AI-Driven Predictive Models For Wound Deterioration: A Pilot Study

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Introduction

Chronic wounds, particularly diabetic foot ulcers, venous leg ulcers and pressure injuries, pose a substantial health challenge, affecting 1-2% population in developed countries.[1] These wounds are at increased risk of infection and complications,[2] leading to a substantially high annual treatment costs estimated between $28 billion and $96 billion (all figures in USD) in the US.[3] Despite advancements in wound care management, the assessment and prediction of healing outcomes remain hindered by the subjective evaluations of clinicians,[4] whose varying levels of accuracy can lead to inconsistent treatment approaches.[5]

Artificial intelligence (AI) has emerged as a

transformative force in wound care, significantly enhancing the prediction of healing outcomes. AI-driven algorithms have demonstrated remarkable effectiveness in measuring wound dimensions accurately and identifying key prognostic features such as tissue composition, granulation, slough, eschar and exudate, all of which are critical for determining wound burden and healing trajectory.[6] Evidence shows machine learning (ML) predictive algorithms evaluate various aspects of wound attributes—such as size, tissue composition, edges, location and exudate—to predict healing trajectories more accurately and flag deteriorating wounds early.[7]

For instance, Berezo and colleagues in 2021 found that ML algorithms could integrate multiple wound characteristics with patient data, resulting in a far more accurate prediction of delayed healing than traditional assessment methods.[8] This enhancement positions AI as a valuable resource for clinicians aiming to implement timely interventions in wound management. Similarly, Patel et al. (2024) utilized a large dataset to explore the effects of AI-driven analytics on wound care. Their findings revealed that AI models could effectively monitor wound progress, detecting subtle changes in healing patterns, thereby providing more reliable predictions than conventional models.[9]

A home health (HH) enterprise operating across 40 states has opted for the AI-powered HealingIndex™ (HI) feature (Swift Medical Inc., Toronto, Canada) – hereafter referred to as the AI Model - which leverages deep-learning and machine learning to analyze a range of wound characteristics, including wound size, tissue composition—such as granulation, slough, epithelialization and eschar—and wound exudates to predict healing trajectories as part of its digital wound care solution to improve the quality of wound care. The AI Model uses advanced deep ML algorithms to assess various factors, such as wound size, tissue types within wounds—including granulation, slough, epithelialization and eschar—and wound exudates to determine healing trajectories. Automating wound assessments and pinpointing deteriorating trends based on these factors enables early detection of declining conditions. This timely alert system allows clinicians to intervene quickly, reducing the risk of overlooked complications and ensuring better patient outcomes.

This quality improvement pilot study aimed to assess feedback from clinicians and branch managers regarding the effectiveness and functionality of this AI technology in identifying deteriorating cases, despite clinicians reporting improvements within the home health enterprise. Furthermore, the study examined clinicians' satisfaction and perspectives on the AI Model escalation reports and their perceived benefits.

Methods

Methodology

Study Design and Setting: This quality improvement pilot study took place in May 2023 at two branches of a home health enterprise specializing in in-home care services. The integration of the AI Model feature was implemented within the wound management workflow at both locations, primarily focusing on scanning wounds that clinicians had documented as showing improvement.

Wound Assessment Using HealingIndex™ (HI): The HI AI Model uses a deep learning model to analyze patient wound records, images and characteristics, generating a hazard ratio that assigns a score between 0 and 100 for each wound. A higher AI Model score signifies an increased risk of delayed healing or deterioration (Gupta et al., 2024). Wound evaluations were flagged based on the following criteria:

- A change in the AI Model score greater than 20 points over a 7- to 14-day period.
- The wound size was greater than 1 cm^2.

When these conditions were met, the individual wound was flagged as deteriorating and included in a report generated for branch managers and clinicians. This report prompted a comprehensive review of the patient's record and plan of care.

Sample and Data Collection: This pilot study was conducted in May 2023. During the pilot period, a total of 900 wound evaluations were performed across the two participating branches. Clinicians

recorded that 595 of these wounds showed improvement. Therefore, these wounds were subsequently scanned using the AI Model feature. According to the predetermined thresholds, 4.5% of the wound assessments originally recorded as improving were flagged by HI as deteriorating, indicating a need for further review by the branch managers. Clinicians feedback on each escalation report was collected.

