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The effectiveness of multicomponent pressure injury prevention programs in adult intensive care patients: a systematic review

Abstract

Background

Pressure injuries are potentially preventable but frequently occurring adverse events. Intensive care patients have major risk factors for pressure injury with a reported pressure injury prevalence of 12-33%. Multi-faceted interventions, also known as programs or care bundles, are recommended to prevent pressure injuries.

Aim

This systematic review evaluated the effectiveness of pressure injury prevention programs in reducing pressure injury prevalence and incidence in the adult intensive care population. It also critically appraised the program components and strategies used to implement these programs.

Method

We searched PubMed, EMBASE (embase.com), Ovid MEDLINE, EBSCOhost CINAHL, and Cochrane Library databases separately for papers published in English and Chinese from the year of 2000 to May 2018. After removing duplicates, two authors independently screened the title and abstracts, then full-text against the inclusion and exclusion criteria. Data was extracted by one author and checked by a second author. Quality appraisal was conducted by two authors by using the Quality Improvement Minimum Quality Criteria Set, and the Mixed Methods Appraisal Tool. Content analysis was used to categorise program components. Implementation strategies were grouped into six classifications: dissemination strategies, implementation process strategies, integration strategies, capacity building strategies, sustainability strategies, and scale up strategies.

Results

Twenty-one peer reviewed papers (12 quality improvement projects, and 9 research papers from 8 studies) were included. Pressure injury prevention programs with 2-11 components were commonly implemented. Common components of the programs included: clarification of staff roles, introducing new roles, repositioning, staff and patient education, support surfaces use, pressure injury risk assessment, skin assessment, nutrition needs assessment, documentation, multidisciplinary team involvement, and mobilisation. Implementation strategies commonly used were education, audit and feedback, and standardising documentation. Five of the eight research studies and one of the quality improvement projects reported significant decrease in pressure injury prevalence, and/or increase in compliance to pressure injury prevention protocols and strategies. Two quality improvement papers reported cost savings of \$1 million and £2.6 million respectively after the implementation of the programs.

Conclusion

Much of the work on multicomponent pressure injury prevention programs has been undertaken as quality improvement projects and before and after research studies with limited rigour. However, positive outcomes and strong theoretical rationales for the components in the programs suggest that

they are beneficial. This calls for future high-quality research such as randomised controlled trials to test the effectiveness of multicomponent interventions and their implementation strategies.

Tweetable abstract:

Some multicomponent pressure injury prevention programs were found to be effective; however, higher level of research evidence is needed.

Key words: care bundles; implementation; intensive care units; pressure ulcer; prevention; strategy; systematic, review

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What is already known about the topic

- Pressure injuries are preventable adverse events that negatively impacts on patients' quality of life and add significant cost to the healthcare system.
- Intensive care patients are at high risk for pressure injury due to the presence of multiple risk factors.
- Current international clinical practice guidelines recommend using multiple strategies to prevent pressure injuries.

What this paper adds

- Multicomponent programs implemented in most quality improvement projects and research studies included in this review were associated with decreased pressure injury incidence and

prevalence. But because of various quality improvement and research study design limitations, these results should be interpreted with caution.

- Most pressure injury prevention programs had similar components, however, the implementation strategies varied.
- Higher quality research is needed to test the effectiveness of the multicomponent interventions and their associated implementation strategies.

Introduction

Pressure injuries, also known as pressure ulcers, are potentially preventable but frequently occurring adverse events in hospitalised patients (Padula et al., 2018). Pressure injuries can occur on various anatomical locations because of intense and/or prolonged pressure, or pressure in combination with shear and friction forces (Edsberg et al., 2016). Pressure injuries can have negative impacts on patients' physical, social, and psychological aspects of quality of life (Gorecki et al., 2009, Jackson et al., 2018), increase financial burden and hospital length of stay, and increase morbidity and mortality (Liu et al., 2019, Spetz et al., 2013, Theisen et al., 2012). A systematic review reported that costs related to the treatment of pressure injuries adds to the national annual budget from €121.44 million to €2.59 billion, with individual pressure injury treatment costs ranged from €15 to €69,472 in the USA, UK, the Netherlands, and Canada (currency was converted into Euros by the review authors) (Demarré et al., 2015). In Australia, pressure injuries are one of the 'top five' most expensive adverse events at a cost of AU\$983 million per annum for hospitalised patients (Nguyen et al., 2015).

Critical care patients have major risk factors for pressure injury development including immobility, poor perfusion, and vasopressor medication infusion (Alderden et al., 2017). A recent systematic review reported that the 95% confidence intervals for cumulative incidence and prevalence of pressure injuries in the adult intensive care unit (ICU) patients were 10.0-25.98% and 16.9-23.8% respectively, indicating ICU patients develop more pressure injuries than the general hospital population of 12-18% (Chaboyer et al., 2018).

