

Clinical, Operational and Economic Benefits of a Digitally Enabled Wound Care Program in Home Health: Quasi-Experimental Pre-post Comparative Design

Heba Tallah Mohammed, Kathleen Corcoran, Kyle Lavergne, Angela Graham, Daniel Gill, Kwame Jones, Shivika Singal, Malini Krishnamoorthy, Amy Casata, David Mannion, Robert D. J. Fraser

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Abstract

Background: The demand for home health (HH) care and nursing visits has steadily increased, requiring significant allocation of resources for wound care. Many HH agencies operate below capacity due to clinician shortages, meeting only 61-70% of demand and frequently declining wound care referrals. Implementing Artificial Intelligence (AI)-powered digital wound care solutions (DWCS) offers an opportunity to enhance wound care programs by improving scalability and effectiveness through better monitoring and risk identification.

Objective: This study assessed clinical and operational outcomes across 14 HH branches that adopted DWCS, comparing pre- and post-adoption data and outcomes with 27 control branches without the technology.

Methods: This quasi-experimental study with pre-post comparative design analyzed clinical outcomes, including average days to wound healing, and operational outcomes such as skilled nursing (SN) visits per episode (VPE) and in-home visit durations, during two seven-month intervals (November-May 2020-2021 and 2021-2022). Data were extracted from 14,278 wound care patients across adoption and control branches. Projected cost savings were also calculated based on reductions in SN visits.

Results: The adoption branches showed a 4.3% reduction in SN VPE and a 2.5% reduction in visit duration, saving approximately 309 staff days. In contrast, control branches experienced a 4.5% increase in SN VPE and a 2.2% rise in visit duration, adding 42 days. Healing times improved significantly in the adoption branches, with a reduction of 4.3 days on average per wound compared to 1.6 days in control branches ($p < 0.001$), with pressure injuries, venous ulcers, and surgical wounds showing the most substantial improvements.

Conclusions: Integrating digital wound management technology enhances clinical outcomes, operational efficiencies, and cost savings in HH settings. A reduction of 0.3 SN visits per episode could generate annual savings of up to \$958,201 across the organization. The adoption branches avoided 1,187 additional visits during the study period. If control branches had implemented DWCS and achieved similar outcomes, they would have saved 18,546 healing days. These findings emphasize the importance of incorporating DWCS into wound care programs to address increasing demands, clinician shortages, and rising healthcare costs while maintaining positive clinical outcomes.

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Clinical, Operational and Economic Benefits of a Digitally Enabled Wound Care Program in Home Health

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Abstract

Introduction:

The demand for home health (HH) care and nursing visits has steadily increased, requiring significant allocation of resources for wound care. Many HH agencies operate below capacity due to clinician shortages, meeting only 61-70% of demand and frequently declining wound care referrals. Implementing Artificial Intelligence (AI)-powered digital wound care solutions (DWCS) offers an opportunity to enhance wound care programs by improving scalability and effectiveness through better monitoring and risk identification. This study assessed clinical and operational outcomes across 14 HH branches that adopted DWCS, comparing pre- and post-adoption data and outcomes with 27 control branches without the technology.

Methods:

This pre-post comparative study analyzed clinical outcomes, including average days to wound healing, and operational outcomes such as skilled nursing (SN) visits per episode (VPE) and in-home visit durations, during two seven-month intervals (November-May 2020-2021 and 2021-2022). Data were extracted from 14,278 wound care patients across adoption and control branches. Projected cost savings were also calculated based on reductions in SN visits.

Results:

The adoption branches showed a 4.3% reduction in SN VPE and a 2.5% reduction in visit duration, saving approximately 309 staff days. In contrast, control branches experienced a 4.5% increase in SN VPE and a 2.2% rise in visit duration, adding 42 days. Healing times improved significantly in the adoption branches, with a reduction of 4.3 days on average per wound compared to 1.6 days in control branches ($p < 0.001$), with pressure injuries, venous ulcers, and surgical wounds showing the most substantial improvements.

Conclusion:

Integrating digital wound management technology enhances clinical outcomes, operational efficiencies, and cost savings in HH settings. A reduction of 0.3 SN visits per episode could generate annual savings of up to \$958,201 across the organization. The adoption branches avoided 1,187 additional visits during the study period. If control branches had implemented DWCS and achieved similar outcomes, they would have saved 18,546 healing days. These findings emphasize the importance of incorporating DWCS into wound care programs to address increasing demands, clinician shortages, and rising healthcare costs while maintaining positive clinical outcomes.

Keywords: Home Health Care; Artificial Intelligence (AI); Digital Wound Care; Wound Assessment; Operational Efficiency; Clinical Outcomes; Healing Time; Cost Saving; Skilled Nursing Visits.

