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Risk factors predicting hospital-acquired pressure injury in adult patients: An overview of reviews

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ABSTRACT

Background: Hospital-acquired pressure injuries remain a significant patient safety threat. Current well-known pressure injury risk assessment tools have many limitations and therefore do not accurately predict the risk of pressure injury development over diverse populations. A contemporary understanding of the risk factors predicting pressure injury in adult hospitalised patients will inform pressure injury prevention and future researchers considering risk assessment tool development may benefit from our summary and synthesis of risk factors.
Objective: To summarise and synthesise systematic reviews that identify risk factors for hospital-acquired pressure injury development in adult patients.
Design: An overview of systematic reviews.
Methods: Cochrane and the Joanna Briggs Institute methodologies guided this overview. The Cochrane library, CINAHL, MEDLINE, and Embase databases were searched for relevant articles published in English from January 2008 to September 2022. Two researchers independently screened articles against the predefined inclusion and exclusion criteria, extracted data and assessed the quality of the included reviews using "a measurement tool to assess systematic reviews" (AMSTAR version 2). Data were categorised using an inductive approach and synthesised according to the recent pressure injury conceptual frameworks.
Results: From 11 eligible reviews, 37 risk factors were categorised inductively into 14 groups of risk factors. From these, six groups were classified into two domains: four to mechanical boundary conditions and two to susceptibility and tolerance of the individual. The remaining eight groups were evident across both domains. Four main risk factors, including diabetes, length of surgery or intensive care unit stay, vasopressor use, and low haemoglobin level were synthesised. The overall quality of the included reviews was low in five studies (45 %) and critically low in six studies (55 %).
Conclusions: Our findings highlighted the limitations in the methodological quality of the included reviews that may have influenced our results regarding risk factors. Current risk assessment tools and conceptual frameworks do not fully explain the complex and changing interactions amongst risk factors. This may warrant the need for more high-quality research, such as cohort studies, focussing on predicting hospital-acquired pressure injury in adult patients, to reconsider these risk factors we synthesised.
Registration: This overview was registered with the PROSPERO (CRD42022362218) on 27 September 2022.

What is already known

- Hospital-acquired pressure injuries remain a significant threat to patient safety.
- A variety of risk factors contribute to the development of pressure injury in acute settings.
- Current pressure injury risk assessment tools have many limitations, such as low validity, low predictive accuracy, low specificity, and limited clinical utility in certain populations and/or clinical settings.

What this paper adds

- This overview showed that diabetes, vasopressor use, length of surgery or intensive care unit stay, and low haemoglobin level are risk

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factors consistently identified as contributing to hospital-acquired pressure injury development.
- Our findings highlighted the limitations of the included reviews' quality, as assessed by various quality assessment tools.
- This overview identified the need for more high-quality research, such as cohort studies, focussing on predicting hospital-acquired pressure injuries for adult patients, to reconsider these risk factors we synthesised.

1. Introduction

Hospital-acquired pressure injuries are one of the most frequently occurring and potentially preventable adverse events (Slawomirski et al., 2017). A pressure injury refers to damaged skin and/or underlying tissue caused by either pressure or shear and/or a combination of these (European Pressure Ulcer Advisory Panel et al., 2019). The global incidence of hospital-acquired pressure injuries is meta-analysed as approximately 5.4 per 10,000 hospital patients per day (Li et al., 2020). Whilst the global prevalence of pressure injuries is around 12 % (Li et al., 2020; Rodgers et al., 2021) amongst adult hospitalised patients, the prevalence of hospital-acquired pressure injuries ranges approximately from 7 % to 9 % (Li et al., 2020; Rodgers et al., 2021).

Despite extensive efforts in developing and implementing quality health service standards, policy directives, and international pressure injury guidelines, the impact of pressure injuries on patients remains (Burston et al., 2023; Vanaki et al., 2023). This threat includes psychological distress, pain, diminished quality of life, and even death (Gorecki et al., 2009; Kim et al., 2019). Pressure injuries prolong hospital stays and negatively impact healthcare organisations (Demarre et al., 2015). The Organisation for Economic Cooperation and Development estimates that up to 15 % of hospital expenditure is spent on treating safety failures with pressure injuries being one of the most expensive adverse events (Slawomirski et al., 2017), costing the health system at least $9–$11 billion in United States of America and about £1.4–£2.1 billion in United Kingdom (Padula and Pronovost, 2018). A recent cost of illness review identified the cost of pressure injuries in Australian public hospitals to be over $9 billion per year with $5.5 billion for hospital-acquired pressure injuries (Nghiem et al., 2022). Yet, these cost estimates do not consider the toll pressure injuries have on patients and carers.

Pressure injury risk assessment is guided by the contemporary guidelines (European Pressure Ulcer Advisory Panel et al., 2019), which recommend the use of several well-known risk assessment tools as one approach to identify risk, particularly when they are not used alone clinically. Notable examples of these tools include Braden (Braden and Bergstrom, 1987), Waterlow (Waterlow, 1985), Norton (Norton et al., 1962), and Cubbin-Jackson scales (Jackson, 1999). However, there is an absence of compelling evidence substantiating the efficacy of these assessment tools in reducing the incidence or prevalence of pressure injuries (Moore and Patton, 2019). Numerous recognised limitations of these tools include their reliance on clinician's subjective judgement-based assessment, targeting relatively finite populations, potentially resulting in an imprecise evaluation of contemporary risk across diverse populations (Moore and Patton, 2019; Samuriwo and Dowding, 2014). Furthermore, the risk factors used in these tools do not necessarily independently predict the development of pressure injuries (Coleman et al., 2013). Additionally, a myriad of other contextual factors may affect their clinical utility, including constrained staffing levels (Fletcher, 2017), a lack of time and staff competence (Nadeem and Healee, 2021; Samuriwo and Dowding, 2014), underdeveloped nursing skills in critical thinking and decision-making (Defloor and Grypdonck, 2005; Nadeem and Healee, 2021), the biasing influence of prior knowledge of assessment tools on clinical judgement (Moore and Patton, 2019) and a lack of tool applicability to a variety of clinical settings (Zhang et al., 2021). Over 30 years following the development of these risk assessment tools, some reviews have identified additional predictors such as emotional stress (Braden, 1998; Nijs et al., 2009) and tissue hypoxia (Flynn and Tooke, 1995; Wang et al., 2016). Coleman et al.'s (2013) systematic review of 54 studies identified eight risk factor domains including mobility, perfusion, skin condition, nutrition, age, haematological measures, skin moisture, and general health. More recently, a systematic review of prognostic factors identified localised oedema as a predictor of pressure injuries in anatomical locations of sacrum and heel (Chaboyer et al., 2022). However, to date a synthesis of evidence-based risk factors predicting the development of hospital-acquired pressure injuries in adult patients has not been undertaken.