Pressure injury prevention is high on governments' and professional organisations' agendas. Current international clinical practice guidelines suggest using a multi-faceted approach to address barriers in pressure injury prevention, and recommend numerous pressure injury prevention strategies, including some specific to the ICU population (National Pressure Ulcer Advisory Panel et al., 2014). While there are published evidence on what specific strategies and programs are

associated with effective pressure injury prevention (Coyer et al., 2015, Donovan et al., 2016), to our knowledge, there has been no systematic reviews conducted on the effectiveness of multicomponent pressure injury prevention programs, their components, and the strategies used to implement such programs.

Therefore, the aim of this systematic review was to synthesise evidence on the effectiveness of pressure injury prevention programs in reducing pressure injury prevalence and incidence in the adult ICU population. Specifically, we aimed to answer the following research questions: 1) what are the components of pressure injury prevention programs used for the adult ICU population? 2) how are pressure injury prevention programs for the adult ICU population implemented? and 3) what are the effectiveness of pressure injury prevention programs? In this review, we define “program” as an intervention which has two or more components.

Methods

This is a systematic review. The study protocol, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (Liberati et al., 2009) was developed and registered on the International Prospective Register of Systematic Reviews (PROSPERO 2018 CRD42018096870).

Search strategy

A search strategy was developed by the author team in consultation with an experienced health librarian. A comprehensive literature search was conducted by searching databases including PubMed (NCBI platform), EMBASE (embase.com), Medical Literature Analysis and Retrieval System Online (MEDLINE) (Ovid), Cumulative Index to Nursing and Allied Health Literature (CINAHL) (EBSCOhost), and Cochrane Library databases for studies published in English from the year of 2000 to May 2018. Search terms included “pressure ulcer”, “pressure injury”, “decubitus

ulcer”, “bed sore”, “pressure sore”, “prevention”, “program”, “bundle”, “multi-component”, “complex intervention”, “ICU”, “intensive care”, “intensive care unit”, “critical care”, “intensive therapy”, and “adult”. Searches were performed using medical subject headings, key words, and free text words depending on the database. Alternative spelling and synonyms were combined using Boolean “OR” and main terms were combined using Boolean “AND”. Reference lists of included articles were searched for other potential articles. One example of search strategy from MEDLINE is provided in Supplementary Table 1.

Inclusion and exclusion criteria

Original peer reviewed studies and quality improvement projects were included if they: were conducted in adult ICU; were published in English or Chinese; reported a multicomponent (more than two components) intervention; reported on the implementation strategies used to implement the program; and reported on program outcomes. Thus, papers had to report findings for all three of this systematic review’s research questions.

Guided by Foster’s (2013) framework on the classification of research or quality improvement projects for ethics review purposes, in this review, papers reporting activities that aimed to improve care process or system, without a clear research question were considered as quality improvement projects. Papers were considered research if they aimed to test or advance knowledge, with a clear research question, and study design. Both quality improvement projects and research studies were included with no restriction on types of study but only papers published from 2000 onwards were included to ensure contemporary practice was captured. Letters, commentaries, editorials, and conference abstracts/presentations were excluded. We excluded the papers where the outcome results for adult ICU patients could not be separated from other patient populations.

Study selection process

Search results were imported into Endnote program (Clarivate Analytics, version 19). Screening was undertaken independently by two reviewers and a third person adjudicated disagreements that could not be resolved between the two reviewers. After removing duplicates, two authors independently screened the title and abstracts, then full-text against the inclusion and exclusion criteria.

Data extraction and quality assessment

Two data extraction forms were purposefully developed for the review. The first form was designed to extract detailed information and quality assessment of the quality improvement projects including author/year/country, sample and setting, intervention, main results, and quality assessment scores using the Quality Improvement Minimum Quality Criteria Set (QI-MQCS) (Hempel et al., 2015). The second form was designed to extract detailed information of the research studies including author/year/country, design, sample and setting, intervention, main results, and quality assessment results using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). One author (ZW) extracted data from the included studies, and a second author (FL) checked the extracted data.

Outcome measures for the pressure injury prevention programs were divided into three categories: patient outcomes, care process outcomes, and organisational outcomes. For patient outcomes, we extracted data on changes in pressure injury incidence, prevalence, and incidence and prevalence of pressure injury in stages. Care process outcomes including compliance to intervention protocols, staff and patient satisfaction rates, and participations rates related to the interventions, and organisational outcomes, where reported, including patients' hospital and/or ICU length of stay; costs to treat Pressure injuries were also extracted.

