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Advancing wound care: a scoping review protocol on biological parameters in smart dressings

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Abstract

Background Chronic wounds pose a major healthcare challenge due to delayed healing, infection risks, and they are associated with chronic conditions, such as diabetes and cardiovascular disease. Smart wound dressings, integrating sensor technologies to monitor biological parameters, offer promising advancements in wound management. However, a comprehensive understanding of the parameters they monitor, and their clinical significance remains limited.

Methods Following the Joanna Briggs Institute (JBI) methodology and PRISMA-ScR guidelines, a systematic search will be conducted in MEDLINE (via Ovid), Embase, Web of Science, CINAHL (EBSCO), and

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derived from the Population, Concept, and Context (PCC) framework.

Data extraction will be performed using Elicit®, an AI tool, and independently verified. A narrative synthesis will categorise themes.

Discussion and conclusions This review will systematically map available evidence, offering insights into key parameters, their relevance in wound management, and gaps in research. Results will guide future studies, healthcare professionals, and policymakers in integrating smart dressings into clinical practice and optimising wound care technologies.

Implications for clinical practice This review will support evidence-based decision-making, aiding in the adoption of smart wound dressings to enhance patient care and treatment outcomes.

Key messages

- This scoping review will systematically map existing literature on biological physiological parameters in smart wound dressings
- The study will explore how smart dressings enhance wound monitoring through real-time biological data collection
- Identifying gaps in current research will help guide innovation in smart wound dressing technologies and applications
- The results will support clinical decision-making and promote evidence-based advancements in wound management

Introduction

Chronic wounds (CWs) are wounds that fail to heal through the normal healing stages, resulting in delayed healing. Wounds are considered chronic after a non-healing period of three months.[1] CWs include diabetic foot ulcers, pressure ulcers, and venous leg ulcers, pose significant challenges due to prolonged healing times, infection risks, and are associated with chronic conditions such as diabetes, cardiovascular disease, peripheral artery disease and venous insufficiency.[2,3] With an estimated prevalence of 2.2 cases per 1000 people,[4] CWs place a substantial burden on healthcare systems. The economic burden is significant, with annual wound management expenses exceeding £8.3 billion in the United Kingdom (UK) and US$25 bilion in the United States of America.[5,6] Traditional wound care relies on intermittent assessments, which can delay the identification of complications such as infection, ischaemia, or excessive inflammation, further increasing treatment costs and worsening patient outcomes.[7] To address these limitations, smart wound dressings have emerged as an advanced solution, integrating real-time monitoring capabilities with therapeutic interventions to enhance wound care.

Smart wound dressings represent a significant advancement in wound management, integrating sensor technologies with therapeutic functionalities to enhance wound monitoring and treatment.[8,9] Unlike conventional passive dressings, smart dressings incorporate embedded biosensors capable of detecting key biological parameters indicative of wound status.[10,11] These parameters, among others, include temperature, pH, moisture levels, oxygen concentration, reactive oxygen species (ROS), glucose levels, uric acid concentration, bacterial activity and inflammatory biomarkers (such as matrix metalloproteinases [MMP] or cytokines levels). By continuously monitoring these factors, smart dressings provide real-time insights into wound progression, enabling timely interventions that can prevent complications such as infection, ischaemia and excessive inflammation.[10,12]

Temperature, pH, oxygenation levels, and moisture are among the most frequently described biomarkers in wound healing research, each playing a critical role in the healing process.[8,13] Temperature fluctuations can indicate infection or impaired perfusion, with localised increases suggesting excessive inflammation and decreases signalling vasoconstriction and delayed healing.[14] Similarly, pH levels provide valuable diagnostic information, as CWs often exhibit an alkaline environment due to prolonged inflammation and bacterial colonisation, whereas healing wounds maintain an acidic pH that promotes tissue regeneration and limits bacterial growth.[15] However, pH monitoring has limitations, as traditional pH sensors require a liquid environment, raising concerns about their reliability in non-exudative wounds.[16]

