Use of point-of-care subepidermal moisture devices to detect localised oedema and evaluate pressure injury risk: A scoping review

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REVIEW

Use of point-of-care subepidermal moisture devices to detect localised oedema and evaluate pressure injury risk: A scoping review

Annette McLaren-Kennedy BN, Honours Candidate[1] | Wendy Chaboyer PhD, Professor[1,2] | Joan Carlini PhD, Lecturer[2,3,4] | Sharon Latimer PhD, Lecturer[1,2]

[1]School of Nursing and Midwifery, Griffith University, Gold Coast, Southport, Queensland, Australia

[2]NHMRC Centre of Research Excellence Wiser Wounds, Menzies Health Institute Queensland, Griffith University, Gold Coast, Southport, Queensland, Australia

[3]Department of Marketing, Griffith University, Gold Coast, Southport, Queensland, Australia

[4]Health Consumer, Gold Coast Hospital and Health Service, Gold Coast, Queensland, Australia

Correspondence
Annette McLaren-Kennedy, School of Nursing and Midwifery, Griffith University, Gold Coast Campus, Southport, QLD 4222, Australia.
Email: annette.mclaren-kennedy@griffithuni.edu.au

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Abstract

Aims and Objectives: To map current literature on bedside clinicians' use of point-of-care subepidermal moisture devices to identify increased pressure injury risk.

Background: Pressure injuries are a substantial healthcare burden. Localised oedema occurs before visible or palpable changes, and therefore is a biomarker of increased pressure injury risk. Novel bedside technologies that detect localised oedema may aid early pressure injury preventative practices.

Design: A scoping review.

Methods: Arksey and O'Malley's six-step framework and the PRISMA-ScR guidelines guided this scoping review. CINAHL Complete, Embase, SCOPUS, Cochrane (wounds) and PubMed databases were searched for primary research and quality improvement projects published in English between 2008–2022. Included studies focused on clinicians' bedside use of subepidermal moisture devices to quantify localised oedema and pressure injury risk. The PAGER framework supported narrative synthesis of the extracted data.

Results: Nine studies were selected from 1676 sources. Two point-of-care subepidermal moisture devices were identified in clinical use, largely by nurses. Inconsistent use and interpretations revealed significant knowledge gaps in clinical practice. Additionally, no included studies engaged patients or the public in their design.

Conclusions: Nurses recognise the value of objective measures in determining the risk of pressure injury and are the primary end-users of point-of-care subepidermal moisture devices. However, standardising procedural instructions and interpretive criteria to guide preventative measures requires further research.

Relevance to Clinical Practice: International pressure injury clinical practice guidelines advocate for subepidermal moisture devices as an adjunct to routine clinical skin assessment, although little is known about bedside use. This scoping review reveals low adoption of such devices and the need to develop standardised procedures in their use and interpretation.

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KEYWORDS
biocapacitance, localised oedema, Pressure injury risk, SEM scanner, skin assessment

1 | BACKGROUND

Pressure injuries are potentially preventable adverse events, impacting approximately 13% of hospitalised patients globally (Li et al., 2020) and are a measure of safety and quality of healthcare services (Weller et al., 2018). Defined as 'localised injury to the skin and/or underlying tissue as a result of pressure, or pressure in combination with shear' (European Pressure Ulcer Advisory Panel [EPUAP] et al., 2019, p. 194), pressure injuries are painful, slow healing wounds that prolong hospital stays, increase susceptibility to infections and may cause sepsis or death (Latimer et al., 2014; Schwendimann et al., 2018). Additionally, pressure injuries substantially raise healthcare expenses globally, costing the US economy USD26.8 billion/year in 2016 (Padula & Delarmente, 2019), the UK economy £1.4–2.1 billion (Dealey et al., 2012) and the Australian economy AUD9.11 billion annually (95% Confidence Intervals: 9.02–9.21) [2019–2020] (Nghiem et al., 2022). Strategies designed to prevent pressure injuries have the potential to enhance patient safety and reduce healthcare costs (Chaboyer et al., 2016). However, nurses' traditional risk assessment and visual skin assessments, have had minimal impact on pressure injury prevention (O'Brien et al., 2018).

In recent years, a greater understanding of the aetiology of pressure injuries has evolved. It is accepted that an individual's risk of developing pressure injuries is due to a complex interplay of increased susceptibility caused by somewhat unmodifiable factors such as age or limited mobility, as well as modifiable variables such as the microclimate against the skin, and magnitude and duration of applied forces (Coleman et al., 2013). It is now understood that the applied pressures or strains trigger inflammatory processes from cell deformation and reperfusion injury and cause localised oedema in the deeper layers or sub-epidermis of the skin, as the superficial layers are less susceptible to pressure-induced injury (Budri et al., 2020; Gefen & Ross, 2020). Although this early inflammation can be halted (Gefen, 2020; Okonkwo et al., 2020), there is a temporal lag between when oedema develops and when the damage propagates at the skin's surface (Oliveira et al., 2017) which makes determining optimal off-loading challenging. Therefore, detecting localised oedema, or subepidermal moisture (SEM) early has the potential to enhance patient outcomes by influencing the timing of preventative measures, such as repositioning (Smith, 2019).

Bedside clinicians use multiple point-of-care technologies to identify localised inflammation and oedema including ultrasonography, thermography, laser Doppler flowmetry and SEM devices (Scafide et al., 2020). Ultrasound measures the density of tissue, by interpreting the speed with which pulsed sound waves are reflected

What does this paper contribute to the wider global community?

- Point-of-care SEM devices are promising advances as an adjunct to routine skin assessment and identifying pressure injury risk.
- Limited evidence exists on clinicians' use of these point-of-care SEM devices.
- Further research is necessary to standardise the use of point-of-care SEM devices before they are adopted into routine clinical practice.