Quality assessment for included papers was independently completed by two reviewers (ZW and FL). The QI-MQCS, a valid and reliable critical appraisal instrument covering 16 quality improvement domains, was used to assess the quality of the quality improvement papers (Hempel et

al., 2015). A quality score is obtained by counting the number of items meeting the 16 QI-MQCS criteria, thus quality scores can vary from zero to 16. But there are no established cut-offs to indicate high or low quality scores. The recently updated 5-item MMAT tool (Hong et al., 2018) was used to assess the quality of the papers reporting research studies. The MMAT tool allows researchers to critically appraise the quality of studies using various study designs. There are five assessment domains for each type of study design, which users can rate a paper as “yes”, “no”, “can’t tell”, and write comments for each item. The authors of the newly updated version of the MMAT discourage the use of percentage to summarise the quality of the papers as was recommended in the previous version of the tool. Rather, the authors recommend users to describe the items that meet the quality assessment items individually. The MMAT was chosen over various risk of bias tools because the latter require design specific tools. Prior to beginning the review we anticipated a wide variety of designs would be represented in the papers, which complicates the quality assessment process when numerous tools are used, with no evidence that one approach is better than another.

Data synthesis

We narratively summarised the characteristics of the included papers, the components of the pressure injury prevention program used, and the outcomes. We summarised the pressure injury prevention programs and their components in a table using the common type of pressure injury interventions used in the papers as labels. We summarised patient outcomes including pressure injury prevalence and incidence results in the data extraction tables. Due to variations among studies on what were implemented and how the interventions were implemented, on outcome definitions and measures, we were unable to perform meta-analyses on patient outcomes.

Content analysis (Graneheim and Lundman, 2004) was conducted to analyse extracted data related to the implementation strategies used. The extracted implementation strategies data was read and reread many times by the first and second author. The findings were reviewed by all authors a few times before finalising them into a table.

For the implementation strategies, a modified classification proposed by Leeman et al (2017) was used as categories for the content analysis. This classification system of five types of strategies focuses on who enacts the intervention and how the implementation strategies are linked to the barriers or facilitators, allowing users to choose the appropriate strategies according to their identified needs. **Dissemination strategies** refer to the strategies that aim to improve the target populations' awareness and knowledge of current research evidence or clinical practice guidelines (CPG) with an aim to aid implementation, which are often enacted by individuals, teams and systems that are responsible for evidence uptake (Leeman et al., 2017). **Implementation process strategies** refer to those strategies that are enacted by staff working in delivery service, including staff working at the bedside, and also the staff who plan and implement research evidence. These strategies are enacted throughout the implementation process. Examples include engaging stakeholders, assessing context, selecting and adapting implementation strategies, and evaluating process outcomes (Leeman et al., 2017). **Integration strategies** are enacted by staff in the service delivery system to integrate new research evidence into practice, which target at individual behaviour (Leeman et al., 2017). Examples of such strategies include reminder systems, tools such as revisions to the medical record systems, new teams, and new equipment. **Capacity building strategies** are often carried out by teams or individuals who work in the support systems to improve the capacity in the delivery system with a long-term goal of improved evidence adaptation. They include training, assistance, and systems change (Leeman et al., 2017). **Scale-up strategies** are enacted by support system actors to spread the implementation to more clinical areas or settings.

These strategies could target both the individual or the organisational behaviour, which could include train-the-trainer, collaborations, and benchmarking strategies (Leeman et al., 2017).

In addition to the five classes, as recommended by Leeman et al. (2017) in their discussion, we added the **sustainability/normalisation** class, which is often seen as the final stage of the implementation cycle. It includes the strategies aimed to embed new practices into routine practice to ensure continued delivery of new/improved practice (Lennox et al., 2018; Moore et al., 2017).

We used a table to show our data analysis results.

Results

The initial search identified 1518 titles; 1479 were excluded after title and abstract screening. Of the remaining 39 full text papers, 18 met the inclusion criteria. Three additional papers were found by searching the reference lists of the 18 included papers. Therefore, a total of 21 papers were included in this review (Figure 1), of which 12 papers reported findings from quality improvement projects (Table 1), and nine reported findings from eight research studies (Table 2). All included papers used the quantitative method. Two of the research papers were written from the same study with one reporting a two-arm cluster trial (Tayyib et al., 2015) and the other report the findings from the intervention site only (Tayyib et al., 2016). No papers published in the Chinese language met the inclusion criteria.

Figure 1. Flow chart of search process.

*Among the 9 papers reported research studies, two reported the same study.