Oxygenation is another crucial factor, as hypoxia is a major contributor to CW persistence.[17] Oxygen plays a critical role in reducing infection risk through the production of reactive oxygen species (ROS), which contributes to antimicrobial defence and overall wound healing. Smart dressings equipped with oxygen sensors can facilitate early detection of inadequate perfusion, enabling timely therapeutic interventions, such as oxygen therapy.[8,10] Moisture balance is equally essential in wound management, as an optimal moist environment accelerates healing.[18] Both excessive moisture and dryness can impede the process, making moisture sensors particularly useful in CWs. These sensors can help determine the optimal timing for dressing changes, reducing the frequency of medical visits while also enabling dressings to actively regulate moisture levels by either providing hydration or draining excess fluid.

In addition to oxygenation and moisture balance, inflammatory biomarkers, such as cytokines (TNF-α, IL-6, IL-8, and TGF-β1) have been identified as potential indicators of wound status. Monitoring these markers could support early intervention strategies, including the timely delivery of anti-

inflammatory drugs or treatments to modulate the wound environment and improve healing outcomes.[19] Beyond simply tracking wound conditions, smart wound dressings may also integrate therapeutic functions, such as controlled drug delivery systems that release antimicrobials, anti-inflammatory agents, or growth factors in response to specific wound conditions.[20,21] Some advanced dressings employ stimuli-responsive materials that modulate drug release based on environmental triggers such as pH changes, temperature fluctuations, or external light.[22,23] Furthermore, recent developments in wireless technology have enabled the integration of real-time data transmission, allowing clinicians to remotely monitor wound status and adjust treatment plans accordingly.[24]

Despite these promising advancements, there remains a gap in understanding the full range of biological and physiological parameters currently being measured in smart wound dressings and their impact on clinical decision-making and patient outcomes. Determining which parameters are most critical for wound monitoring remains unclear, as some may be redundant while others provide more precise insights, an issue insufficiently addressed in the literature. Additionally, there are practical constraints, including sensor size, data quality, and variations in wound conditions (such as exudative versus non-exudative wounds), which can influence the reliability and applicability of these technologies. Furthermore, this field is rapidly evolving with technological advancements, adding another layer of complexity. Therefore, this protocol outlines a planned scoping review aimed at mapping the existing literature on the biological parameters monitored in smart wound dressings, highlighting their significance in wound management, and identifying areas for future research.

Review questions

The following research questions will be addressed:

- What biological parameters are currently being measured in smart wound dressings?
- What is the clinical relevance of these parameters in wound healing and patient management?

Objectives

The objectives of this scoping review protocol are to present a transparent process, in particular:

- To search the literature and identify studies reporting on biological parameters measured in smart wound dressings
- To describe information sources of the identified studies and categorise the types of biological parameters assessed

- To extract and summarise data from the included studies regarding the relevance, reliability, and clinical implications of measuring these biological parameters in smart wound dressings

Method

This scoping review will be conducted by applying the Joanna Briggs Institute (JBI) methodology, which aims to systematically map available evidence, to the biological parameters measured in smart wound dressings.[25,26] The protocol has been developed in alignment with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) guidelines, as recommended by JBI.[25] To ensure transparency and reproducibility, the protocol has been registered in the Open Science Framework (OSF) (DOI 10.17605/OSF.IO/RUXEG). Any modifications or deviations from the initial protocol will be documented, and updates will be reflected in the OSF record.