(Scafide et al., 2020). Thermography uses infrared technology to detect changes in skin temperature linked to the inflammatory process (Oliveira et al., 2017) with cooler temperatures detected in the centre of damaged tissue relative to surrounding tissue (Cox et al., 2016). Laser Doppler determines the increased concentration of haemoglobin resulting from reactive hyperaemia by catching the reflected light from moving red blood cells (Scafide et al., 2020). SEM devices assess the biocapacitance of tissue (the capacity to store an electrical charge), with tissues with greater water content providing higher values; hence, comparison of adjacent tissue has the potential to reveal localised oedema (Ross & Gefen, 2019). While all these instruments are accessible, some, such as thermography and ultrasonography, need specialised training to operate and interpret and are thus not commonly used. However, there are a growing number of studies describing the use of SEM devices in both research and clinical practice.

These point-of-care SEM devices are tentatively recommended for use as an adjunct to skin assessment in practice (Chaboyer et al., 2022; EPUAP et al., 2019; Scafide et al., 2020), but little is known about how clinicians use them. To facilitate translation into practice, specific and evidence-based procedural protocols must be established and used consistently (Drain et al., 2014). Hence, this scoping review aimed to synthesise the breadth of evidence on bedside clinicians' use of point-of-care SEM devices for pressure injury prevention and identify procedural knowledge gaps.

2 | METHODS

Scoping reviews are a methodological approach for evidence synthesis that contributes to evidence-based practice by analysing a comprehensive overview of a topic to clarify key concepts, capture sources

of evidence that influence practice and identify knowledge gaps to drive future research (Arksey & O'Malley, 2005; Peters et al., 2020). This scoping review followed Arksey and O'Malley's (2005) six-staged approach and its later revisions (Levac et al., 2010; Peters et al., 2020), including the optional step of incorporating a health consumer, which added both methodological rigour and an important health consumer perspective. The Patterns, Advances, Gaps, Evidence for Practice, and Research Recommendations (PAGER) framework directed the analysis (Bradbury-Jones et al., 2021) and the Preferred Reporting Items for Systematic reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR) checklist (Tricco et al., 2018) guided reporting (Appendix S1).

2.1 | Stage 1: Research questions

The following specific research questions were proposed:

(i) What types of point-of-care SEM devices are being used by bedside clinicians for detecting localised oedema for pressure injury risk assessment?
(ii) Which bedside clinicians use point-of-care SEM devices for detecting localised oedema for pressure injury risk assessment?
(iii) How do bedside clinicians use the point-of-care SEM devices?
(iv) What are the training requirements for the use of the point-of-care SEM devices?
(v) What is the extent of health consumer involvement in the conduct of research on clinical use of SEM devices?

Guided by the evidence, these questions were developed by the research team prior to beginning the review and revised during the review process.

2.2 | Stage 2: Search strategy

The search strategy was developed with guidance from a health librarian and included searches of both electronic databases and clinical trial registers. As recommended by the Joanna Briggs Institute, keywords and phrases were identified prior to database searches, to return a comprehensive and targeted search (Peters et al., 2020). Literature published from 2008–January 2022 was considered. The 2008 year was chosen based on Bates-Jensen et al.'s (2007) seminal pilot study on monitoring SEM to predict pressure injuries in nursing home patients, in order to uncover relevant contemporary studies on the clinical application of point-of-care SEM devices. CINAHL Complete (EBSCOhost), Embase (Elsevier), SCOPUS, Cochrane (wounds) and PubMed electronic databases were searched for both primary research and quality improvement projects. Clinical trials were searched using Google Scholar and ProQuest. Additionally, reference lists from included studies were examined for relevant sources. Due to financial constraints, only studies published in English were considered for inclusion, as the employment of a translator was not feasible.

Database searches were conducted in February 2022. A population, concept and context framework allowed the identification of the main topics to inform the search strategy (Appendix S2). To ensure comprehensive coverage and accuracy, searches were undertaken using Medical Subject Headings (MeSH) and the Excerpta Medica Thesaurus (Emtree), as well as Boolean operators (AND, OR), truncations and quotations around key phrases (Bramer et al., 2018). The searchrefiner tool was used to refine and validate the identification of relevant studies based on search strings (Scells & Zuccon, 2018). Searchrefiner facilitates collaboration by delivering outputs for each iteration of the literature search process (Chaboyer et al., 2022).

2.3 | Stage 3: Study selection

Inclusion and exclusion criteria for literature selection were developed and revised by the research team. Clinical trials, reviews of studies and quality improvement projects were considered regardless of study design. All full-text studies that focused on clinicians' bedside use of point-of-care SEM devices to measure local oedema to assess risk of pressure injury by any healthcare provider, in any healthcare setting were included. The studies were excluded if the point-of-care SEM devices were chiefly used by researchers, if objective equipment did not measure localised oedema (e.g. thermography, laser Doppler), if the focus was on the use of ultrasonography, or if they were animal studies.

A two-stage process was used to screen and select studies. In stage one, the reference management software EndNote (Version X9, Clarivate Analytics, 2020) was used to import the results into Covidence software (Veritas Health Innovation, 2019) where duplicate studies were removed. To reduce the risk of selection bias two reviewers independently completed the initial screening, of titles and abstracts. Studies that met the inclusion criteria and addressed at least one research question of interest were marked for stage two. In the second stage, full texts of potential studies were sourced, and their eligibility assessed independently by two reviewers. Disagreements were adjudicated by a third research team member.

2.4 | Stage 4: Charting data

The study team agreed on definitions (Appendix S3) for each extraction field (or keyword), and three studies were pilot tested, with data extraction tables revised based on results. The first author initially extracted data using the tables, which were subsequently reviewed by the other three authors.