To evaluate clinicians' perspectives on the AI Model escalation reports, an online survey was administered using SurveyMonkey. This survey consisted of seven quantitative questions aimed at gathering feedback from both clinicians and branch managers regarding their experiences with the flagged reports and the AI-driven recommendations. The survey was sent to all seven clinicians and branch managers who had received and reviewed the escalation reports during the pilot study.

The survey was available for two weeks starting on February 26, 2024, providing participants adequate time to share their feedback. All clinicians and branch managers who received the survey completed it.

Results

The survey results indicated that 85.7% of respondents were satisfied with their overall experience in receiving and using escalation reports. Also, 85.7% of participants believed the automated AI Model escalation reports to be accurate in monitoring wound progress and identifying clinical concerns. Furthermore, they agreed that these reports effectively identify potential misinterpretations of wound progress.

Additionally, 85.7% of respondents acknowledged that using the AI Model escalation reports enhances the efficiency of patient care management and improves the quality of care provided to large patient populations within the organization. They also noted that the reports facilitate better care coordination among health-care professionals and are particularly useful in identifying deteriorating wounds. Moreover, these escalation reports can prevent adverse events by ensuring timely flagging of wound deterioration.

Out of the 595 wounds recorded as having improved, 27 assessments were flagged by the AI Model as deteriorating and requiring further review by branch managers. Among these, clinicians who reviewed the cases agreed that 14 instances (52%) showed signs of deterioration rather than improvement after further examining the reports and patient records. In nine cases (33%), the wound alerts did not indicate actual deterioration but highlighted the need for quality improvements, such as better education on documentation to prevent misinterpretation. In the remaining four cases, the reviewers concluded that the deterioration flags were not sufficient to warrant a change in status in their clinical judgement.

Sample: Confirmed Case of Deterioration 1

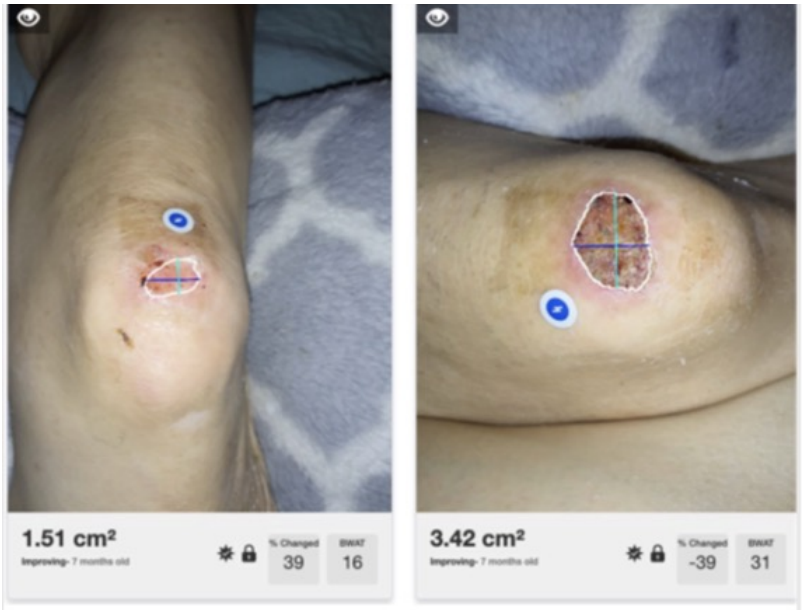

Figure 1: Images of wound marked as improving and flagged as deteriorating by the AI Model.

Figure 1 illustrates an image to the right, taken nine days after the left image, was marked as improving. The documentation noted 75%-100% soft black eschar, with wound depth obscured by necrosis, and the AI Model flagged the wound as deteriorating. Upon further review, the branch manager agreed with the signs of deterioration and suggested orders changes (antimicrobial and moisture promoting dressing for dry wound bed).