Introduction

The demand for home health (HH) care and nursing visits has surged due to the persistent rise in the prevalence of comorbidities and the aging population [1,2]. In the United States, 2% of the population suffers from complex chronic wounds, further driving the growing demand for home health care services [3]. Approximately, a third of HH patients have at least one wound [4,5], leading to a substantial allocation of a home health care's budget and resources for nursing visits dedicated to wound assessment and care [5]. Nursing visits in in-home health agencies consume a significant proportion of healthcare delivery costs, primarily due to the time spent by nurses in assessing and managing wounds [6]. Studies have indicated that wound management utilizes, on average, about 50-70 % of the nurses' resources [7, 8, 9,10,11], with over 60% of their time dedicated to changing dressings [12] (O'Keeffe, 2008), resulting in an average of extra three visits per week [7].

According to the 2019 report from the Centers for Medicare & Medicare Services (CMS), 1.6% of the US population received wound care at a Medicare certified home health agency, totaling 5,266,931 individuals with wounds [13]. This suggests that approximately 15,800,793 patient contacts for dressing changes occur per week, requiring around 7,900,396 clinician hours per week to be spent on wound care visits in home health agencies (HHAs) [13]. Research supports the notion that effective wound care management is best achieved through a collaborative healthcare team [14]. However, the absence of a standardized approach to evaluating wounds and the limited communication platforms for supporting collaboration between clinicians may lead to unnecessary or prolonged visits and extended healing times [15].

Research studies have reported that wounds, especially pressure injuries pose the highest risk factor for hospitalization, increasing hospitalization stay by an average of 4.31 [16],[17]. Thus, with one in three of the HH population dealing with wounds, a focus on providing higher quality, more efficient care for wound patients has the potential to lead to faster healing and reduced complications for patients, and a substantial cost savings and improved reimbursement for HH agencies and the healthcare system.

The increasing number of visits, visit duration, healing time for wounds, and hospital stays have placed a significant burden on the already financially strained healthcare system, compounded by a shortage of specialized nurses [18]. The majority of home health agencies operate below capacity due to clinician shortage, only meeting 61-70% of the demand for wound care, leading many to reject wound care referrals [19,20]. This crisis is partly due to inadequate allocation of resources, funding constraints at the organizational level, and the increasing number of nurses leaving the practice or retiring [18]. Thus, addressing the substantial resource demand for managing

chronic wounds poses a significant challenge for these agencies [5].

In light of these challenges, it remains crucial to control costs while optimizing outcomes within the healthcare system. Recognizing the high complexity and resource costs of providing wound care in HH, the CMS allocated the highest base reimbursement for the wound clinical grouping under its Patient Driven Groupings Model value-based payment regime, which was rolled out nationwide in 2020 [13]. Additionally, to address the sustainable healthcare costs associated with unintended hospital use (such as acute care hospitalizations and emergency department visits), CMS introduced its Expanded Home Health Value Based Purchasing Model in 2023. This program adjusts an HH agency's annual Medicare reimbursement based on the achievement of various quality measures, with the most heavily weighted measure being "unintended hospital use."

Utilizing a digital wound care solution (DWCS) for wound patients has been linked to faster healing times [21] and more efficient wound care documentation [22]. DWCS integrates artificial intelligence (AI) to monitor wound progress and identify potential risks [23], and is interoperable with organizational systems, allowing efficient and secure data exchange. The seamless data exchange through AI technologies [24] is crucial for establishing a cohesive wound care program that can adopt and scale digital documentation and objective AI assessment data. Recognizing these benefits, many healthcare settings have transitioned to incorporating digital technologies to enhance clinician efficiency, capacity, and confidence, ultimately allowing them to deliver a higher quality of care to more wound-care patients [21,22,25].

In 2021, CenterWell Home Health (CenterWell), a home healthcare agency with 355 branches

across 40 states in the US, launched a comprehensive wound care program to deliver high-quality care. The program involved providing advanced education and training for clinicians in wound management and utilizing the DWCS Swift Skin and Wound for quality wound care evaluations. The training program, known as Prevention Intervention, Management, and Education (PRIME), was designed to build the knowledge, skills, and abilities of clinicians in wound care, establishing a network of skilled wound care champions in the field. The DWCS is an evidence-aligned AI-based technology that captures precise wound images and accurate measurements and provides predictive analytics supporting the Wound Escalation processes to provide ongoing performance support.

There is a lack of research evaluating the impact of integrating technology into wound care delivery within an HH setting. To our knowledge, this study represents the first attempt to outline the clinical and operational advantages of a wound care program incorporating digital technology in an HH environment. The study's objective was to evaluate the enhancements in clinical outcomes (such as the average time required to heal a wound) and operational outcomes (including the volume of skilled nursing (SN) visits per episode and the duration of in-home SN visits) at 14 CenterWell branches (initially scoped for this implementation and study). We examined the same seven-month period (November to May) before (2020) and after (2021) the implementation of the digital wound care management solution as part of the comprehensive wound care model in HH. Additionally, the study compared the changes in these clinical and operational benefits with a similar control group of PRIME-certified home health branches that had not yet adopted the digital solution.

Methods

Study design and data sources

This benefits evaluation study employed a pre-post comparative design, utilizing wound care

data captured in the Homecare Homebase (HCHB) health information system. HCHB is an electronic medical records (EMR) software developed in 1999. This software is hosted on the cloud and is designed to facilitate HH care frontline workers' abilities to monitor their clinical outcomes and operational activities to enhance the quality of patient care.