2.5 | Stage 5: Collating, summarising and reporting results

Initially, data extraction to a characteristics table and a summary table of the results in relation to the research questions, including

limitations, aided data interpretation. The PAGER framework was employed to table results and facilitate reporting (Bradbury-Jones et al., 2021). Patterns of bedside-clinical use of point-of-care SEM devices for pressure injury prevention and approaches to research were recognised, and knowledge gaps were highlighted. This allowed future practice and research implications to be identified.

2.6 | Stage 6: Consultation: patient and public involvement

The review design included health consumer engagement to provide valuable insight and positively impact research priorities (National Health and Medical Research Council [NHMRC], 2016). A health consumer advocate was invited to join the research team and agreed to participate in the development of the study's protocol, research questions, confirmation of data extraction and discussion of the findings.

3 | RESULTS

The database search yielded 1676 studies. After eliminating duplicates and screening for eligibility, nine studies were included in this evaluation, one of which was identified in a reference list. The study selection process for the included studies is outlined in the PRISMA-ScR flow diagram in Figure 1 (Page et al., 2021).

3.1 | Characteristics of included studies

Table 1 provides a summary of the characteristics of the nine included studies (Gefen & Gershon, 2018; Kim et al., 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Park et al., 2018; Raizman et al., 2018; Smith, 2019). They were all published between 2018–2021. Four (44%) were conducted in the United Kingdom (Musa et al., 2021; Nightingale & Musa, 2021; Ore & Carver, 2020; Smith, 2019), two (22%) in South Korea (Kim et al., 2018; Park et al., 2018), one (11%) in the United States (Gefen & Gershon, 2018), one (11%) in Canada (Raizman et al., 2018), and one (11%) international study undertaken across the United States and the United Kingdom (Okonkwo et al., 2020). Just two research teams conducted six of the nine studies (67%): two in South Korea and four in the United Kingdom.

The included studies' characteristics were not homogeneous in design however they all focused on clinicians' bedside use of point-of-care SEM devices, that measure localised oedema for pressure injury prevention. Six studies (67%) used observational methods (Kim et al., 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Park et al., 2018; Smith, 2019), two (22%) were pilot studies (Gefen & Gershon, 2018; Ore & Carver, 2020), with the remaining one (11%) being mixed methods (Nightingale & Musa, 2021). The studies were conducted in a variety of settings with two in community palliative care settings (Musa et al., 2021; Ore & Carver, 2020), one a nursing home facility (Kim et al., 2018), one a post-acute centre (Gefen & Gershon, 2018) and five inpatient hospital settings (Musa

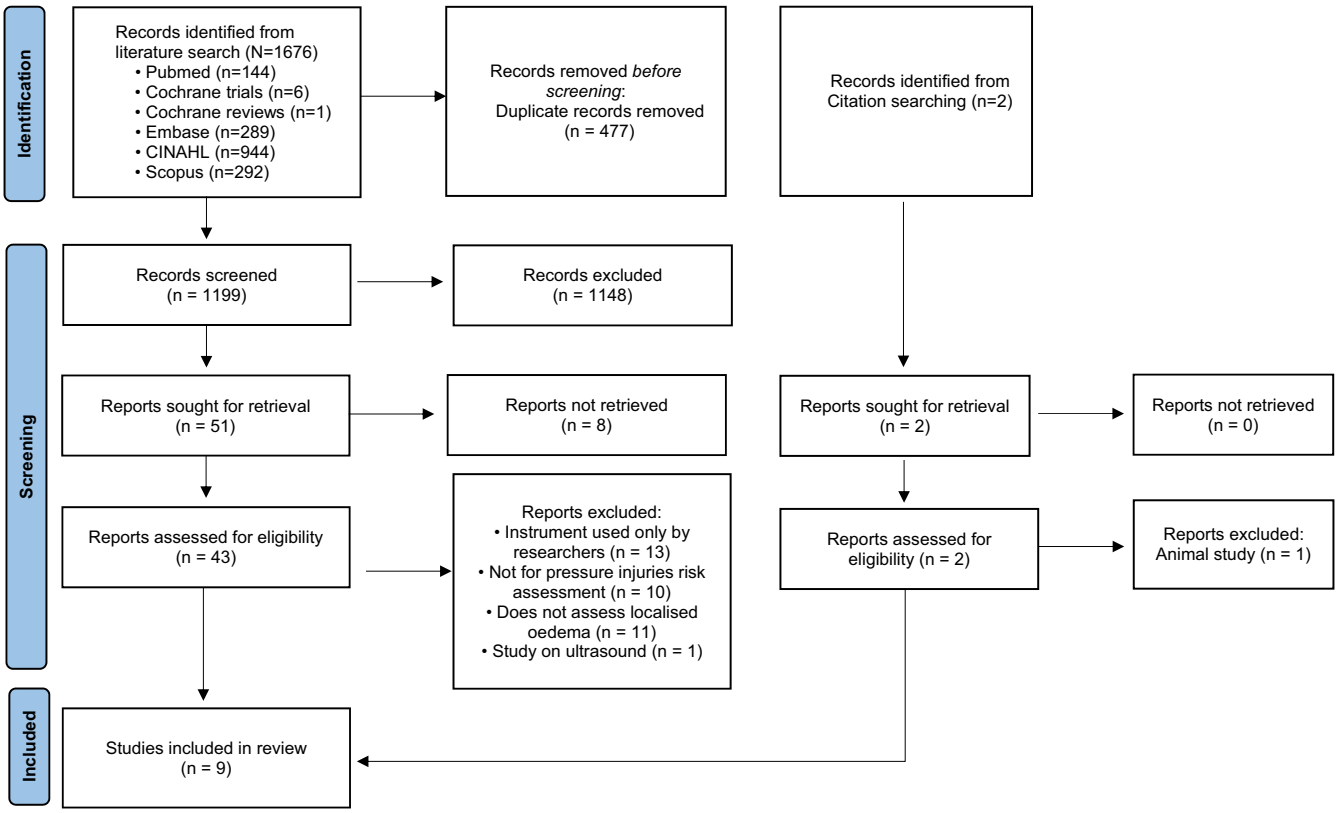

FIGURE 1 PRISMA 2020 flow diagram. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Summary of characteristics of included studies.