Sample: Confirmed Case of Deterioration 2

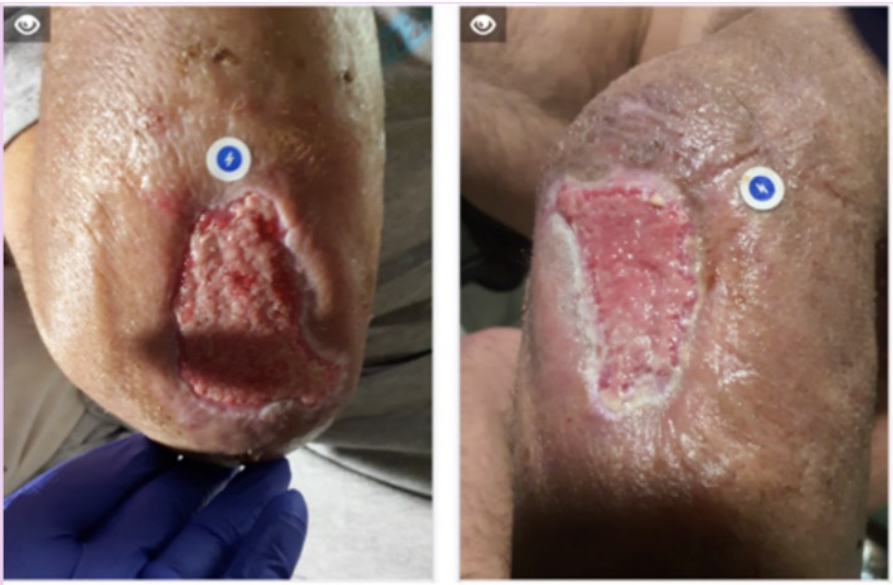

Figure 2: Images of wound marked as improving and flagged as deteriorating by the AI Model.

Figure 2 illustrates a wound that was initially marked as improving, but the AI Model escalation report flagged a deterioration. Upon review, it was found that the wound depth measurement was inaccurately documented as partial thickness instead of full thickness, and the wound edges were incorrectly documented as not attached when they were clearly attached.

Discussion

The current study assessed the acceptance and accuracy of this AI technology in identifying deteriorating wounds that had initially been recorded as improving within a home health setting. One key finding from this research is that 4.5% of the 595 wounds, which were originally classified as improving, were subsequently flagged by the AI Model system for further review due to signs of deterioration. After further evaluation by clinicians and branch managers, it was found that 52% of the cases identified by the AI Model system were indeed experiencing deterioration. This underscores the important role of AI technologies in reducing subjectivity in wound assessments. Traditional evaluation methods often depend heavily on clinicians' interpretations, leading to inconsistencies.[4] This finding aligns with Smith et al. (2021), which highlights the superior precision of AI algorithms compared to traditional assessment methods in predicting delays in healing.[8]

This percentage of identified deteriorations becomes particularly significant when applied to an enterprise with a large wound care population. For instance, in an organization managing 100,000 wound episodes each year, this data translates to around 4,500 flagged cases annually.

Among these, 2,340 cases have been identified by the AI Model solution as experiencing true deterioration, highlighting a critical opportunity for early intervention. By recognizing these cases, which might otherwise remain unnoticed, we can significantly enhance patient outcomes by preventing or reducing adverse events through timely clinical actions. Research emphasizes the importance of early detection in wound care. Untreated or overlooked wounds can lead to serious complications, including infections, increased hospitalization rates, and escalating health-care costs. [1,10]

Research indicates that the average cost of treating a chronic wound can vary significantly, ranging from around $3,000 for non-complicated cases to $50,000 or more for those with severe complications, including infections or hospital readmissions.[2,3] This highlights the substantial clinical implications and potential cost savings associated with early interventions, which are crucial for health-care systems.

If the AI tool flags 2,340 cases that are subsequently confirmed to be deteriorating and receives timely intervention, a significant reduction in complications—such as hospital readmissions, long-term care, and the need for advanced treatments—could be achieved. According to Yap and colleagues, early intervention in deteriorating wounds can prevent up to 30% of hospital readmissions.[7] Applying this statistic to our study, we could potentially avoid approximately 702 hospital readmission cases at a HH enterprise. Given that the average cost of a wound-related hospital stay is approximately $20,000.[3] the overall cost savings from these avoided hospitaliza-

tions could reach around $14.04 million.

Additionally, early identification of a deteriorating wound often allows for the prevention of its progression to more severe stages, which typically require intensive treatment. These treatments—such as surgical debridement, extended antibiotic courses, or specialized therapies—can add significant costs, ranging from $10,000 to $15,000 per patient.[3,10] If the AI tool can successfully prevent 50% of the flagged truly deteriorating cases from advancing to these severe stages, approximately 1,170 patients could avoid intensive treatments, resulting in estimated cost savings of around $11.7 million to $17.55 million to the health-care system.