Through the HCHB platform, a HH organization can extract a wide range of clinical and administrative data. This includes admission/referral data, patient assessment details such as start date of wound care, 60-day episode start and end dates, wound types and stages, as well as the date and time of visits within the 60-day episode. Additionally, it can retrieve information about the discipline and service code of clinicians conducting the visits, discharge dates, hospitalization details, patients' demographics, comorbidities, and payer types. The study's focus was to extract structured data that pertains to the comprehensive management of patients with wounds. This involved filtering the data within the study periods to include records of patients with wounds in the Integumentary Command Center (ICC).

In this study, for the post-adoption data, the DWCS used industry-standard protocols (e.g., Health Level 7 [HL7]) to wirelessly transfer encrypted wound care information (wound images and documentation recorded by clinicians at the participating branches using the solution) bidirectionally with HCHB in real time to ensure outcome data could be monitored and to eliminate double documentation. Wound care data were then accessed from the EMR for tracking and analysis. All communications to the servers follow the Advanced Encryption Standards and comply with the Health Insurance Portability and Accountability Act.

The Institutional Review Board approval was provided by CenterWell HealthCare Center for

this quality improvement (QI) descriptive evaluation study. This QI study, which adheres to Tri Council Policy Statement (TCPS) QI policy, was granted an exemption of ethics review (ID:2023-0100) from Pearl IRB, LLC, an independent institutional review board.

Data abstraction process and sample

The anonymous wound care assessment records were collected from the ICC, an entity focused on the comprehensive management of patients with wounds, at 14 CenterWell branches where the DWCS was implemented as part of the comprehensive wound care model. Additionally, records were obtained from 27 control branches at CenterWell that had not yet adopted DWCS into practice. The 27 control sites were carefully selected to match the criteria of the adopted branches in terms of size, geographical locations, capacity, volume of referrals, and the clinicians' levels of clinical wound care education, training, skills, and expertise. This rigorous selection process aimed to ensure an unbiased comparison when assessing the impact of DWCS technology on clinical and operational outcomes.

This study compared the change in clinical outcomes by analyzing the median days to heal a wound in the pre- and post-adoption periods within the study timeframe for the 14 adoption sites and the 27 control sites. Additionally, operational outcomes were compared, including the number of skilled nursing (SN) visits per episode (VPE), the associated projected cost-savings and the duration of in-home SN visits in the same periods for the adopted and control branches.

The study and analysis included wound assessments of all patients with any type of wound that met the following criteria:

1. Wound records (primary and secondary diagnoses) of any type recorded on admission from both adopted and control branches at CenterWell that were referred to and managed at these sites during the seven-month study period (Nov 1, 2020- May 31, 2021, and Nov 1, 2021- May 31, 2022).
2. For the post-adoption period, wounds had to be assessed and managed using the Swift Medical solution at the participating 14 adoption branches in the post-period.
3. The records pertained to adult patients 18 years of age or older.

Any wounds outside of the study period were excluded from the analysis. Patients at adoption branches who did not receive wound care using the technology during the study period were not included in the analysis in the post-adoption period. This exclusion applied to patients with closed surgical wounds, external fixators, bruising, cellulitis, and extensive diffuse dermatological conditions.

We collected and included data from 5,239 60-day wound episodes of 3,738 unique patients in 2020/2021 (pre-adoption) and 3,958 60-day wound episodes involving 2,757 unique patients in 2021/2022 (post-adoption) from the 14 adopted branches. Similarly, for the 27 control branches, the analysis incorporated data from 5,592 60-day episodes in 2020/2021 (pre-period) of 3,859 unique patients, and 5,429 episodes of 3,924 unique patients in 2021/2022 (post-period).

The organization's wound care research team (KJ, AR, DG, and KC) independently extracted all required wound patient data for the adoption and control branches based on the wound start data and medical record number (MRN) from the HCHB electronic medical records (EMR) during the first week of August 2022. Using the same instrument, filters, steps and procedures, the eligible wound data was accessed and then de-identified for sharing with the evaluation team (HTM and DM) for analysis. Each patient was assigned a study and episode ID number, with no MRN-study ID developed to ensure patient anonymity.

The de-identified data, including essential wound assessment-related variables such as patients' characteristics, episode ID, referral date, branch code, type of wound, classification and anatomical location of wound, wound care start date and effective date of care, start and end dates of episode, wound status, primary diagnosis, visit start date and time, visit end time, duration of visit, service code and description, discipline code, and payor type, was shared in an Excel TM spreadsheet with the evaluation team through a secure platform.