Author/s (year), country	Study aim (comparator if applicable)	Study design time of data collection	Setting	Sample
Gefen and Gershon (2018), United States	To ascertain whether SEM scanner readings are consistent with ultrasound in examination of deep tissue injuries, and if SEM scanner data precedes VSA and ultrasound in identifying the development of PI	Observational prospective cohort pilot study 3 months	One post-acute care centre	Sample: Inpatients 3–10 days Sample size: $n = 15$; convenience sample Inclusion criteria: >55 years Four participant study groups with different inclusion criteria: (1) At PI risk without PI; (2) Existing Stage 1 sacral PI; (3) Existing suspected deep tissue injury; (4) no wound or PI risk For groups 1, 2 and 3, Braden score <13, poor mobility sub score ≤2 or clinically observed limited movement for >4 h. Group 4 (the control group) consisted of age-matched participants
Kim et al. (2018), South Korea	To examine the relationship of SEM values between VSA-staged PI and to develop a SEM skin damage prediction model	Longitudinal observational study 12 weeks	One nursing home for elderly people	Sample: Residents of aged care facility Sample size: $n = 29$ however complete data sets were collected from 25 residents Inclusion criteria: over 60 years
Musa et al. (2021), United Kingdom	To ascertain the impact on the incidence of HAPI (≥ category II) of SEM scanner when used in routine clinical practice and the influence of SEM scanner on decision making	Observational and clinical audit 1.25–6-month period over 6 years	15 mixed gender care settings – 13 acute care wards, 1 palliative ward, 1 community setting	Sample: Adult patients in acute, palliative or community setting Sample size $n = 1478$ Inclusion criteria: Waterlow score > 10 and PU free on admission
Nightingale and Musa (2021), United Kingdom	To evaluate the impact of adding SEM scanning to standard practice on the incidence of HAPI category II and above	Correlational mixed method design 6 months	Across four wards 2 orthopaedic trauma wards, 1 neurological rehabilitation and 1 medical ward	Sample: Adult patients Sample size $n = 697$ patients Inclusion criteria: A Waterlow score ≥10 who have intact skin at sacrum and heels and are on the ward for a minimum of 3 days
Okonkwo et al. (2020), United Kingdom (UK) and United States	To evaluate the sensitivity and specificity of SEM biomarker and to determine if SEM biomarkers precede expert skin assessments in identifying PI	Prospective cohort study 21 days	12 inpatients settings – 6 acute and 3 post-acute in the USA and 3 acute settings in the UK	Sample: Adult patients Sample size $n = 182$ enrolled with $n = 170$ included in the analysis Demographic data was on 182 Inclusion criteria: ≥55 years of age, inpatient for a minimum of 6 days, with either a Braden score <15 (91% of participants), Waterlow score ≥10 (9% of participants)
Ore and Carver (2020), United Kingdom	To evaluate the impact of SEM scanner measures as an adjunct to standard care on PI incidence Evaluate the changes in clinical decision making and Review financial impact and return on investment	Pilot study 12 weeks	Two community districts	Sample: In-home palliative care patients Sample size $n = 17$ Inclusion criteria: Waterlow score > 10, unbroken skin and the availability to be scanned for 5–7 consecutive days (However the range of scanning was from 1–26 days with an average of 12)

Sample characteristics	Conclusion	Limitations	Funding conflicts of interest
Female *n* = 10 (67%), Male *n* = 5 (33%) Mean age = 74 ± 10.9 years Fitzpatrick scale II or III (*n* = 11) and > III (*n* = 4) Mobility status = poor Urinary incontinence (*n* = 1) History of PI (*n* = 2) Mean Braden scale score 11.4 ± 2.7	SEM readings identified risk 2 days prior to visual signs	Single site and small sample size limits generalisability	Funding and potential conflict as the study received an unrestricted grant from Bruin Biometrics
Female *n* = 25 (86.2%) Male *n* = 4 (13.8%) Mean (SD) age = 81.2 years (SD ± 7.5) with 69% over 80 years History of PI *n* = 4 (13.8%) Mean Braden scale score = 18.3 (SD ± 2.7)	SEM values are usually more sensitive than VSA and the higher the reading the greater risk of skin damage	Single site and small sample size limits generalisability	No funding stated No conflicts of interest declared
Demographics of sample population not reported	SEM Scanner can inform health professionals about the increased risk of PU, allowing them to intervene before visual signs as the objective information allowed for anatomically specific interventions	Hawthorne effect may have influenced results as clinicians may have been more diligent with skin care, however the authors were unable to comment to what extent	Equipment supplied free of charge by Bruin Biometrics LLC. Editorial support provided by Bio script Authors declared no conflict of interest
Mixed population Mean Age ≥ 65 Patient level demographics are not accessible due to Trust policies	Elevated SEM values occur before visible and tactile signs of damage	Hawthorne effect may have influenced results however only minimally. The Hawthorne effect fades with time and the staff had been utilising PI strategies for over a year The study design did not have a control group, limiting internal validity of results	Equipment supplied free by Bruin Biometrics The authors declared no conflict of interest
47% male (*n* = 85) and 53% female (*n* = 97) Age mean (SD) = 76 (11) years BMI mean (SD) = 26.8 (7.65) Poor mobility Poor nutrition Braden and Waterlow scores reported categorically	SEM scanner is an adjunct to VSA to inform specific interventions for at risk anatomical sites. Specificity of SEM is to be determined	Authors states SEM delta increases will not always lead to PI; however, a PI will be preceded by changes in SEM limiting the specificity of SEM measurements with the SEM scanner	Bruin Biometrics funded the trial Authors were sponsored by Bruin Biometrics to present at a company symposium
Not reported	SEM scanner use did not reduce incidence of PI in the community	As this is a pilot study it provides information for feasibility of future research only Limited information provided for changes in clinical decision making Did not address the financial impact. Calculations were on the assumption of only one PI per patient	Funding and conflict of interested were not reported