Current systematic reviews have focussed on various risk factors for different anatomical locations (Dube et al., 2022), populations (Grigorian et al., 2017; Najmanova et al., 2022), settings (Haisley et al., 2020; Lima Serrano et al., 2017), medical devices (Barakat-Johnson et al., 2019; Brophy et al., 2021), procedures (Bulfone et al., 2018), medications (McEvoy et al., 2022), and specific clinical conditions such as diabetes (Nasiri et al., 2021) and incontinence (Beeckman et al., 2014). Whilst their findings have contributed to a clinical focus on pressure injury prevention, they are fragmented and do not provide a synthesis of risk factors.

A contemporary understanding of risk factors for developing hospital-acquired pressure injury in adult patients may facilitate the development of evidence-based approaches to pressure injury risk assessment, which in turn inform more targeted and personalised preventive care plans. Current assessment tools were either developed using empirically selected predictors in the absence of advanced statistical methods or based on pre-defined hypotheses (Shi et al., 2019). New approaches, such as machine learning, using vast health data without being constrained by existing knowledge and theory (Scott et al., 2021), are rapidly emerging (Hu et al., 2020; Jiang et al., 2021; Nakagami et al., 2021; Song et al., 2021), with the potential to develop new knowledge and theory (Scott et al., 2021).

The aim of this overview of systematic reviews was to summarise and synthesise hospital-acquired pressure injury risk factors in adult patients. These findings may help to inform the development of pressure injury risk prediction models such as those developed using machine learning techniques.

This overview had one primary and one secondary question. The primary question was: What risk factors predict hospital-acquired pressure injuries in adult patients? The secondary question focussed on three subgroups of patients was: What risk factors predict hospital-acquired pressure injuries in medical, surgical, and intensive care patients?

2. Methods

2.1. Review design

An overview of systematic reviews, guided by both the Cochrane Collaboration resources (Pollock et al., 2022), and the Joanna Briggs Institute Manual (Aromataris et al., 2020), was undertaken. Overviews, also known as umbrella reviews, meta-reviews, or reviews of reviews (Aromataris et al., 2020; Pollock et al., 2022), aim to address broader research questions with greater scope than those examined in individual systematic reviews. It uses systematic reviews as the unit of searching, inclusion, and data analysis (Pollock et al., 2022), to summarise and synthesise evidence on a topic based on explicit and systematic methods to contribute to better decision making (Hunt et al., 2018; Pollock et al., 2022). Considering the significant surge in systematic review publications over recent decades (Hoffmann et al., 2021), an overview that summarises and synthesises review findings is necessary. As these findings may inform the development of pressure injury assessment tools or prediction models, especially when overviews are relatively scarce in the field of risk factors related to pressure injuries.

The research questions were developed using the population, prognostic factors, and outcome approach (Munn et al., 2018). We have deliberately chosen this approach, rather than using the population, exposure, outcome approach, prioritising prediction over causation. In research questions, the population was hospitalised adults (aged 16 years and older), ensuring that all risk factors summarised only related to the period of hospitalisation (Chaboyer et al., 2022). The exposures investigated were risk factors that predicted the development of hospital-acquired pressure injuries, including intrinsic factors such as patient's body mass index, nutritional status, comorbidities, and extrinsic factors such as type and length of surgery, and medication administration. The outcomes of interest were any stage of hospital-acquired pressure injury as defined by the International Pressure Injury Guideline (European Pressure Ulcer Advisory Panel et al., 2014). The overview's protocol was registered in the international prospective register of systematic reviews (PROSPERO) (registration number: masked for blinded peer review) on 27 September 2022. The results of this overview were presented based on the research questions and objectives, using narrative, graphical and/or tabular summaries. As a meta-analysis was not possible because of marked study heterogeneity, the findings were presented in a narrative format.

2.2. Inclusion and exclusion criteria

Inclusion and exclusion criteria for selecting reviews were reported in Table 1. Systematic reviews with and without meta-analyses published in English between January 2008 and September 2022 were included. We only included articles published in English due to resource constraints. We excluded reviews that included cross-sectional studies, as the temporal order between predictor and outcome cannot be established, therefore, they cannot differentiate cause and effect from association (Mann, 2003).

Whilst using multivariate analysis for risk factor identification is important for predictive purposes, our inclusion and exclusion criteria did not restrict our search scope based on specific statistical methods used in the included review and their primary studies. This aligns with the overall aim of this overview to capture a wide range of literature that identifies risk factors.

To ensure the inclusion of contemporary data and minimise the potential impact of outdated pressure injury prevention guidelines and practices, we focussed on reviews published from 2008 onwards. This was because pressure injury prevention practices have markedly progressed over this period. These changes have informed further iterations of the international clinical practice guidelines in this area, starting from 2008 (Gillespie et al., 2021).

The terms “risk factors,” “predictors,” and “prognostic factors” are often used interchangeably in publications and the terms “association” and “prediction” are also used interchangeably (Varga et al., 2020). As a result, the systematic reviews that adopted these terms were included to reduce the possibility of missing relevant reviews that identified risk factors. Systematic reviews of studies focussed solely on certain medical conditions and/or targeted patient populations were excluded as their findings could not be generalised.