Statistical analysis

We analyzed wound data in both the adoption and control groups during the pre-post period. This analysis encompassed both numeric variables, such as patients' age, and categorical variables, including patients' sex, wound type, payor type, episode status, and comorbidities. In addition, the study calculated several data indicators:

- **Home visit Utilization:** assessed based on the average number of SN visits per 60-day episode: This metric was determined by dividing the number of SN visits (numerator) by the total number of episodes cared for (denominator) at the participating branches during the study period.
- **Home visit Efficiency:** assessed based on average time to complete a SN visit per 60-day episode: It involved calculating the mean time to complete a skilled nursing (SN) visit, measured in minutes. This calculation was based on the time lapse between the start and end time of each in-home visit per 60-day episode. This analysis considered visits conducted by SNs (registered nurse (RN) and licensed practical nurse (LPN)). These visits included the following specific service description codes: RN Oasis Admission, SN high Tech Visit- Lasting 1.5 Hours, SN Infusion Subsequent Visit, SN PRN Visit as Needed, SN Rapid Subsequent Visit, and SN Subsequent Visit. As no out-of-home documentation occurs for

routine/SN visits, the calculated time encompassed all patient care and documentation activities within a visit. Overall, the findings were summarized using frequencies, mean and standard deviations (SD).

- **Average days to heal a wound:** The analysis of average days to heal a wound focused on any type of wound with an inactive date and considered as “healed”, as determined by CenterWell, were included. The study collected the first and last date (inactive date) of the wound and calculated the average days (mean) to heal based on the number of days between the start date and the inactive date of healed wounds. Open wounds and discharged patients were not included if the wound was not known to be healed. This analysis segmented the data by wound type (i.e., pressure injury, venous ulcer, etc.). A Student sample t-test was used to examine average difference in average days to heal a wound across adopted sites and control branches pre vs. post periods. The significance of the statistical test was accepted at the P value <0.05 .

Data analysis was conducted using the Statistical Package for Social Sciences (SPSS) (SPSS, IBM Corp, Armonk, NY. Version 28; 2022).

The analyses showed that the days to heal for both the adopted and control groups were normally distributed, as assessed by Shapiro-Wilk's normality test ($P>0.05$). Additionally, there was homogeneity of variances, as assessed by Levene's test for equality of variances for both the adopted and control groups ($P=0.167$, $P=0.321$, respectively).

Results

Overall characteristics

The data were collected from 14,278 patients with wounds from both the adoption and

control branches, all of whom were recorded in the ICC platform and fulfilled the inclusion criteria. Of these patients, 26% were from the adoption branches in the pre-period and 19% were from the adoption branches in the post-period. The age of the patients ranged from 23 to 108 years, with approximately half of the participants being female. The included wounds encompassed various types, with surgical wounds and pressure injuries being the most common (Table 1).

Overall, there were no statistically significant differences ($P>0.05$) between the adoption and control groups in the different time periods, indicating a comparable distribution of wound types across the groups.

Table 1: Overall characteristics of wound records at adopted and control branches pre- and post-periods

	Adopted Branches 2020/2021 Nov-May	Adopted Branches 2021/2022 Nov-May	Control Branches 2020/2021 Nov-May	Control Branches 2021/2022 Nov-May
Number of unique patient admission, n	3,738	2,757	3,859	3,924
Age, (Mean±SD)	73.1±13.4	72.3±13.7	73.6±13.2	74.6±11.6
Male n (%)	1,854 (49.6%)	1,331 (48.3%)	1,863 (48.3%)	1,879 (47.9%)
Female n (%)	1,884 (50.4%)	1,426 (51.7%)	1,996 (51.7%)	2,045 (52.1%)
Number of wounds episodes managed at participating branches, n	5,239	3,958	5,592	5,429
Arterial Ulcer n (%)	41 (0.8%)	23 (0.6%)	30 (0.5%)	31(0.6%)
Burn n (%)	24 (0.5%)	11 (0.3%)	37 (0.7%)	36 (0.7%)
Diabetic Ulcer n (%)	254 (4.8%)	120 (3.0%)	326 (5.8%)	285 (5.2%)
Pressure Injury n (%)	1445 (27.6%)	1081 (27.4%)	1535 (27.4%)	1483 (27.3%)
Skin Tear n (%)	278 (5.3%)	230 (5.8%)	416 (7.4%)	379 (7.0%)
Surgical Wound n (%)	1739 (33.2%)	1374 (34.7%)	1406 (25.3%)	1435 (26.4%)
Traumatic Wound n (%)	357 (6.8%)	306 (7.7%)	505 (9.0%)	489 (9.0%)

Venous n (%)	358 (6.8%)	444 (11.2%)	457 (8.2%)	506 (9.3%)
Other* n (%)	743 (14.2%)	369 (9.3%)	880 (15.7%)	785 (14.5%)
Episodes associated with comorbidities, n (%)	2664 (50.8%)	2182 (55.1%)	3143 (56.2%)	3202 (59.0%)
Episodes not associated with comorbidities, n (%)	2575 (49.2%)	1776 (44.9%)	2449 (43.8%)	2224 (41.0%)
Current episodes n (%)	396 (7.6%)	270 (6.8%)	178 (3.2%)	225 (4.1%)
Discharged episodes n (%)	2341 (44.7%)	1780 (45.1%)	2725 (48.7%)	2615 (48.2%)
Recertified episodes n (%)	2502 (47.8%)	1908 (48.3%)	2689 (48.1%)	2589 (47.7%)