(Continues)

TABLE 1 (Continued)

Author/s (year), country	Study aim (comparator if applicable)	Study design time of data collection	Setting	Sample
Park et al. (2018), South Korea	To explore the time relationship between SEM and VSA for blanching erythema	Cohort study 6 weeks	One Tertiary hospital	Sample: Adult inpatients Sample size $n = 22$ Inclusion criteria: Bedridden inpatients with jaundice and Braden scores ≤18
Raizman et al. (2018), Canada	To examine the clinical use of the SEM scanner and the interventions informed by it	Case series, two-phase design 4 weeks for phase 1 and 4.5 months for phase 2	One Community hospital	Sample: Inpatients Sample size for Phase 1: $n = 89$ Inclusion criteria Phase 1: medical stroke unit patients with Braden scores ≤14 Sample size for Phase 2: $n = 195$ Inclusion criteria Phase 2: patients from alternative care unit and any unit in the hospital if the patient had a score of ≤3 on the Braden mobility sub-score
Smith (2019), United Kingdom	To evaluate the clinical use of SEM scanner	Cohort prospective study design 2 months	Medical surgical mixed ward	Sample: Adult patients Sample size $n = 35$ Inclusion criteria: Waterlow score ≥10 and/or could not be repositioned

Abbreviations: PI, pressure injuries; SEM, sub-epidermal moisture; VSA, visual skin assessments.

et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Park et al., 2018; Smith, 2019), with data collection ranging from 21 days (Okonkwo et al., 2020) to 6 months (Nightingale & Musa, 2021). The sample sizes of patients recruited to the studies ranged from 15 (Gefen & Gershon, 2018) to 1478 (Musa et al., 2021), with participants recruited to the study based on scores from their Braden or Waterlow risk assessments. All studies included males and females with most patient participants over 55 years of age, with limited reporting on other confounding characteristics of pressure injury risks, such as incontinence or nutritional status.

3.2 | Summary of use of point-of-care SEM devices for pressure injury prevention

Table 2 includes detailed information on clinicians' use of point-of-care SEM devices in clinical practice. The results will be presented as they pertain to the scoping review research questions.

(i) What types of SEM devices? Two different point-of-care SEM devices were used by clinicians for detecting localised oedema for pressure injury risk assessment in patients. Seven studies examined the Bruin Biometrics SEM Scanner Point of Care 200 (Gefen & Gershon, 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Raizman et al., 2018; Smith, 2019) with the NOVA Petite Dermal Phase meter used in two studies (Kim et al., 2018; Park et al., 2018).

(ii) Which clinicians use the SEM devices? While various clinicians used the devices, the majority ($n = 7$; 78%) of included studies focussed on nurses' use of SEM devices (Kim et al., 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Park et al., 2018; Raizman et al., 2018). Other bedside clinicians using SEM devices included physicians (Gefen & Gershon, 2018; Okonkwo et al., 2020), healthcare assistants (Smith, 2019) and surgical assistants (Okonkwo et al., 2020).

(iii) How do bedside clinicians use the point-of-care SEM devices?

a. What anatomical sites were assessed? Using the Bruin Biometrics SEM Scanner Point of Care 200, clinicians in seven studies (78%) undertook measurements for localised oedema on three anatomical areas on patients: the sacrum and both heels (Gefen & Gershon, 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Raizman et al., 2018; Smith, 2019). Clinicians using the NOVA Petite Dermal Phase metre measured localise oedema at the buttocks, ischial tuberosities, trochanters, sacrum and coccyx in two (22%) studies (Kim et al., 2018; Park et al., 2018).

b. When are measurements taken? Clinicians used the Bruin Biometrics SEM scanner 200 daily (Gefen & Gershon, 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Smith, 2019) five times per

Sample characteristics	Conclusion	Limitations	Funding conflicts of interest
54.5% males ($n = 12$), 45.5% females ($n = 10$) Mean age = 70.5 ± 8.6 years Mean BMI = 23.5 ± 5.5 On bed rest 81.8% ($n = 18$), Quadriplegia 13.6% ($n = 3$) Incontinence – 81.8% ($n = 18$) urinary and 59.1% ($n = 13$) faecal Past history of PI = 22.7% ($n = 5$) Mean Braden score = 18.3 ± 2.7	Demonstrated a relationship of SEM and blanching erythema in Koreans with jaundice	Small sample size Used blanchable erythema to compare to SEM however this is not considered a stage of PI Unit of analysis for the odds ratio was the SEM measurement and not the patient Multiple measures on the same patient in the analysis	Funded by the ministry of education science and technology
Demographic details not reported except to say phase 1 and 2 participants were similar in demographics except Phase 2 90% of participants experience incontinence	SEM scanner detects non-visible skin damage and alters clinicians' judgement. No Hawthorne effect with only using the SEM Scanner	The hospital wide incidence of PI ranges from 0%–5% however this includes all patients not only those with low Braden scores. Potential bias in Braden scores daily if completed after SEM data collection, although the order is not specified	The supervising author received payment from Bruin Biometrics. SEM scanner was provided at no cost by Bruin Biometrics. Authors declared no conflict of interest
51% female ($n = 18$) and 49% male ($n = 17$) Age – 9% ($n = 3$) between 65–75 years and 74% ($n = 26$) were >75 year the age of remaining 16% not reported	Skin damage may not be visible for several days	Small sample size The high or very high-risk profile implies that regardless of SEM delta, all interventions would have been considered. Hawthorne effect with biweekly visits by Bruin Biometrics staff Blanching erythema is not classified as stage 1 PI	SEM scanner was provided by Bruin Biometrics

week (Raizman et al., 2018), three times per week (Raizman et al., 2018) and weekly (Ore & Carver, 2020). For the NOVA Petite Dermal Phase meter, clinicians completed weekly measurements on patients (Kim et al., 2018; Park et al., 2018). Two studies reported measurements were completed in the morning (Park et al., 2018; Smith, 2019).