Eligibility criteria

To establish the key areas of investigation and define the inclusion criteria, this scoping review will apply the Population, Concept, Context (PCC) Framework:

Population: This review will include all literature discussing biological parameters measured in smart wound dressings within the context of CW management

Concept: The primary focus will be on literature examining the types of biological parameters assessed, their clinical relevance, and their impact on wound healing and patient management

Context: The review will include studies conducted in any healthcare setting where smart wound dressings are utilised, without geographical limitations, to ensure a comprehensive analysis of global research trends

The review will incorporate quantitative, qualitative, and mixed-method studies, as well as grey literature, including conference abstracts, theses, clinical practice guidelines, editorial articles, and opinion pieces. Any studies that do not address the measurement of biological parameters in smart wound dressings will be excluded. Literature sources will be restricted to English, German, French, and Italian, based on the authors' language proficiency.

Information sources

Searches will be conducted across multiple electronic databases and search tools, including MEDLINE (via Ovid), Embase, Web of Science, CINAHL (EBSCO), and Google Scholar. These sources have been selected to ensure

comprehensive coverage of relevant literature on biological parameters measured in smart wound dressings.

Search strategy

The search strategy will be designed and implemented in collaboration with two experienced reference librarians from the HES-SO University of Applied Sciences and Arts Western Switzerland, with input from the research team to ensure a systematic and comprehensive approach. The development of electronic search strategies will adhere to the Peer Review of Electronic Search Strategies (PRESS) 2015 Guideline Statement[27] to enhance search quality and reproducibility. To maximise coverage, the search will incorporate controlled vocabulary (such as Medical Subject Headings [MeSH]) along with keywords, including various truncations, wildcards, parentheses and quotation marks. Boolean operators (AND, OR), proximity operators (such as wildcards, parentheses, quotation marks), and database-specific syntax will be applied across all search platforms. A preliminary search strategy was developed and piloted on 17 February 2025 to refine search terms and optimise sensitivity. The final searches will be conducted in multiple databases, initially using broad research design filters, followed by more targeted qualitative filters. A summary of the search strategy for MEDLINE and CINAHL is provided in Table 1.

Table 1. Search strategy for MEDLINE and CINAHL

MEDLINE VIA OVID		
		Hits
SMART	((smart* or intelligen*) **adj5** (bandage* or dressing* or hydrogel*)).ti,ab,kw.	1562
WOUND	(Ulcer/ or exp Skin Ulcer/ or exp "Wounds and Injuries"/ or exp Wound Healing/ or exp Wound Infection/ or (ulcer* or wound* or injur*).ab,kw,ti.)	2,257,010
SMART + WOUND	(((smart* or intelligen*) adj5 (bandage* or dressing* or hydrogel*)).ti,ab,kw.) AND (Ulcer/ or exp Skin Ulcer/ or exp "Wounds and Injuries"/ or exp Wound Healing/ or exp Wound Infection/ or (ulcer* or wound* or injur*).ab,kw,ti.)	430

CINAHL		
		Hits
SMART	(((TI (smart* OR intelligen*) OR AB (smart* OR intelligen*)) **N4** (TI (bandage* OR dressing* OR hydrogel*) OR AB (bandage* OR dressing* OR hydrogel*))	36
WOUND	((MH "Wounds and Injuries+") OR (MH "Ulcer") OR (MH "Skin Ulcer+") OR (MH "Wound Healing+") OR (MH "Wound Infection+") OR TI (injur* OR ulcer* OR wound*) OR AB (injur* OR ulcer* OR wound*)))	587,960
SMART + WOUND	(((TI (smart* OR intelligen*) OR AB (smart* OR intelligen*)) **N4** (TI (bandage* OR dressing* OR hydrogel*) OR AB (bandage* OR dressing* OR hydrogel*)) **AND** ((MH "Wounds and Injuries+") OR (MH "Ulcer") OR (MH "Skin Ulcer+") OR (MH "Wound Healing+") OR (MH "Wound Infection+") OR TI (injur* OR ulcer* OR wound*) OR AB (injur* OR ulcer* OR wound*)))	34

Data management

All references will be compiled into a single EndNote X20 library, where duplicate entries will be identified and removed. The refined reference list

will then be transferred to Rayyan, a screening tool designed to streamline the study selection process.