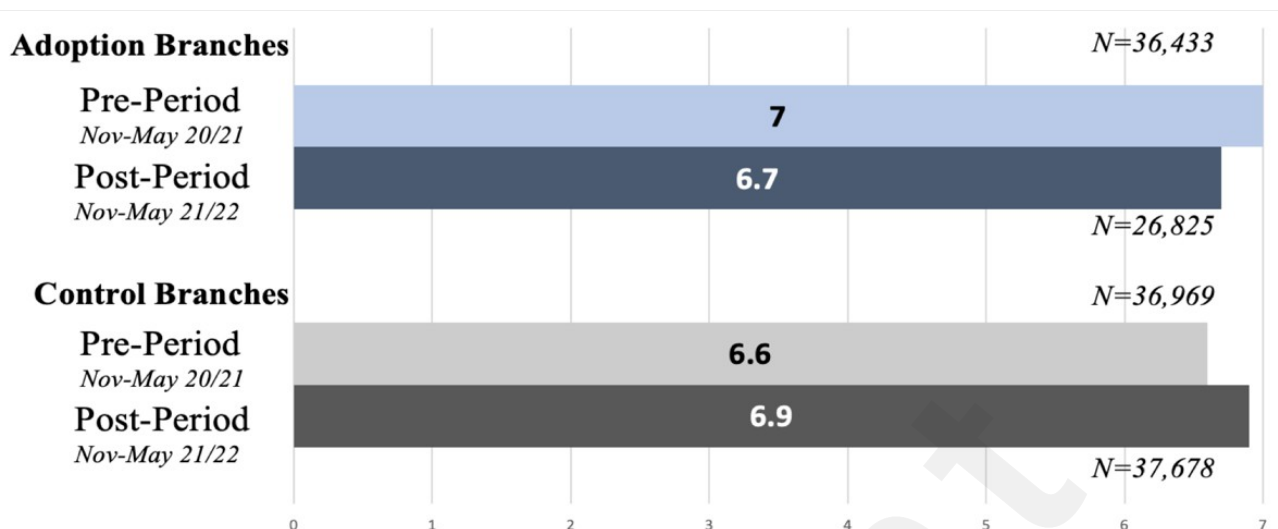
SD, Standard deviation

*Other Types of wounds: Abrasion, laceration, blisters, seroma, carcinoma, hematoma

Reduction in utilization of skilled nursing home care visits

The data shows that the adoption branches experienced a decrease in the average number of SN visits per 60-day episode during the post-adoption period as compared to the pre-adoption period. This led to a decline of 4.3% in the average number of SN visits per wound episode from pre-post periods. On the other hand, the control branches saw a 4.5% increase in the average SN visits per episode. Consequently, the adopted branches showed an 8.7% improvement in visit utilization compared to the control branches over the same period, as illustrated in (Figure 1).

Figure 1: Comparison of average skilled nursing visits per episode between adopted and control branches pre and post periods