2.3. Search strategies

Four databases were searched, including CINAHL (via EBSCOhost), MEDLINE (via EBSCOhost), Embase (via Elsevier) and Cochrane library (via Wilson), and no geographical restrictions were applied. A comprehensive search strategy including medical subject headings (MeSH) was outlined in Supplementary File 1. Searches were undertaken by two researchers independently on 21 September 2022. Backward searching of the full-text article's reference list and forward searching of the article's citations after its publication (in Scopus) were also undertaken to find additional eligible reviews.

Table 1
Inclusion and exclusion criteria.

Inclusion	Exclusion
1. Systematic reviews of prospective or retrospective cohort studies focussing on risk factors of the development of hospital-acquired pressure injuries in adult patients. 2. Published between 2008 and 2022. 3. Published in English.	1. Systematic reviews of primary intervention studies. 2. Hospitalised patients' subset data that could not be extracted from the review (the analytic results were not reported separately), e.g., hospital and nursing home data were combined.

2.4. Screening

Systematic review software Covidence was used to screen eligible reviews (Veritas Health Innovation, 2023). Titles and abstracts were screened independently by two researchers according to the inclusion and exclusion criteria. Full-text copies of potentially eligible systematic reviews were then screened by two researchers independently and adjudicated by a third reviewer as needed.

2.5. Data extraction

Data were extracted independently by two researchers and adjudicated by a third if required. A data extraction form was pilot tested on two (12.5 %) included systematic reviews, which led to relevant form modifications. Extracted data comprised authors' names, year of publication, reviews' analytic methods, number of included primary studies, population or clinical settings, number of risk factors summarised, sample size, risk factors identified by review authors, sex and age of participants, and key findings. Where necessary, review authors were contacted to identify missing information or inconsistency of reported data.

2.6. Data synthesis and analysis

Individual risk factors were inductively categorised as conceptualised risk factor groups associated with mechanical boundary conditions, individual susceptibility and tolerance, or both, based on the conceptual framework first proposed in the International Pressure Injury Guidelines in 2009 (European Pressure Ulcer Advisory Panel et al., 2009) and subsequently adapted twice in 2014 and 2019 (Coleman et al., 2014; European Pressure Ulcer Advisory Panel et al., 2019).

Mechanical boundary conditions refer to the magnitude, duration and type of mechanical load (i.e. shear, friction and pressure) whilst individual susceptibility and tolerance includes mechanical properties of the tissue, morphology of the tissue and bone, tissue transport and thermal properties, as well as physiology and tissue repair (European Pressure Ulcer Advisory Panel et al., 2019). Typical risk factors linked with mechanical boundary conditions include immobility and medical device use, whereas poor perfusion and cardiovascular disease are related to individual susceptibility and tolerance.

2.7. Quality appraisal

Version 2 of “A MeaSurement Tool to Assess Systematic Reviews” was used to assess the methodological quality of the systematic reviews (Shea et al., 2017). Originally developed with a focus on evaluating the quality of systematic reviews of randomised controlled trials, the tool has been recommended as an appropriate quality appraisal tool for various overviews (Pollock et al., 2022) to evaluate aspects, such as study selection, data extraction, and synthesis of results. This tool comprises 16 items to evaluate the overall rating of the systematic reviews, based on methodological weaknesses in both critical and non-critical domains with authors identifying seven mandatory critical domains (Shea et al., 2017), including: registration of the protocol prior to the commencement (item 2), adequacy of the literature review (item 4), justification for the exclusion of studies (item 7), risk of bias of included studies (item 9), appropriateness of a meta-analysis (item 11), the impact of risk of bias in individual studies (item 13) and impact of publication bias (item 15).

To ensure this tool was fit for purpose, some modifications relevant to items one, eight and nine were made based on previous literature (A. Pollock et al., 2017). The items of ‘Intervention’ and ‘Comparator group’ were removed and replaced with 'Risk factors' in item one. Similarly in item eight, the item of 'described interventions and comparators' was replaced with 'described risk factors'. The item of 'methods used to ascertain exposures and outcomes' in item nine under non-randomised studies of intervention was placed with 'risk factors'. All items were assessed using a scale of 'yes', 'partial yes', 'no', and 'no meta-analysis conducted', for an overall rating of High, Moderate, Low and Critically low confidence (Shea et al., 2017). One critical domain assessed as either 'partial yes' or 'no' will result in a 'low' rating whilst two critical domains resulted in a 'critical low' rating. However, an overall rating should not to be considered alone (Shea et al., 2017). Instead, the compliance to each item, especially critical items is important (Shea et al., 2017). 'Partial yes' and 'no' will be regarded as 'no' for the purpose of calculating the percentage of compliance rates. A compliance rate above 50 percentage on a scale from zero to 100 for each quality appraisal item indicates that the included reviews demonstrate reasonable adherence in that specific item. Two researchers were trained to independently assess quality of included reviews, with disagreements discussed until consensus was reached.

3. Results

3.1. Search outcomes

In total, 11 eligible reviews met the inclusion and exclusion criteria (Fig. 1). After full-text screening, 85 reviews were excluded, with citations and reasons for exclusion outlined in Supplementary File 2. Research designs other than systematic review were excluded, however, one scoping review undertook a systematic review process and was therefore included after full-text screening.