Selection process

Two independent reviewers (SG, AS), both healthcare professionals specialising in wound management, will screen titles and abstracts to identify studies that meet the eligibility criteria. Full-text articles of potentially relevant studies will be retrieved and evaluated in detail to determine their inclusion. Each reviewer will independently assess the full texts to extract key study characteristics. Any excluded studies will be documented in a table, with clear justifications for their exclusion. In the event of discrepancies between the reviewers, a third reviewer (SP) will be consulted to ensure an objective resolution. To maintain transparency, a PRISMA flowchart will be generated to illustrate the study selection process.

Data extraction

A structured data extraction form will be developed and piloted to ensure consistency and accuracy in data collection. Data from the included studies will be extracted using Elicit®, an artificial intelligence tool,[28] and subsequently verified for accuracy and completeness by two independent reviewers (AS, SP). The extracted information will include study characteristics, such as study ID, authors, publication year, and journal, along with methodological details, including study objectives, setting, design, outcome measures and data analysis approach. Additionally, findings related to the biological parameters measured in smart wound dressings, their clinical relevance, and their impact on wound healing will be documented.

In cases where data is unclear or incomplete, study authors will be contacted for clarification. Any discrepancies between the reviewers will be resolved through discussion, and if consensus cannot be reached, a third reviewer (DP) will be consulted to ensure an objective resolution.

Data synthesis

A systematic approach will be employed to collate and synthesise the findings from the included studies. Initially, relevant data will be extracted using a standardised data extraction form, ensuring consistency in capturing key study characteristics such as authorship, publication year, country of origin, and study design. Information on patient demographics, clinical settings, and specific physiological parameters measured in smart wound dressings will also be recorded. Once extracted, the data will be organised by SP and SG into thematic categories to facilitate a structured synthesis. These thematic areas may include the types of physiological parameters monitored, their clinical significance, the technological approaches used for measurement, and the implications for patient outcomes and wound

management strategies. A narrative synthesis will be conducted to summarise the findings within each thematic category, identifying common trends, key patterns, and notable discrepancies across studies. Particular attention will be given to how biological parameters are defined, the methods used for their assessment, and the clinical settings in which smart wound dressings are applied. Where applicable, quantitative data related to clinical outcomes, such as wound healing rates, infection control, and patient management efficiency, will be integrated into the synthesis. Descriptive statistics will be used to summarise these findings, allowing for comparisons that highlight emerging trends and research gaps.

The synthesis will also consider contextual factors influencing the use of smart wound dressings, including healthcare settings (hospitals, home care, outpatient clinics), regional and cultural variations in wound management practices, and the roles of healthcare professionals involved in their application. This contextual analysis will enhance the understanding of the applicability and transferability of the findings to different clinical environments.

Discussion

Improving patient outcomes and advancing wound care strategies are central to healthcare professionals managing CWs. A deeper understanding of the biological parameters measured in smart wound dressings will enhance clinical decision-making and optimise treatment approaches. The findings of this scoping review will provide a comprehensive overview of the existing literature on the role of smart dressings in wound management, highlighting key biomarkers, technological advancements, and their clinical relevance. This knowledge will serve as a foundation for future research aimed at refining and expanding the use of smart wound dressings, ultimately improving patient care. Additionally, the results will be valuable for healthcare providers, equipping them with insights into the effectiveness of these technologies in clinical practice.

Author contribution

SP and DP conceptualized the protocol. SP drafted the initial version. NB and MTP conducted the literature searches and contributed to data acquisition. SG, AS, and DP critically revised the protocol for important intellectual content. All authors reviewed and approved the final version of the protocol.

Conflict of interest

The authors declare no conflict of interest.

Ethics statement

As this is a protocol for a scoping review, it does not involve primary data collection or direct interaction with human subjects. Therefore, ethical approval is not required. The review will adhere to established guidelines and standards for conducting scoping reviews.

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