c. What procedures are followed prior to measurements? Only two (22%) studies (Gefen & Gershon, 2018; Park et al., 2018) reported clinicians cleaned and dried patients' skin at the anatomical location prior to measurements. The majority of studies using the Bruin Biometrics SEM scanner lacked details on the procedural instructions other than stating manufacturer instructions were followed (Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Raizman et al., 2018).

d. How does the objective data guide the implementation of pressure injury prevention strategies? Although all studies ($n = 7$; 78%) using the Bruin Biometrics SEM scanner reported the parameter of increased pressure injury risk to be ≥0.6 SEM delta units (i.e. the difference between the highest and lowest values at any one anatomical site), the number of elevated data points required to influence and inform pressure injury prevention clinical decisions varied (Gefen & Gershon, 2018; Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Raizman et al., 2018; Smith, 2019). One study (11%) reported 2 consecutive days of SEM delta readings ≥0.6 should inform the implementation of preventative clinical practice (Gefen & Gershon, 2018), while others ($n = 2$; 22%) suggested two or more SEM delta readings ≥0.6 from 3 consecutive days (Okonkwo et al., 2020; Ore & Carver, 2020). Four studies (44%) did not report the number of data points required to inform preventative practice (Musa et al., 2021; Nightingale & Musa, 2021; Raizman et al., 2018; Smith, 2019). The NOVA Petite Dermal Phase meter studies ($n = 2$; 22%) also reported differences in parameters of measurements that indicated increased pressure injury risk of either 20 dermal phase units (Kim et al., 2018), 50 dermal phase units (Kim et al., 2018; Park et al., 2018), and 100 dermal phase units (Kim et al., 2018; Park et al., 2018). Four (44%) studies reported the use of SEM devices improved nursing confidence in making pressure injury prevention clinical decisions and was a valuable adjunct to routine care (Musa et al., 2021; Nightingale & Musa, 2021; Raizman et al., 2018; Smith, 2019).

(iv) What are the training requirements for the use of SEM devices? Training and ongoing technical support were reported in five (56%) of the studies (Musa et al., 2021; Nightingale & Musa, 2021; Okonkwo et al., 2020; Ore & Carver, 2020; Park et al., 2018; Raizman et al., 2018; Smith, 2019), with two (22%) studies reporting between 75% (Musa et al., 2021) and 100%

TABLE 2 Summary of use of point-of-care biocapacitance instruments.

Author/s (year), country	What type of instrument measured localised oedema?	Who used the instrument?	On what anatomical position?	When was the instrument used and how frequently?	What procedures were followed prior to measuring?
Gefen and Gershon (2018), USA	Bruin Biometrics SEM Scanner Point of Care 200	1× Physician undertook SEM readings	Sacrum and heels	Once daily	Not reported
Kim et al. (2018), South Korea	Nova Petite Dermal Phase meter with a range of 0–999 dermal phase units	1× trained Wound care nurse collected baseline and weekly SEM data	8 locations: Both buttocks, ischia, trochanters, as well as sacrum and coccyx	Baseline and once a week for 12 weeks	To ensure consistency in measurements, the anatomical site was marked with an insoluble pen. The VSA was conducted prior to SEM data collection
Musa et al. (2021), United Kingdom	Bruin Biometrics SEM scanner (model not specified although SEM 200 model pictured)	All nursing staff were trained by Bruin Biometrics	Sacrum and heels	Once daily for acute and palliative settings Details for community setting not specified	Scans were conducted as per manufacturer's instructions for use.
Nightingale and Musa (2021), United Kingdom	Bruin Biometrics SEM scanner model not specified	All nursing staff were trained by Bruin Biometrics and assessment for their comprehension and competence	Sacrum and heels	Once daily	Scans were conducted as per manufacturer's instructions for use.
Okonkwo et al. (2020), United Kingdom and United States	Bruin Biometrics SEM scanner 200	Registered nurses, surgical assistants and medical doctors	Sacrum and heels	Once daily	Scans were conducted as per manufacturer's instructions for use.
Ore and Carver (2020), United Kingdom	Bruin Biometrics SEM scanner 200	Nursing staff	Sacrum and heels	Varies from daily to weekly depending on prior results	Scans were conducted as per manufacturer's instructions for use.
Park et al. (2018), South Korea	Nova Petite Dermal Phase meter with a range of 0–999 dermal phase units	Wound care nurse	7 sites – both buttocks, ischial tuberosities, trochanters and sacrum coccyx	Once per week between 9–10 AM	SEM measurements required a small wand to be placed on skin for 5 secs. Patients with incontinence were cleaned and dried prior to SEM measurements
Raizman et al. (2018), Canada	Bruin Biometrics SEM scanner 200	9 Registered practical nurses	Sacrum and heels	Phase 1 – 5×/week for up to 1 month Phase 2 – alternative care unit patients 5×/week for up to 2 weeks. All others a minimum of 3× in first 7 days of admission.	Scans were conducted as per manufacturer's instructions for use.
Smith (2019), United Kingdom	Bruin Biometrics SEM scanner	Healthcare assistants scanned and registered nurses interpreted results to implement targeted interventions	Sacrum and Heels	Daily at the same time each day	Details not reported

Abbreviations: PI, pressure injuries; SEM, sub-epidermal moisture; VSA, visual skin assessments.