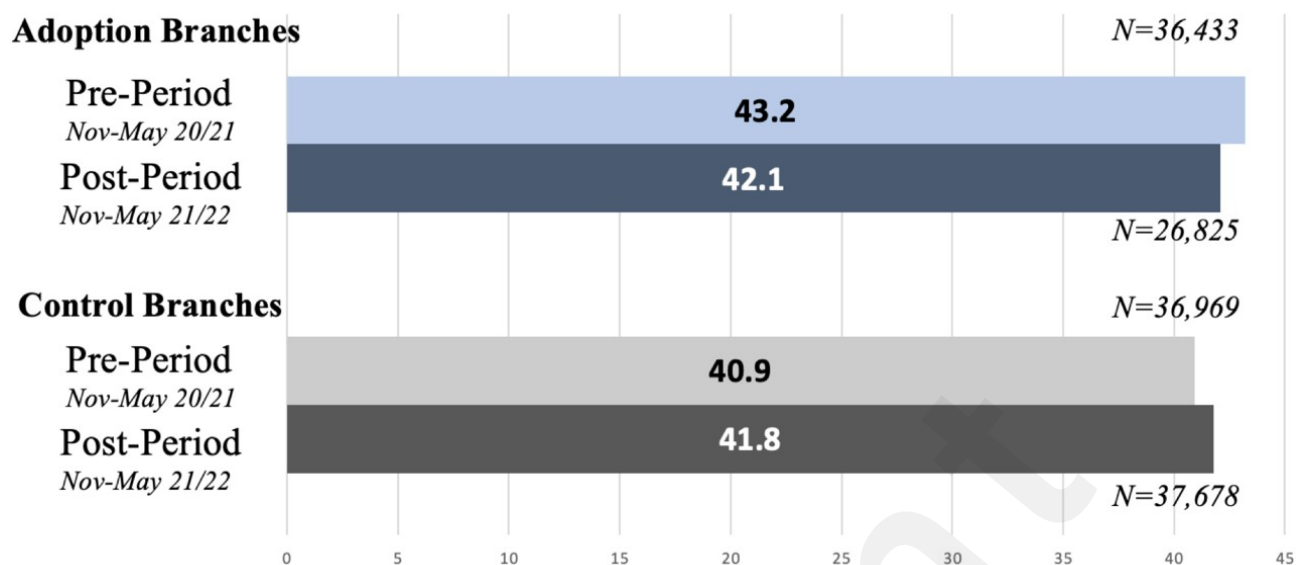


Improved skilled nursing wound care visit efficiency

During the pre-adoption period, the adopted branches spent an average of 43.2 ($\pm$ 40.27) minutes per episode, amounting to 1,573,171 minutes for completing visits. However, in the post-adoption period, the average time per episode reduced to 42.1 ($\pm$ 37.52) minutes, resulting in a total time spent by the adopted branches of 1,128,658 minutes. This decrease led to a 2.5% reduction in the average time required to complete a visit. In total, the adoption group saved 309 days (equivalent to 444,513 minutes) of staff time spent on SN home visits.

On the other hand, the control branches experienced a 2.2% increase in the average time to complete the SN visit, from an average of 40.9 minutes ($\pm$ 34.20) to 41.8 minutes ($\pm$ 36.37). Overall, the adopted branches saw a 4.4% improvement compared to the control group from pre-adoption to post-adoption periods, as depicted in (Figure 2).

Figure 2: Comparison of average time (mean in minutes) to complete a skilled nursing visit between adopted and control branches pre and post periods



Improved average days to heal a wound

A significant decrease in the average healing time of wounds was observed at the adoption branches compared to the control branches ($P<0.001$). On average, the adoption group saw an average reduction of 4.3 days per wound (from 19.7 days to 15.4 days), which was greater than the control group's average reduction of 1.6 days (from 25.9 days to 24.3 days). This corresponds to a 2.7-day improvement compared to the control group, and an overall 15.7% improvement in healing time for the adopted branches (Table 2). Additionally, significant differences were noted in the average days saved between the pre- and post-periods for adopted branches, particularly the reduction in days to heal for pressure injuries, venous ulcers, and surgical wounds ($P=0.010$, $P<0.001$, $P<0.001$, respectively).

In contrast, the average healing time for traumatic wounds, surgical wounds and diabetic ulcers were increased from pre-to post-periods for the control groups. No significant differences were found for any saved days for different types of wounds between the control group pre/post-periods (Table 2).

Table 2: Average days to heal a wound per adopted and control branches pre and post periods

Type of wound	Adopted Branches 2020/2021 Nov-May Mean±SD (N)	Adopted Branches 2021/2022 Nov-May N (Mean±SD)	P Value	Control Branches 2020/2021 Nov-May N (Mean±SD)	Control Branches 2021/2022 Nov-May N (Mean±SD)	P Value
All wounds	19.7±13.9 (N =2185)	15.4±15.0 (N=1856)	<0.001	25.9±20.4 (N=2770)	24.3±19.7 (N= 2200)	0.976
Diabetic Ulcer	17.9±12.6 (N= 106)	16.8±15.4 (N= 55)	0.676	34.0±21.1 (N= 326)	34.2±18.3 (N= 261)	0.985
Pressure Injury	18.9±13.0 (N=679)	15.3±14.3 (N= 540)	0.010	30.4±21.2 (N=735)	29.9±18.6 (N=695)	0.877
Skin Tear	16.8±11.6 (N=72)	14.3±11.7 (N= 80)	0.137	14.4±15.2 (N=116)	14.2±14.6 (N= 110)	0.922
Surgical Wound	20.8±15.2 (N=608)	15.4±15.9 (N=508)	<0.001	18.3±18.0 (N=514)	21.3± 16.7 (N=345)	0.010
Traumatic Wound	20.8±13.5 (N=136)	17.9±15.6 (N=183)	0.056	22.9±19.9 (N=305)	24.0±19.8 (N= 125)	0.191
Venous Ulcer	18.9±13.3 (N= 268)	13.4±15.4 (N= 313)	<0.001	31.9±21.1 (N= 357)	29.8±20.5 (N= 255)	0.852
Other	21.2±15.7 (N=316)	17.6±15.5 (N= 177)	0.062	28.1±20.9 (N= 280)	30.5± 19.1 (N= 274)	0.319

Discussion

To our knowledge, this descriptive pre/post-evaluation study is the first to investigate the impact of adopting digital wound management technology in a home health setting as part of a comprehensive wound care program. Overall, our study recorded a general improvement in clinical and operational benefits among the adopted branches in the post-implementation period compared to the pre-implementation period, surpassing the control group over the same time frame. For instance, skilled nurses in the adoption group saved 444,513 minutes, equivalent to 309 days, spent conducting

in-home wound care visits after implementing the technology in practice, while the control group added 42 days to the time spent conducting the visits. This finding is crucial for addressing the consequences of the growing shortage of trained nurses in the healthcare system [26] and the increasing demand to cope with the continuous rise in wound prevalence and the aging population [27].

