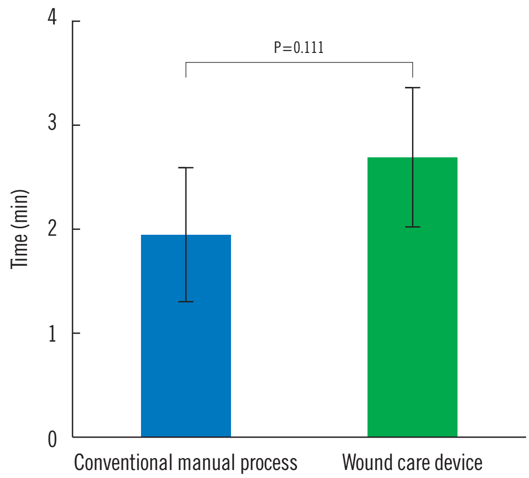

Fig. 5. Bar graph comparing wound measurement and photography times. Time difference between the conventional manual process (mean±SD, 1.95±1.72; 95% CI, 1.31–2.59) and wound care device (mean±SD, 2.69±1.79; 95% CI, 2.02–3.35) for wound measurement and photography. SD, standard deviation; CI, confidence interval.

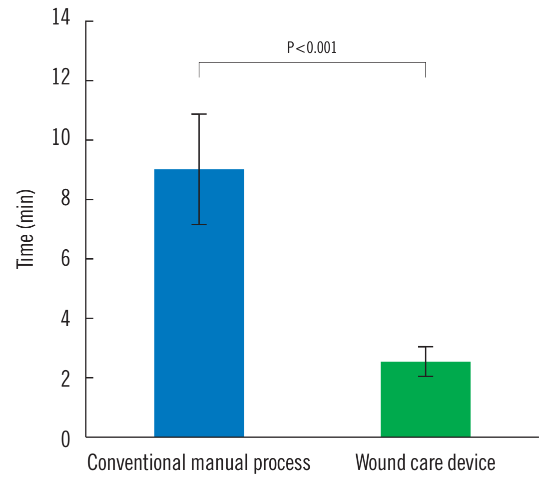

Fig. 6. Bar graph comparing wound information documentation times. Time difference between the conventional manual process (mean±SD, 9.01±4.83; 95% CI, 7.21–10.81) and wound care device (mean±SD, 2.54±1.27; 95% CI, 2.07–3.02) for wound information documentation. SD, standard deviation; CI, confidence interval.

utes (SD=1.81) faster using the WCD, although this was not statistically significant (P=0.111). This is because nurses used supplementary functions of the WCD to capture additional images of wound exudate and wound dressing products, as well as thermal images of the limbs for detecting complications. The WCD has a thermal imaging function which can help identify underlying ischemic conditions that are not easily detected by the naked eye. Therefore, the 0.74 minutes additional time can add valuable data for well-informed decisions when viewing the automatically generated reports.

Fig. 6 presents the t-test results with mean and SD differences between the conventional manual process and WCD in wound information documentation. The mean time taken for the conventional manual process and WCD was 9.01 minutes (SD=4.83) and 2.54 minutes (SD=1.27), respectively. This comparison shows the advantage of using the WCD, which saved a mean of 6.47 minutes (SD=3.95) for the documentation section (P<0.001).

Fig. 7 presents the t-test results together with mean and SD differences between the conventional manual process and WCD for wound measurement, photography and documentation combined. The mean time taken for the conventional manual process and WCD was 10.96 minutes (SD=6.00) and 6.10 minutes (SD=2.76), respectively. The use of the WCD had a mean process time of 4.86 minutes (SD=4.63) shorter than the conventional manual process (P<0.001) after considering

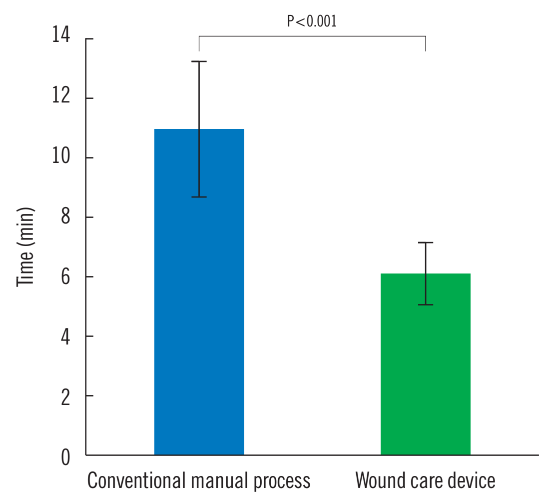

Fig. 7. Bar graph comparing times for wound measurement, photography and documentation. Time difference between the conventional manual process (mean±SD, 10.96±6.00; 95% CI, 8.72–13.20) and wound care device (mean±SD, 6.10±2.76; 95% CI, 5.07–7.13) for wound measurement, photography and documentation combined. SD, standard deviation; CI, confidence interval.

the additional time taken to key in details to the WCD (0.9 minutes) and for wound measurement and photography using the WCD (0.74 minutes). This means that the WCD could reduce the time required for wound measurement, photography, and documentation by 44%. With an estimated saving of 5 minutes per patient, total saving amounts to 6,631 hours per year or a total of 3.42 nursing full-time equivalent (FTE) savings per year based on an estimated load of 218 patients per day requiring wound care at an acute care institution in Singapore, and FTE of one nurse being equivalent to 1,940.4 hours per annum.