What parameters informed implementation of pressure injury prevention strategies?	What training was required and did clinicians report ease of use?	Who involved health consumers in research process
Abnormal SEM reading defined as ≥0.6 SEM delta for 2 or more consecutive days	Training not reported Ease of use not reported	No health consumer engagement was reported
Differences of 20, 50 and 100 dermal phase units, were considered. Higher differences indicating a higher SEM value and increased risk.	Training not reported Ease of use not reported	No health consumer engagement was reported
Abnormal SEM reading defined as ≥0.6 SEM delta, however no number of data points to make a clinical decision reported. 88% commented the SEM scanner was a useful adjunct to their clinical decision	Training by manufacturer including supervised practical assessment on 'normal skin' volunteers and patients with type I PI. 75% found SEM scanner easy to use	No health consumer engagement was reported
Abnormal SEM reading defined as ≥0.6 SEM delta, however no number of data points to make a clinical decision reported. If SEM delta indicated damage but not obvious on VSA then PIP interventions were commenced 88% ($n = 30$) nurses report SEM scanning supported clinical decision making	Training by manufacturer and company support was available in person bi-weekly for 6 months and via email. 100% ($n = 34$) nurses reported easy to learn to use. 76% ($n = 26$) reported they would choose to use the SEM scanner in future practice. 47% ($n = 16$) nurses report SEM scanning added time to cares.	No health consumer engagement was reported
≥0.6 SEM delta of two or more from 3 consecutive days. However, clinicians assessing were not involved in interventions in this study.	Training by manufacturer Ease of use not reported	No health consumer engagement was reported
Abnormal SEM reading defined as ≥0.6 SEM delta of two or more from 3 consecutive days. Clinical decision matrix was used to inform clinical judgement	Training by manufacturer Ease of use not reported	No health consumer engagement was reported
50 or 100 dermal phase unit increase indicated increased risk of PI.	Training was provided for the study and included staging of PI. Ease of use not reported	No health consumer engagement was reported
Abnormal SEM reading defined as ≥0.6 SEM delta Nurses reported improved confidence with experience in use of SEM scanner and valued training and follow up support As results were reported back to the nurses their confidence increased, and this may have influenced the results	In Phase 1 staff not trained in interpretation of SEM. In Phase 2 staff trained in interpretation and received ongoing support In Phase 2 Deltas and Braden scores were recorded on a single page and prompting additional interventions if risk increased in either score	No health consumer engagement was reported
Abnormal SEM reading defined as ≥0.6 SEM delta Although SEM scanner use is reasonably rapid it does increase time of skin assessments, however, provides immediate feedback which was valued by staff, as it influenced decision	Training was provided by manufacture and a representative of Bruin Biometrics visited biweekly to support evaluation of measures	No health consumer engagement was reported

TABLE 3 PAGER framework.

Patterns	Advances	Gaps	Evidence for practice	Research recommendations
Evidence of the use of point-of-care SEM devices	There is some evidence of two point-of-care SEM devices being used by bedside clinicians.	There is a need for large multi-site empirical studies into the clinical use of point-of-care SEM devices and their cost-effectiveness.	The use of objective tools may assist nurses in identifying those at risk of pressure injuries.	To continue to develop, validate, implement and evaluate the use of SEM devices.
Operation of point-of-care SEM devices to ensure accurate measurement	There is some evidence that nurses are the primary clinicians who use point-of-care SEM devices to periodically assess the risk of pressure injury at the sacrum, heels, pelvis and hips, following limited pre-scanning procedures.	There is a paucity of research about the use of SEM devices by the multi-disciplinary team, for all at-risk anatomical sites, and on uniform pre-scanning protocols and scheduling of use.	As nurses offer continuous care, they are well positioned to coordinate frequent pressure injury risk assessments and advocate for sustainable, standardised tools to facilitate accurate interpretation and timely implementation of pressure injury prevention initiatives.	To research, the suitability of the point-of-care SEM devices used by the multi-disciplinary team. To continue to develop evidence-based protocols for use of SEM devices for all at-risk anatomical sites.
Interpreting measurement to determine pressure injury risk	There is some evidence on parameters of interpreting SEM devices readings.	There is conflicting research on the number of readings required to interpret results.	It is important for nurses to have standardised protocols to allow for accurate interpretation of results across shifts.	To develop evidence-based standardised interpretation of SEM devices.
Health consumer involvement	Point-of-care SEM devices are being used in a variety of patient groups.	There was no evidence of health consumers' involvement in the included studies.	Health consumers' involvement in research provides valuable insight into health priorities.	One strategy for fostering active engagement in health research by health consumers is to adopt a structured framework to describe the health consumer's position on the research team.

(Nightingale & Musa, 2021) of clinicians found the SEM devices easy to use.

(v) Consumer involvement in the conduct of research on clinical use of SEM devices? No consumer engagement was reported at any stage of the research process in any of the included studies.