On average, nurses provide patients with three dressing changes per week [28,29,30], and, according to O'Keefe (2006), this takes up to 66% of available nursing time [12]. Also, literature has shown that up to 35% of this time is spent on documentation [26, 31,32,33,34], and 21% is spent on care coordination [26, 31]. In a previous study, Lindholm and colleagues stated that among 694 wound patient populations, changing wound dressings alone consumed time comparable to full-time employment of at about 57 nurses [35].

The time spent changing a dressing in a typical wound care visit is not only about the physical act of changing the dressing, but also always involved other activities such as wound assessment, measurement, and decision-making on the need to change a dressing and the choice of dressing. This comprehensive approach can make the process time-consuming for nurses, as highlighted in studies by Hadcock (2000) and Fletcher & Wasek (2016) [36, 37] and could be challenging at times [37]. Moreover, the advent of electronic health records (EHRs) was intended to streamline wound care coordination and documentation at HH organizations [38], but studies by [39], Sockolow et al. (2016) [40], and [38] have shown that EHRs may only partially support these processes and can add to the nurses' workload.

The time-saving benefits documented in our study aligns with a previous study that found implementing Swift Medical in an outpatient clinic could potentially save up to 51.7 days of

clinicians' time per year compared to traditional wound assessment methods [22]. The observed time saved during home visits may be attributed to the provision to nurses of a technology helping to facilitate effective wound management. The technology allowed for accurate clinical wound information and precise wound images to be captured, enabled online documentation during visits, electronic exchange of clinical information, and facilitated remote monitoring with experts. This accessibility to best practice wound assessment ultimately led to improved care and cost outcomes.

Further, after implementing the technology, the adopted branches also experienced a 4.3% reduction in the average number of SN visits needed to care for a wound per episode. This reduction in SN home visits per episode could generate significant cost savings in the home health care setting. Assuming the average hourly rates of LPN and RN conducting the SN visits in home health care range from \$26.85 to \$42.85, according to the US Bureau of Labor Statistics [41], CenterWell could potentially save \$600,413 to \$958,201 annually across the organization for every 0.3 reductions in SN visits per episode, based on a total of 60,898 episodes cared for at the organization in a year. Furthermore, compared to the control group, if the adopted branches had not implemented Swift, they would have conducted an additional 1,187 visits during the study period.

Evidence suggests that incorporating technology into wound care management can lead to substantial cost savings by reducing nurses' transportation costs and the utilization of wound care materials with each additional visit [42]. Additionally, Lindholm and colleagues demonstrated in a cost-effectiveness study that saving 260 hours of nurses' time per year could result in up to an 80% reduction in management costs [5]. This, in turn, could lead to a reduction in care delivery costs and an increase in practice capacity, allowing for better resource management and reduced workload on clinicians, which may mitigate costs associated with staff burnout, attrition, and recruitment [43]. The time saved could be redirected to managing other patients or engaging in valuable activities [5].

A survey study indicated that clinicians expressed a strong interest in using any saved time to educate current patients on dressing change techniques, thus creating an opportunity for additional time savings that could be allocated to care coordination [37].

It's important to note that despite conducting fewer visits per wound episode and saving time on each visit at the adopted branches, the quality of care provided at these branches remained consistently high. In fact, there was a significant improvement in the average days to heal a wound between the pre- and post-period at the adopted branches. Several research studies have shown that chronic wounds often have extended healing times, which can lead to increased consultation time, treatment supply consumption, dressing changes, and assessment sessions [44, 45,46,47,48]. Moreover, prolonged healing times can increase the risk of complications and hospitalization, ultimately adding to the total cost of wound care [44, 45,46,47,48]. As a result, time to heal could be the principal driver in reducing total wound care costs [45,46,47,48]. Our findings revealed a 15.7% reduction in the average days to heal a wound for the branches that adopted the technology from the pre- to post-period ($P<0.001$), resulting in a savings of 4.3 days for the adoption branches, and only 1.6 days for the control branches. It is projected that if the control branches had adopted the solution and experienced the same improvement as the adoption group, they would have saved 18,546 days in healing patients with wounds over the same period.

The management of wound care involves a variety of practices including assessment, treatment delivery, utilization of advanced products, services, and supportive tools to improve skills and optimize wound care and management [49,50,51]. The inclusion of AI technology in wound care can significantly enhance clinicians' ability to manage patient care through precision, efficiency, and interoperability. A study by Chairat and others demonstrated that AI integration can streamline documentation and ensure smooth data exchange across the healthcare system [24]. Research also

has demonstrated that AI algorithms, when applied to wound images captured by smart devices, can achieve over 90% accuracy in identifying wound types and dimensions, streamlining the documentation process, and ensuring seamless data exchange across healthcare systems [24]. Therefore, integrating technology as an essential component of the program is crucial for enhancing wound care, as evidenced by various studies [44, 49,50,51,52].

Our research indicates that implementing wound care management technology enhances patient outcomes and contributes to cost containment and savings. This aligns with the estimated \$15.7 trillion expansion of the global economy by 2030 attributed to the implementation of AI-based technologies, including assisted intelligence, automation, and autonomous intelligence [53]. Additionally, staying current with wound care knowledge and advancements and integrating technology can significantly improve proficiency in wound care and assist evidence-informed clinicians in delivering effective treatment recommendations, irrespective of wound complexity or clinician expertise.