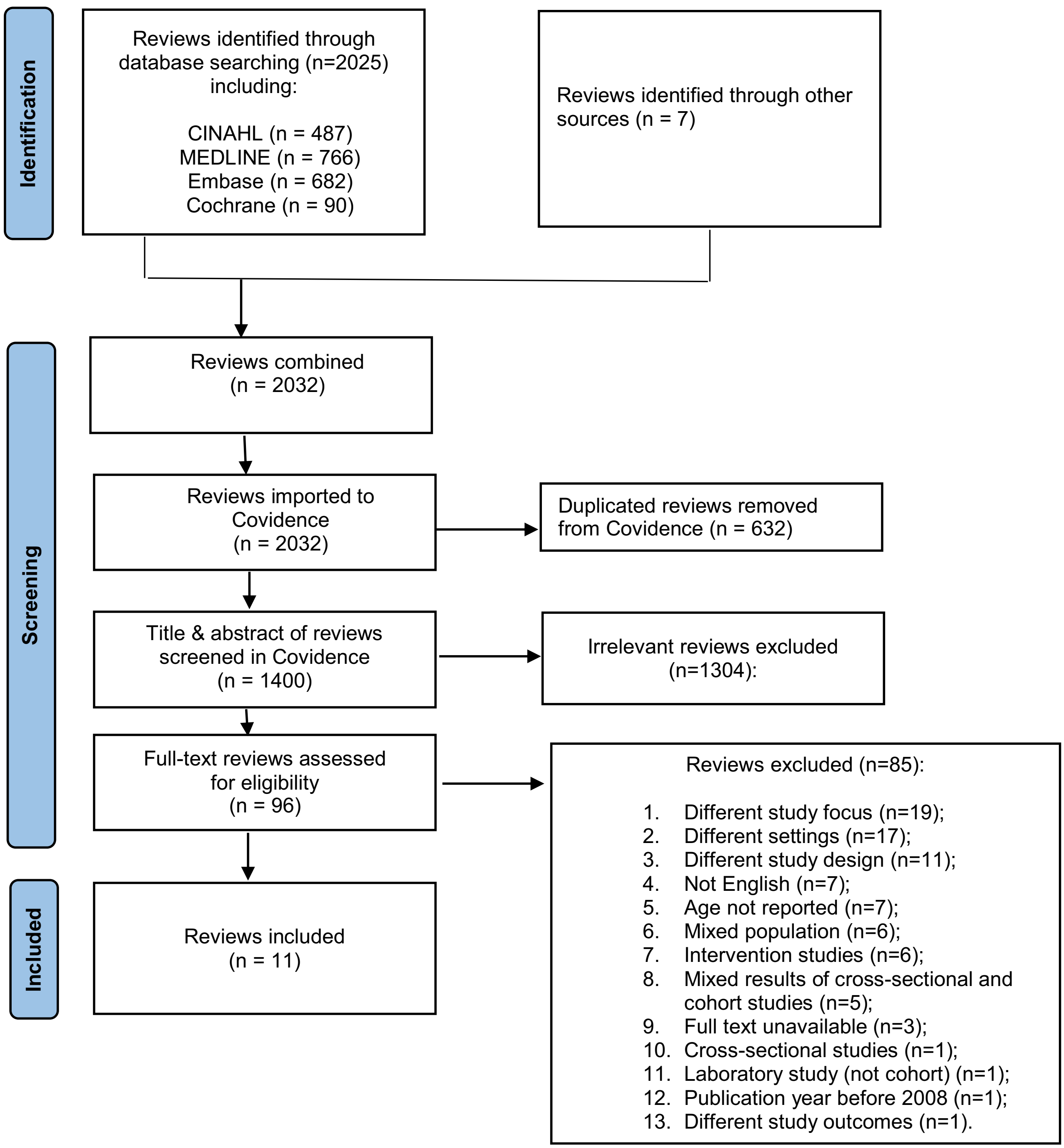

Fig. 1. PRISMA flow diagram.
Note. From: "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews", by M. J. Page, et al., *British Medical Journal 2021*, 372, p. n71.

3.2. Study characteristics

All reviews included in this overview involved a combination of prospective and retrospective cohort studies. Table 2 presented a summary of included reviews. Of the 11 reviews, five (45 %) reviews (Alderden et al., 2017; Cox, 2013; Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021) provided a narrative description of risk factors, whilst the remaining six (55 %) reviews conducted meta-analyses. None of the review authors reported using multivariate meta-analysis methods. Risk factors were identified in intensive care units by six (55 %) reviews (Alderden et al., 2017; Cox, 2013; Fulbrook et al., 2021; Lima Serrano et al., 2017; McEvoy et al., 2022; Weber et al., 2021), in mixed hospital settings by one (9 %) review (Rao et al., 2016), whilst the remaining four (36 %) reviews focussed on perioperative or surgical settings. The risk factors predicting hospital-acquired pressure injuries in specific medical and surgical patient cohorts were not reported. Sample sizes ranged from 1482 to 40,712 patients, however, two reviews (Haisley et al., 2020; McEvoy et al., 2022) did not report the sample size.

3.3. Summary of risk factors

Common risk factors synthesised in this overview included diabetes in six (55 %) reviews (with four meta-analyses), length of surgery or intensive care unit stay in six (55 %) (with two meta-analyses), vasopressor use in six (55 %) (with one meta-analysis), and low haemoglobin level in two (18 %) (with one meta-analysis). The category of hospital-acquired pressure injury, sex and age of participants was not reported in most included reviews, contributing to a lack of information. A summary of these risk factors was presented in Table 3.

Diabetes emerged as a significant risk factor for hospital-acquired pressure injury in this overview. Two meta-analyses (Haisley et al., 2020; Liang et al., 2017) reported similar risk ratios (RR = 1.49, 95 % confidence interval 1.29–1.71; RR = 1.77, 95 % confidence interval 1.45–2.16, respectively). A subgroup analysis of another meta-analysis (Kang and Zhai, 2015) showed that diabetes increased the risk of pressure injury development in cardiac surgical patients (OR = 2.00, 95 % confidence interval 1.42–2.82), general surgical patients (OR = 1.75, 95 % confidence interval 1.42–2.15), and major lower limb amputation patients (OR = 1.65, 95 % confidence interval 1.01–2.68). Notably, there was no significant difference in pressure injury incidence between patients with and without diabetes following hip surgery (Kang and Zhai, 2015), whilst another meta-analysis (Wei et al., 2017) underscored diabetes increased the risk of pressure injury in hip fracture patients (OR = 1.82, 95 % confidence interval 1.37–2.43).