Moreover, research indicates that 10-20% of chronic wounds, especially those that deteriorate, may advance to stages necessitating prolonged care if left untreated.[1,2] This long-term care can incur costs of about $30,000 annually per patient.[1] Consequently, if the AI tool can help avert long-term care needs in approximately 234 patients, it could yield additional savings of roughly $7.02 million.

The HH enterprise stands to gain significantly from indirect financial benefits associated with enhanced resource allocation and a reduction in adverse events, such as hospital readmissions. These improvements can positively influence HH performance metrics and result in higher reimbursements under value-based purchasing models, including Medicare's Home Health Value-Based Purchasing models.[11]

While Canadian data on episodic wound care spending is difficult to find, US spending illuminates the financial burdens of wound care. With an estimated 60,000 Patient-Driven Groupings Model (PDGM) episodes managed annually by a HH enterprise,[12] and Medicare reimbursements for a typical 60-day care episode ranging from $3,600 to $4,000,[13] the projected annual revenue could reach between $216 million and $240 million. Under the HHVBP model, enterprises that meet or exceed quality metrics—such as decreased readmissions and improved patient outcomes—can receive bonuses of up to 5% on their Medicare revenue.[11] For an enterprise generating $216 million to $240 million in Medicare revenue, this bonus could translate to an additional $10.8 million to $12 million annually.

Moreover, by consistently achieving high-quality outcomes, the reputation of the HH enterprise would improve, driving an increase in referrals and providing a competitive edge in the marketplace.[14]

Another key finding is the identification of flagged cases, which reveal potential areas for quality enhancement. Although these cases did not demonstrate any real deterioration of wounds, they underscored a crucial secondary benefit of the tool of enhancing the accuracy and consistency in wound documentation. This observation aligns with other research demonstrating that AI tools can bolster clinician training and support continuous quality improvement. For example, a study in *BMC Medical Education* highlighted that AI tools enrich clinical education by providing real-time feedback, enabling medical trainees to make informed decisions and enhance care accuracy.[15]

The cumulative impact of AI-driven tools extends beyond mere outcomes and cost efficiency; it significantly improves the quality of care, ultimately easing the strain on health-care resources. Our findings highlight the transformative potential of AI-driven tools like the AI Model in the field of wound care. By adeptly identifying clinical challenges and fostering continuous enhancements in documentation practices, the AI Model minimizes variability in wound care assessments, leading to more consistent and accurate evaluations. This consistency facilitates timely interventions, reduces the risk of wound deterioration and supports personalized treatment approaches, all of which contribute to better patient outcomes. Furthermore, enhanced accuracy in tracking wounds and planning interventions reduces preventable complications, hospital readmissions, and the necessity for more intensive therapies.

Limitation

While the insights obtained from the sample were valuable in evaluating the functionality of the AI tool, the results are limited to the two participat-

ing branches and may not accurately reflect the tool's effectiveness in other home health environments. This limitation hinders the ability to generalize the findings to broader health-care settings. Future research should focus on larger sample sizes and diverse patient demographics, as well as varying wound types, to further validate these findings. Additionally, although clinicians reported a general satisfaction with the AI tool, ongoing training and enhancements to documentation processes will be crucial for optimizing the effective integration of AI in wound management.

Conclusion

This study highlights the significance of AI-driven tools like HealingIndex™ in enhancing wound care management. By facilitating the detection of deteriorating wounds and improving the quality of documentation, these technologies foster better care coordination and ultimately lead to improved quality of care.

Future research should prioritize exploring the effects of AI-driven tools on wound care outcomes and their potential applications in diverse health-care environments.

Research Ethics and Patient Consent

This study adhered to the Declaration of Helsinki guidelines for research involving human subjects. The home health agency implementing the technology did not require formal research ethics board approval as it was part of a quality improvement program under the oversight of the clinical operations leadership. In the program analysis, no personal or identifiable information was accessible to the researchers.

Conflict of Interest

HTM is the Associate Director of Clinical Innovation at Swift Medical. **RDJF** is employed by Swift Medical as the Vice President of Clinical Innovation. **RG** was formerly employed by Swift Medical as Head of AI. **SW** is Chief Medical Officer at Swift Medical. **AC** is employed by Swift Medical as the Senior Vice President of Client Success.

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