4 | DISCUSSION

Point-of-care technologies offer the potential to improve the delivery of high-quality, effective and efficient healthcare, however, a paucity of evidence exists on bedside clinicians' use of SEM devices for pressure injury risk assessment. Table 3 presents our findings using the PAGER framework (Bradbury-Jones et al., 2021), which guides our discussion. This scoping review found two point-of-care SEM devices were used to detect localised oedema in clinical practice; the Bruin Biometrics SEM Scanner Point of Care 200 and the NOVA Petite Dermal Phase meter. The Bruin Biometrics SEM scanner was predominant at the bedside because as Bryant et al. (2021) explains, it is the only Food and Drug Administration (FDA) pressure injury prevention device authorised for clinical use, with the NOVA Petite available for research only. Two studies (Kim et al., 2018; Park et al., 2018) that used the NOVA Petite were included in this review because bedside clinicians, not researchers, undertook the measurements. Devices that measure localised oedema are recommended in the international pressure injury prevention clinical practice guidelines (EPUAP et al., 2019); however, the World Health Organization (2022) acknowledges innovative healthcare technologies are expensive which can reduce clinician and patient access. As preventing pressure injuries can reduce healthcare costs (Nghiem et al., 2022) research into the cost-effectiveness of these point-of-care technologies is needed.

Although all health professionals are responsible for preventing injuries, nurses have the most direct contact with patients 24 h a day (Redley et al., 2022). Our review found the principal users of SEM devices are nurses in hospital settings with localised oedema assessed at the anatomical sites of the sacrum, pelvis, hips and/or heels. These findings are consistent with the nursing professional role of coordinating pressure injury risk assessment and prevention care (Sim et al., 2018) and the sacrum and heels being the most common sites of pressure injuries (Li et al., 2020). Manufacturers provided training, and the SEM devices were reported to be simple to use (Musa et al., 2021; Nightingale & Musa, 2021) and supported nursing judgements (Musa et al., 2021; Nightingale & Musa, 2021; Raizman et al., 2018; Smith, 2019).

Several studies, which were conducted in acute care settings describe using the SEM scanner on a daily basis (Musa et al., 2021; Okonkwo et al., 2020), which is substantially less frequent than current pressure injury prevention clinical practice guidelines, which recommends two hourly skin assessment for at-risk patients (EPUAP et al., 2019). Furthermore, the number of repeated elevated readings required to support clinical judgement also varied (Gefen & Gershon, 2018; Okonkwo et al., 2020; Ore & Carver, 2020). The manufacturer (Bruin Biometrics, 2020) and international pressure injury prevention clinical practice guidelines (EPUAP et al., 2019) do not provide specific guidance but suggest bedside clinicians use these point-of-care devices as an adjunct to routine clinical skin assessment. These devices may help prevent pressure injuries (Chaboyer et al., 2022; Li et al., 2020) and improve the quality of healthcare services patients receive (Weller et al., 2018), so providing clinicians with specific guidance on procedure for use is needed. This also highlights the present knowledge gap in the clinical use of the two SEM devices examined and the need for further clinical studies.

Point-of-care technologies for pressure injury risk assessment require extra clinical considerations for interpretation as they seek to detect risk rather than diagnose and therefore consideration of the impact of modifiable risk factors is required. We know increases in localised oedema measurements do not always indicate a pressure injury, however, a pressure injury is always preceded by increased localised oedema (Okonkwo et al., 2020). Pre-stage pressure damage is reversible with intervention (Moore et al., 2017), however, once a pressure injury is present it is not. We found discrepancies in the parameters used to interpret the SEM device data and little guidance supporting nursing judgements on implementing timely pressure injury prevention strategies (Musa et al., 2021; Nightingale & Musa, 2021; Raizman et al., 2018; Smith, 2019). Given the potential fluctuations in localised oedema with the body's homeostatic process and gravity (Gefen et al., 2021; Okonkwo et al., 2020), clear evidence-based guidelines are needed to interpret clinical SEM data to inform prevention strategies.

This scoping study did not identify any evidence of engagement of health consumers in the research process. Health consumer involvement is associated with higher-quality and more clinically relevant research (Tobiano et al., 2021) and is supported by funding organisations such as the NHMRC of Australia, the Medical Research Council (20 of the United Kingdom, and the Health Research Board (2021) of Ireland. As such, there are opportunities for researchers, policy makers and healthcare organisations in the future to gain valuable insights by involving health consumers in this area of pressure injury risk assessment research.

5 | LIMITATIONS

We acknowledge several limitations to this scoping review. Despite a comprehensive approach to this review, our efforts may have missed eligible studies. Due to funding limits, our literature search only included literature published in English, and all but two studies were from English-speaking countries, which may have further limited our findings. Our focus was on bedside clinicians' use and thus we did not synthesise evidence on the procedural instructions utilised by researchers.

6 | CONCLUSIONS

This scoping review mapped and synthesised the available literature to evaluate point-of-care SEM devices used by bedside clinicians to detect localised oedema and objectively measure pressure injury risk. The review identified nurses as the principal users of two bedside devices in the assessment of pressure injury risk. The SEM devices were reported to be easy to use, and nurses acknowledged that the use of objective measures influenced their clinical judgements on pressure injury prevention care. However, the scarcity of procedural instructions and variability in indicative readings and frequency, highlights a significant gap in knowledge. Evidence-based assessments require accurate instrument interpretation and further research into the impact of modifiable factors on localised oedema is required.

7 | RELEVANCE TO CLINICAL PRACTICE

The use of objective tools has the potential to enhance nursing practise. Although devices, like the SEM scanner and NOVA Petite meter, may enhance pressure injury risk assessments as an adjunct to routine skin assessment, the potential benefit may not be realised in the absence of clear procedural instructions. Although little is known about bedside use, the international pressure injury clinical practice guidelines recommend that clinicians receive training in the use of SEM devices to facilitate consistent methods across time and between users (EPUAP et al., 2019). The scarcity of published clinical research and varied approach to using the SEM devices summarised in this scoping review poses questions about the elements required in this training. Nurses and nursing researchers are well positioned to lead the development of evidence-based standardised procedures for the use and interpretation of point-of-care SEM devices to augment pressure injury prevention practice.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing interests.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Annette McLaren-Kennedy https://orcid.org/0000-0003-4124-1460

Sharon Latimer https://orcid.org/0000-0003-2704-150X

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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