Length of surgery, as a risk factor, was defined in minutes in one meta-analysis (Haisley et al., 2020), whilst length of stay in intensive care unit was measured in days in another meta-analysis (McEvoy et al., 2022), Both reviews presented mean differences for duration (MD = 69.81 min, 95 % confidence interval 2.36–137.26; MD = 11.46 days, 95 % confidence interval 7.10–15.82, respectively). Whilst one narrative review (Rao et al., 2016) specified length of hospitalisation exceeding three days as a risk factor, three other reviews (Haisley et al., 2020; McEvoy et al., 2022; Weber et al., 2021) generally identified longer duration as a risk factor, without the precise definition of what constituted ‘longer’ duration.

One meta-analysis (McEvoy et al., 2022) investigated pressure injury risk related to the use of vasopressor drugs in intensive care patients, according to dose, duration and the specific type of agent (noradrenaline, vasopressin, dopamine, and adrenaline). Whilst the authors did not report odds or risk ratio, the mean differences were presented for duration and dose of vasopressor (MD = 65.97 h, 95 % confidence interval 43.47–88.47; MD = 8.76 μg/min, 95 % confidence interval 6.06–11.46, respectively). Additionally, five narrative reviews (Alderden et al., 2017; Cox, 2013; Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021) also identified vasopressor use as a broad risk factor for patients in intensive care units.

Other important risk factors identified by one meta-analysis (Haisley et al., 2020) included low haemoglobin levels (Mean difference = −7.94 g/l, 95 % confidence interval −13.2 to −2.76), cardiovascular disease (Risk ratio = 2.24, 95 % confidence interval 1.56–3.22), and respiratory disease (Risk ratio = 3.28, 95 % confidence interval 1.89–5.71). However, the last two risk factors were not reported by the included narrative reviews, and versa vice, some risk factors were only identified in narrative reviews, such as, increasing age reviews (Alderden et al., 2017; Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021), medical devices related to mechanical ventilation use in intensive care unit (Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021), the Braden score (Rao et al., 2016; Weber et al., 2021), dialysis (Lima Serrano et al., 2017; Rao et al., 2016) and vascular (Rao et al., 2016).

3.4. Risk factors by domains

A total of 37 distinct risk factors were synthesised. These risk factors were then categorised inductively into 14 groups of risk factors as outlined in Table 4, which were further categorised into three aetiological domains: mechanical boundary conditions, susceptibility and tolerance of the individual, and both (European Pressure Ulcer Advisory Panel et al., 2019).

Within the 14 groups, four (29 %) and two (14 %) groups of risk factors were related to the mechanical boundary conditions and the susceptibility and tolerance of the individual domains, respectively. However, eight (57 %) groups of risk factors were evident in both domains and sex was related to neither (see Table 4).

Table 2
Characteristics of included reviews (n = 11).

First author, year	Analytic method	Number of included primary studies	Population/clinical settings/subgroups	Number of risk factors summarised	Number of participants
Alderden et al., 2017	Narrative	18	Intensive care unit	4	7908
Cox, 2013	Narrative	10	Critical care patients Medical/surgical intensive care units, general intensive care units, a long stay peri-anaesthesia care unit	7	5989
Fulbrook et al., 2021	Meta-analysis	15	Cardiac intensive care unit	1	8570
Haisley et al., 2020	Meta-analysis	14	Surgical patients undergoing surgery under general anaesthesia (in relation to postoperative pressure injuries)	1	NR
Kang and Zhai, 2015	Meta-analysis	13	Perioperative patients	1	14,420
Liang et al., 2017	Meta-analysis	16	Perioperative diabetic patients (in relation to postoperative pressure injuries)	1	24,112
Lima Serrano et al., 2017	Narrative	17	Intensive care unit	10	19,363
McEvoy et al., 2022	Meta-analysis	13	Intensive care unit	4	NR
Rao et al., 2016	Narrative	20	Surgical critically ill cardiac patients	30	40,712
Weber et al., 2021	Narrative	6	Intensive care unit	9	1482
Wei et al., 2017	Meta-analysis	8	Perioperative patients with hip fracture	1	22,180

Abbreviation: NR, not reported.

Table 3
Risk factors in relation to domain, outcomes, and review's quality (n = 11).