Discussion

Assessment and management of chronic wounds can take up a substantial portion of specialized wound care nurses' time. Wound care nurses are required to cover multiple locations across the hospital when attending to wound cases referred by non-specialized nurses. As described in the Supplementary Material, the WCD was able to measure wound dimensions, assess wound tissue types and detect wound complications in a similar manner to qualified clinical staff, indicating further potential of the WCD to enable non-specialized nurses and wound care nurses to manage their wound caseloads in a more efficient way. Hence, the accuracy of the WCD was not assessed as part of the time motion study. Documentation is usually done on various printed and electronic clinical notes and uploading of wound photos onto existing documentation also requires a lengthy process. Table 2 illustrates the identified 12 distinct processes involved in chronic wound care in this acute care institution, two of which were highlighted and measured for comparison between manual and automatic processes. The greatest proportion of time (approximately 30%) is spent on wound documentation, and greatest productivity gain can be achieved from use of the device here. With future integration to electronic medical records, additional FTE savings are to be expected as nurses can significantly reduce the amount of time spent on documenting and reviewing wounds.

Overall mean time required for each wound care procedure is expected to decrease by 4.86 minutes increasing productivity by approximately 44% in steps where the WCD is involved. Cost savings using the WCD were estimated solely based on the time-saving aspect. It should be noted that time saved for higher-level clinicians, administration, patient transportation (for outpatient clinics), and clinician transportation (for homecare) is not included in this calculation, and accounting for these additional time-saving aspects could substantially increase the time and FTE saving estimations. Furthermore, the current estimates assume that there is only one wound per patient and one nurse caring for these patients. Greater time savings may be achievable should this be rolled out on a larger scale.

Should the WCD be rolled out to a wider group of nurses with the main aim of empowering junior nurses and non-specialized nurses, even greater productivity gains can potentially be realized. By empowering junior nurses with the capability to perform more accurate and objective wound analyses, they can now be an integral part of the wound assessment workforce. The WCD allows efficient and effective deployment of both non-specialized nurses and specialized wound care nurses, with key decisions made by the wound care nurses. All nurses can use the dashboard to view the progress of each patient and determine which patient's conditions require consultation of specialized wound care nurses, freeing up the specialists' time to take on more complex wound cases. Using the WCD, data collection and documentation can also be aggregated across the continuity of care from hospitals to the community, allowing for improved patient education and communication with post-discharge caregivers.

A published systematic review assessing the use of mobile applications to support health care providers in primary care who care for patients with chronic wounds demonstrated that using smartphone applications in wound management had positive outcomes [7]. Of the listed studies in the review, only one assessed productivity improvement using digital imagery for better documentation and analysis [8]. However, the study did not make any comparison with traditional methods for comparative analysis. Time measurement was an estimation based on author's experience rather than actual timing. Our study has the advantage of acquiring more precise estimates through a time motion study. The above methodology described on FTE savings can be adapted to respective healthcare institutes context to calculate and ascertain cost savings.

Some study limitations are acknowledged including the possibility of bias resulting from repeated measurements carried out by the nurses. This could lead to the times observed in the second measurement being more reduced than the first. Our study attempted to minimize this bias through randomizing the sequence of the measurement and documentation procedures to be carried out by the nurses. Information bias in the form of observer bias was also a possible issue in this study. We attempted to address this by ensuring the research assistant was well trained to recognize the various steps in the wound care process, ensuring the time measurements were done as precisely as possible. Another limitation of this study was that random assignment was generated assuming a possible recruited sample size of up to 40 inpatients. As the recruited patient number was stopped at 30 (which was already

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above the sample size required of 19 inpatients), this resulted in a proportional difference between those receiving the conventional manual process or WCD first.

In conclusion, the adoption of a mobile WCD such as the KroniKare Wound Scanner has potential to improve work productivity and result in FTE savings for all nurses involved in wound care. Most importantly, the WCD could provide clinically beneficial outcomes for the patient by enhancing the management and documentation of wound care.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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Supplementary material

Supplementary Material. KroniKare Proof of Value (PoV) Report.

Supplemental data can be found at: https://doi.org/10.22467/jwmr.2022.01991.

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