Chronic wounds are often tied to comorbid conditions, increasing the complexity of wound management and placing more burdens on clinicians and patients [46]. Meanwhile, CMS expects HHAs to take on more responsibility in caring for these clinically complex patients and bridge the referral gap in this population [13].

Hence, it is essential to modernize healthcare and implement wound management technology to bolster evidence-based practices and enhance clinical management [50], regardless of the wound complexity or the practitioners' experience [50, 54,55,56]. This can be accomplished through the practical implementation of deep learning for automated tracing of wound dimensions, accurate measurements [22], automated wound tissue segmentation [57], and predictive modelling [58], thus

enabling real-time decision-making that ensures timely patient-centered care.

As evidenced by our study, the branches that adopted the digital solution demonstrated improvements in managing more complex wounds with comorbid conditions, showing a 1.5% increase compared to the control group. Additionally, these branches reported a 5% improvement in the rate of healed wounds from the pre-post period, contrasting with the observed 9% decrease in the overall rate of healed wounds at the control branches. These findings illustrate a modest improvement in the effectiveness of utilizing advanced wound management solutions that have the opportunity of a larger impact if adopted across additional branches within the enterprise. Therefore, integrating AI-powered wound management technology into a comprehensive wound care model enables better wound care delivery and management.

Limitation/Strength

A major strength of this study is the inclusion of wound care patients managed at 41 different branches at one of the largest home health agencies in the US. We also included a control group of 27 PRIME certified branches, allowing us to compare operational and clinical changes and marginal benefits against them for the same periods. However, while the branches (adoption and control groups) were comparable with regard to demographics, clinical variables, and wound care education/training, generalizing the results warrants caution. Other institutions may not be similar in size, patient demographics, and operational and clinical workflow, so the results should be interpreted within this context.

We utilized the as-treated analysis approach to gain valuable insight into the impact of implementing the Swift Medical solution in practice. To ensure the accuracy of our findings, we excluded patients who had not undergone assessment using Swift at the adopted sites during the

study period. This approach provided a focused understanding of the true impact of the technology on the assessed outcomes.

It's important to note that this study was conducted within a specific time frame of 7 months (November to May) in both 2020-2021 and 2021-2022. The Covid-19 pandemic significantly disrupted priorities and various aspects of the wound care continuum in 2020, as highlighted by Sen et al., 2021 [59]. The increased infection rates of the respiratory pathogen among populations with comorbidities prompted heightened attention to high-risk patients [59] in the pre-adoption period, and this may have had an unforeseen impact on our findings, either positive or negative.

In addition, due to a lack of data, the study did not assess the sociodemographic variables of patients with wounds, diagnostic methods, nurses' travel costs, cost of utilized wound supplies, patient costs or quality of life. Including these variables in exploring the technology's cost-effectiveness would provide valuable insight into the potential savings associated with technology in wound care. A future comprehensive cost-effectiveness study that includes all these variables would be beneficial in informing policymakers and payers about the tangible economic impact of adopting technology for home health to reduce care costs and improve patient outcomes.

Nevertheless, the present study presented preliminary data on the impact of adopting a comprehensive wound care management model with the inclusion of technology. Our findings illustrated that home health agencies could realize cost savings and clinical and operational improvements by integrating this technology into the wound care program. Therefore, the results may hold significant value for healthcare providers, administrators, policymakers, and insurance companies.

Conclusion

Incorporating wound management technology into the wound care paradigm can improve operational efficiencies in home health settings by reducing the time required to complete in-home visits and decreasing the volume of skilled nursing visits per episode. These benefits can lead to significant cost savings. In addition, this approach also supports more effective clinical care, leading to faster wound healing, which facilitates the managing of more wound episodes annually, ultimately increasing revenue.

There is a clear need to establish a standardized comprehensive approach that incorporates digital tools as part of the wound care program. Doing so can help address challenges related to wound care assessment, the increasing demands, the limited human health resources and increased burnout within the healthcare setting.

Furthermore, by following Centerwell's example of enhancing clinicians' wound care knowledge and skills with the aid of wound care management technology, other home healthcare organizations can achieve similar results. This includes reducing the average healing time of wounds by 27% and saving clinicians approximately 530 days annually that would have been spent on conducting more in-home wound care visits.

Conflicts of Interest

HTM, AC, RDJF are all current employees of Swift Medical Inc. DM is a former employee of Swift Medical Inc. All other authors have no conflicts to declare.

Abbreviation

Home health agencies (HHAs)

Centers for Medicare & Medicare Services (CMS)

digital wound care solution (DWCS)

artificial intelligence (AI)

CenterWell Home Health (CenterWell)

skilled nursing (SN)

Homecare Homebase (HCHB)

electronic medical records (EMR)

Integumentary Command Center (ICC)

quality improvement (QI)

visits per episode (VPE)

medical record number (MRN)

registered nurse (RN)

licensed practical nurse (LPN)

standard deviations (SD)

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