First author, year	Risk factors	Pooled estimates (OR/RR)	95 % confidence interval	p	Quality assessment as reported by review authors		ARMSTAR 2 quality appraisal
Alderden et al., 2017	Age	NR	NR	NR	A tool developed by the author.	61 % of the included studies were rated as low or very low quality.	Low
	Mobility/activity level	NR	NR				
	Poor perfusion	NR	NR				
	Vasopressor infusion	NR	NR				
Cox, 2013	Vasopressor agents	NR	NR	NR	NR	NR	Critically low
Fulbrook et al., 2021	Cardiac surgery	NR	NR	NR	A modified tool developed by Hoy et al. (2012)	An overall risk of bias was low, with scores ranging between eight and ten.	Critically low
Haisley et al., 2020	Diabetes	RR 1.49	1.29–1.71	0.001	NOS	All studies were rated as high quality (scoring over five on a scale of zero to nine). However, 42 % of the included studies did not report on the comparability of the patient groups or the completeness of data.	Critically low
	Cardiovascular disease	RR 2.24	1.56–3.22	<0.001			
	Respiratory disease	RR 3.28	1.89–5.71	0.001			
	Longer duration of surgery	MD 69.81 min	2.36–137.26	0.04			
	Lower levels of haemoglobin	MD −7.94	−13.12, −2.76	0.003			
Kang and Zhai, 2015	Pre-existing diabetes (overall all surgeries)	OR 1.74	1.40–2.15	0.014	NOS	All included studies were rated as high quality, with scores ranging from five to eight points (five or more points were defined as high quality).	Low
Liang et al., 2017	Pre-existing diabetes mellitus	RR 1.77	1.45–2.16	<0.001	NOS	14 high-quality studies (scoring six or higher) and two low-quality studies (scoring less than six).	Low
Lima Serrano et al., 2017	Vasopressor support	NR	NR	NR	The CASPe	Six studies were of high quality (scoring over eight points), whilst 11 studies were rated as moderate quality (scoring between six and eight points).	Critically low
	Age	NR	NR	NR			
	Diabetes	NR	NR	NR			
	Intermittent haemodialysis or continuous veno-venous haemofiltration therapy	NR	NR	NR			
	Length of stay in the intensive care unit	NR	NR	NR			
	Length of mechanical ventilation	NR	NR	NR			
	Mechanical ventilation	NR	NR	NR			
	Sedation	NR	NR	NR			
	Time of mean arterial pressure <60–70 mmHg	NR	NR	NR			
	Turning (postural changes)	NR	NR	NR			
McEvoy et al., 2022	Vasopressor agents	NR	NR	NR	EBL	Out of the ten studies, three were rated as having high validity, whilst the remaining seven were deemed to have low validity. The validities ranged from 45 % to 90 %, with an average score of 69 % (SD: 13 %).	Critically low
	Shorter duration of administration of vasopressor agents	MD 65.97 h	43.47–88.47	0.0001			
	Lower dose of vasopressors	MD 8.76 μg/min	6.06–11.46	<0.00001			
	Mean length of stay in intensive care unit	MD 11.46 days	7.10–15.82	<0.00001			
Rao et al., 2016	Admission haemoglobin	NR	NR	NR	The Johns Hopkins Nursing Evidence-Based Practice Rating Scale	12 included studies were graded as high or good quality (Grade A or B) based on their study design.	Critically low
	Age	NR	NR	NR			
	Anaemia	NR	NR	NR			
	Application of sedative drugs	NR	NR	NR			
	Creatinine >3 mg/dL	NR	NR	NR			

	Diabetes	NR	NR	NR			
	Faecal incontinence	NR	NR	NR			
	Friction/shearing force	NR	NR	NR			
	General skin problems	NR	NR	NR			
	Haemodialysis	NR	NR	NR			
	Hours in the intensive care unit	NR	NR	NR			
	Inhibited sense of pain	NR	NR	NR			
	Insufficient nutrition	NR	NR	NR			
	Length of stay > 3 d	NR	NR	NR			
	Limited mobility	NR	NR	NR			
	Low preoperative Braden Scale score	NR	NR	NR			
	Low weight/body mass index	NR	NR	NR			
	Malignant tumour	NR	NR	NR			
	Mechanical ventilation	NR	NR	NR			
	Postoperative Braden Scale score	NR	NR	NR			
	Postoperative steroid use	NR	NR	NR			
	Presence of pain	NR	NR	NR			
	Previous pressure ulcer	NR	NR	NR			
	Severity of illness (ASA, APACHE II, A risk of mortality rating system)	NR	NR	NR			
	Skin problems in areas at risk for pressure ulcer	NR	NR	NR			
	Spinal cord injury	NR	NR	NR			
	Total number of surgeries	NR	NR	NR			
	Total time in operating room	NR	NR	NR			
	Use of vasopressors postoperatively	NR	NR	NR			
	Vascular disease	NR	NR	NR			
Weber et al., 2021	Admission type	NR	NR	NR	The JBI Critical Appraisal Checklist	75 % of the included studies were rated as good or excellent.	Low
	Age	NR	NR	NR			
	Development of another non-device related hospital-acquired pressure injuries	NR	NR	NR			
	Enteral feeding	NR	NR	NR			
	Length of intensive care unit stay	NR	NR	NR			
	Low Braden score	NR	NR	NR			
	Mechanical ventilation	NR	NR	NR			
	Severity of illness (SAPS II)	NR	NR	NR			
	Vasopressor administration	NR	NR	NR			
Wei et al., 2017	Diabetes	OR 1.82	1.37–2.43	0.001	NOS	Scored six to eight out of nine (high scores indicating high quality).	Low

Abbreviation: ASA, American Society of Anaesthesiologists; APACHE, acute physiology and chronic health evaluation; SAPS, simplified acute physiology score; RR, risk ratio; OR, odds ratio; MD, mean difference; NR, not reported; ARMSTAR, a Measurement Tool to Assess Systematic Reviews; NOS, the Newcastle-Ottawa Scale; EBL, the evidence based librarianship critical appraisal checklist; JBI, the Joanna Briggs institutional critical appraisal checklist; CASPe, the Critical Appraisal Skills Program Espana.

Table 4
Mapping of risk factors to categories and aetiological domains.

Risk factors identified from included reviews	Categorised groups	Aetiological domains of categorised groups
(n = 37)	(n = 14)	(n = 3)
Braden score	Assessment score	Both
Anaemia	Comorbidities	
Cancer		
Cardiovascular disease		
Diabetes		
Dialysis		
Respiratory		
Severity of illness		
Spinal		
Vascular		
Age	Demographics	
Body mass index		
Type of admission		
Hospital length of stay	Duration	
Length of stay in the intensive care unit		
Length of stay in the operating room		
Longer duration of surgery		
Sedative drugs	Medication	
Steroid		
Vasopressor		
Enteral feeding	Nutrition	
Nutrition		
Present of hospital acquired pressure injury	Skin status	
Incontinence		
Risky skin		
Skin status		
Number of surgeries since admission	Surgical factor	
Surgical factor		
Medical devices/ventilation	Medical devices	Mechanical boundary conditions
Mobility	Mobility	
Force	Pressure	
Turning/repositioning		
Pain	Sensory	
Creatinine	Biomarker	Individual susceptibility and tolerance
Haemoglobin		
Blood pressure	Vital signs	
Perfusion		

3.4.1. Mechanical boundary conditions domain

This domain categorised four groups of risk factors that affected the magnitude and duration of mechanical load, including the use of medical devices (Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021), immobility (Alderden et al., 2017; Rao et al., 2016), point pressure (Lima Serrano et al., 2017; Rao et al., 2016), and impaired sensory perception of pain (Rao et al., 2016).

Medical devices used in clinical settings, such as oxygen masks, indwelling urinary catheters and peripheral intravenous catheters, often have direct contact with patients and can apply sustained pressure on specific areas of the body leading to pressure injuries. This sustained pressure can be due to shear force, normal force perpendicular to the skin surface, friction, or a combination of these forces. When a patient's mobility is reduced, as indicated by reduced pain sensitivity, or infrequent repositioning, sustained pressure can compromise the patient's mechanical boundary conditions. Over time, this can cause internal strain or stress that potentially exceeds the individual's damage threshold, resulting in the development of pressure injuries.

3.4.2. Susceptibility and tolerance domain

This domain categorised two groups of risk factors: abnormal values of biomarkers (Haisley et al., 2020; Rao et al., 2016) and vital signs (Alderden et al., 2017; Lima Serrano et al., 2017). These risk factors reflect an individual's physiology and tissue repair, as well as tissue transport and thermal properties. For example, a low haemoglobin level plays an important role in the early stage of cell ischemia, especially for patients with longer expected surgical durations (Haisley et al., 2020).

3.4.3. Across domains

Across two domains, eight groups of risk factors were classified, including comorbidities (Haisley et al., 2020; Kang and Zhai, 2015; Liang et al., 2017; Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021; Wei et al., 2017), length of hospitalisation, surgical procedures, stays in intensive care unit and operating rooms (Haisley et al., 2020; Lima Serrano et al., 2017; McEvoy et al., 2022; Rao et al., 2016; Weber et al., 2021), use of vasopressors, sedative drugs and steroids (Alderden et al., 2017; Cox, 2013; Lima Serrano et al., 2017; McEvoy et al., 2022; Rao et al., 2016; Weber et al., 2021), skin status such as oedema (Rao et al., 2016; Weber et al., 2021), nutritional status (Rao et al., 2016; Weber et al., 2021), number of surgeries since admission (Fulbrook et al., 2021; Rao et al., 2016), demographics of age, body mass index and type of admission (Alderden et al., 2017; Lima Serrano et al., 2017; Rao et al., 2016; Weber et al., 2021) and pressure injury risk assessment scores (Rao et al., 2016; Weber et al., 2021).

Risk factors categorised across both domains play into complex, population-specific causal pathways (Coleman et al., 2014; European Pressure Ulcer Advisory Panel et al., 2019). For example, longer duration of surgery (Haisley et al., 2020) and pre-existing diabetes (Kang and Zhai, 2015) were significant risk factors for cardiovascular surgical patients in two meta-analyses. Other meta-analyses found that patients with cardiac conditions undergoing general anaesthetic (Haisley et al., 2020), or cardiac surgical patients admitted to intensive care unit (Fulbrook et al., 2021) were at a higher risk of developing pressure injuries.

3.5. Quality appraisal

Using the Version 2 of "A MeaSurement Tool to Assess Systematic Reviews" tool, the overall quality of the 11 systematic reviews was found to be low (45 %) and critically low (55 %) (Table 3 and Supplementary File 3). These findings were attributed to insufficiency in two critical domains: a lack of a complete list of exclusions with justification (compliance rate, 0 %), and an incomprehensive search (9 %). However, over half (56 %) quality appraisal items (Q1, 5, 6, 8, 9, 11, 13, 14, 16) have achieved a compliance rate of over 50 percentage (Supplementary File 3), including three critical domains of risk of bias (Q9), statistical methods (Q11) and risk of bias in individual studies (Q13). The review authors generally reported the quality of the primary studies in their review was reasonable, however, their assessments were based on diverse quality assessment tools (Table 3).

4. Discussion

This overview resulted in a list of risk factors, which may not be independent of each other, given the absence of risk adjustment in some included reviews and the low quality of the included reviews. However, the four key risk factors, which are either not included or under-emphasised in traditional pressure injury risk assessment tools, comprise diabetes, length of surgery or stay in intensive care unit, vasopressor use, and low haemoglobin level. These findings are consistent with the theoretical schema (Coleman et al., 2014) and the contemporary guideline (European Pressure Ulcer Advisory Panel et al., 2019).

Diabetes, affecting over 8 % of the global adult population (World Health Organization, 2016), is associated with increased pressure injury risk in perioperative settings across three included reviews (Haisley et al., 2020; Liang et al., 2017; Wei et al., 2017). Yet, two included reviews (Kang and Zhai, 2015; Wei et al., 2017) reported inconsistent results, for specific surgeries, such as hip replacements. The reviews did not provide further information, such as state of diabetes (controlled, uncontrolled, or remission), duration of a disease, and existing organ or tissue damage. Additionally, the reviews did not mention whether other conditions including cardiovascular disease and anaemia had been considered as potential confounding factors. This suggests the need for future researchers to collect and report this information. This could help explain the inconsistent results and aid future reviewers in extracting this data if available.

The length of surgery or intensive care unit stay is well-established pressure injury risk factors (Braden and Bergstrom, 1987). However, the included reviews did not define 'longer duration' or assess its specific impact on pressure injury risk, especially in contexts with interacting factors such as the use of vasopressor and mechanical ventilation. Furthermore, the dose–response relationship between duration and other risk factors remains undefined. The interdependencies between duration, patient-specific factors (skin status, perfusion, and immobility) and unknown variables necessitate further research for clarity on pressure injury development.

For decades, vasopressors have been widely used in critical care settings. Despite the guideline development of vasopressor therapy (Evans et al., 2021; Panchal et al., 2019), understanding the pharmacokinetics and the pharmacodynamics of each agent, which determines the microcirculation and tissue viability effects, remains limited. This may explain why the included reviews were unable to establish clear correlations between vasopressor agent infusion regimens and hospital-acquired pressure injuries. To address this issue, future research should investigate individual vasopressor agents rather than grouping them as a single class.

Biomarkers, highly sensitive objective measures, can respond swiftly to changes in a patient's condition, providing valuable predictive insights for pressure injuries in the early, pre-visible stage (Garcia-Gutierrez et al., 2020; Wang et al., 2022). The included reviews (Haisley et al., 2020; Rao et al., 2016) highlighted the importance of pre-operative or admission haemoglobin level measurements, however, they did not explore the broad spectrum of other potential biomarkers, or patients' exposures to specific medications or interventions. Although a recent study (Wang et al., 2022) indicates that combining biomarkers could improve predictive precision, the overall accuracy and the most reliable biomarker remain uncertain. Therefore, robust research, such as cohort studies, is urgently needed to thoroughly examine the predictive capabilities of these biomarkers.

Most risk factors we summarised span both domains, suggesting a single risk factor can trigger or augment multiple risk factors, leading to pressure injuries through various concurrent interactions. Direct causal factors, such as skin status, perfusion, and immobility, are foundational prerequisites for a pressure injury to occur. In contrast, indirect causal factors can alter these foundational factors through diverse interactions (Coleman et al., 2014). For example, cardiovascular disease, an indirect causal factor, can reduce peripheral tissue perfusion, a direct causal factor, resulting in pressure injuries in immobile patients. Indirect causal factors can also interact with one another, creating intricate relationships influenced by timing of onset, severity, and duration. Thus, accurately predicting risk of hospital-acquired pressure injuries at any given time requires identification of multiple risk factors and their interdependencies.

For this reason, current pressure injury risk assessment tools (Braden and Bergstrom, 1987; Norton et al., 1962; Waterlow, 1985) are inaccurate, even they can be a user-friendly parsimonious prognostic model, such as Braden Scale. These tools do not incorporate all relevant risk factors and their interactions. In contrast, machine learning, a type of Artificial Intelligence, uses advanced computer software to analyse large amounts of patient data. Concerns associated with the use of health data, such as privacy protection and data security have been proactively addressed (Department of Industry, Science and Resources, 2019). Machine learning establishes data parameters based on exiting knowledge and theory of pressure injury aetiology, advanced statistical methodologies, and computational techniques. These parameters are subsequently incorporated into prediction models or algorithms, allowing for recognition of patterns and associations on a regular basis, potentially unveiling previously unknown risk factors for pressure injuries. These algorithms have already found their utility in various hospital settings including critical care step-down units (Raju et al., 2015), intensive care units (Anderson et al., 2021; Deng et al., 2017; Kaewprag et al., 2017), surgical wards (Chen et al., 2018; Su et al., 2012), and general hospital settings (Anderson et al., 2021; Do et al., 2022; Hu et al., 2020; Jiang et al., 2021; Levy et al., 2020; Lustig et al., 2022; Nakagami et al., 2021; Song et al., 2021; Wu et al., 2022). Thus, machine learning, holds the potential to develop more accurate pressure injury risk assessment models or algorithms, capable of providing real-time predictions as clinical circumstances change.

5. Limitations

This overview has several limitations. Firstly, this overview included only English-language sources due to resource constraints, so there may be a language bias. This bias could potentially restrict the variety of risk factors we summarised. Secondly, although the results of the quality of appraisal highlighted the limitations of the included reviews, the use of the "A MeaSurement Tool to Assess Systematic Reviews" was designed and primarily used for assessing intervention studies only (M. Pollock et al., 2017). Future researchers should consider using the "Risk Of Bias In Non-randomized Studies of Interventions" tool (Sterne et al., 2016) for reviews of observational studies. However, the specific reasons for the low-quality ratings and the evaluation of the potential impact of these limitations on the overview's conclusions should be considered. These ratings were mainly attributed to the review authors' limited search coverage and inadequate justification of the excluded studies. This may restrict the review results. Nonetheless, this overview provided a synthesis of the results from these 11 reviews and the risk factors we summarised are consistent with current understanding of aetiological of pressure injuries. Additionally, heterogeneity of the included reviews in their study designs also limited our ability to undertake a quantitative meta-analysis, requiring a narrative approach only. The inability of the review authors to conduct multivariate analysis due to data constraints in the primary studies suggests that our findings may be influenced by other factors, including potential confounding. Certain risk factors may have been missed due to the diverse inclusion and exclusion criteria applied in the included reviews. Thus, we recommend caution when interpreting the results.

6. Conclusion

This overview synthesised systematic reviews that identify risk factors for hospital-acquired pressure injuries in adult patients, uncovering four important risk factors that have not been emphasised in previous reviews. Our findings highlighted the limitations in the methodological quality of the included reviews that may have influenced our results regarding risk factors. These findings also emphasised the limitations of currently available pressure injury risk assessment tools. Additionally, current conceptual frameworks do not fully explain the complex and changing interactions amongst risk factors. Whilst more high-quality research, such as cohort studies is needed to explore dynamic frameworks and risk assessment tools that are more applicable and fit for purpose, new techniques such as machine learning algorithms, may offer a means for achieving these aims. The risk factors we synthesised may suggest some uncertainty, which may warrant a reconsideration of these risk factors in future research focussed on predicting hospital-acquired pressure injuries in adult patients.

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CRediT authorship contribution statement

Isabel Wang: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Rachel M.**

Walker: Writing – review & editing, Supervision, Methodology, Conceptualization. **Brigid M. Gillespie:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Ian Scott:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Ravilal Devananda Udeshika Priyadarshani Sugathapala:** Writing – review & editing, Data curation. **Wendy Chaboyer:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Data availability

Data supporting the findings in this overview is available upon request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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