Table 1. Quality improvement project description and quality assessment (n=12)

Author Year Country	Sample and setting	PIP Programs and components (in dot points)	Main results (only ICU results are listed here in projects that included non-ICU samples)	QI-MQCS* criteria met
Azuh et al. 2016 USA	68-bed Medical ICU Sample: patients admitted to MICU with Braden Scale score < 19 n=3233	Early mobilisation program <ul style="list-style-type: none"> Assessing patients' mobility level Introducing a new staff role: patient mobility assistant Mobilising patient: repositioning, sitting on edge of bed/on chair, walk with/without assistance Staff education Patients/family education 	<ul style="list-style-type: none"> PI cumulative incidence: significant decrease from 9.2% in 2011 to 6.2% in 2013 (p=0.041) Hospital readmission of MICU: significant decrease from 17.1% in 2011 to 11.5% in 2013 (p=0.001) Significant care processes improvements in repositioning; assistance with daily living activities; bed to chair mobility (P<0.001) Patient satisfaction: 97% (207/213). Total of 213 patients were surveyed for this item. 	13/16
Baldelli et al. 2008 USA	An ICU in a university medical centre Sample and sample size: no information	Pressure ulcer prevention bundle <ul style="list-style-type: none"> PI risk and skin assessment Elevating bed head at $\leq 30^\circ$ Moisture prevention Repositioning Elevating heels Optimising nutrition Using pressure relief mattress Staff education 	<ul style="list-style-type: none"> PI period prevalence: decrease from 42% in 2005 to 20% in 2006 (significance not reported) PI cumulative incidence: decrease from 18% in 2005 to 10% in 2006 (significance not reported) 	11/16
Ballard et al. 2008 USA	2 ICUs: a 26-bed ICU (trauma, neurosurgical, and surgical combined); and an 18-bed medical ICU in a hospital Sample and sample size: no information	A multicomponent program <ul style="list-style-type: none"> Redesigned risk assessment and documentation chart Staff education Repositioning Revising existing protocols Weekly prevalence assessment Using a new skin care wipe 	<ul style="list-style-type: none"> PI period prevalence: reduced from >30% to <10% over 18 months (significance not reported) 	11/16
Donovan et al. 2016 USA	a 22-bed surgical ICU in a 913-bed hospital sample: appear to be adult ICU patients	A multidisciplinary process program <ul style="list-style-type: none"> Equipment use Monitoring patient sitting time Standardising documentation of PIP strategy use An interdisciplinary rounding checklist 	<ul style="list-style-type: none"> PI cumulative incidence: 2.3% (5/221) in the surgical ICU during the 10-week pilot program, below benchmarks 	14/16

Author Year Country	Sample and setting	PIP Programs and components (in dot points)	Main results (only ICU results are listed here in projects that included non-ICU samples)	QI-MQCS* criteria met
	n=221 patients			
Elliott et al. 2008 Australia	A 14-bed adult general ICU in 600-bed hospital Sample: ICU patients n=563	A hospital-wide PIP program <ul style="list-style-type: none"> • Staff education • PI occurrence monitoring • Educating staff on device ordering • Targeted interventions such as using pressure relieving devices 	<ul style="list-style-type: none"> • PI period prevalence: decrease from 50% in 2003 to 8% in 2005 (significance not reported) • PI severity: downward trend in all stages 2003-2006 • Using pressure-relieving devices for patients at high risk and very high risk: increased from 75% during 2003 to 100% during 2005 and 2006 (significance not reported) 	14/16 criteria met
Gage. 2015 UK	4 ICUs in five hospitals Sample and sample size: no information appear to be adult ICU patients	A set of “essential standards” and audit tool <ul style="list-style-type: none"> • Using set of “essential standards” <ul style="list-style-type: none"> - Using correct pressure-relieving devices - PI risk and skin assessment - Incontinence management - Bathing - Nutrition and fluid management - Standardising documentation - Bedside wound care handover - Referral of PIs of stage $\geq$ to tissue viability nurse - Staff education • Introducing an audit tool 	<ul style="list-style-type: none"> • PI cumulative incidence in each ICU: downward trend from up to 18 incidents to below 2 incidents in 2 years (significance not reported) • PI severity: no grade III or IV PI since the implementation 	14/16
Gill. 2015 UAE	One ICU in a hospital Sample and sample size: no information	Plan, do, check, act quality improvement program <ul style="list-style-type: none"> • Staff education • PI risk and skin assessment • Repositioning • Introducing a skin barrier spray and an adhesive foam dressing • Incontinence management • Referral of any patient with skin excoriation to the TVT team 	<ul style="list-style-type: none"> • PI cumulative incidence: reduced from 6 incidents to 2 or below in 2013 (significance not reported) • Process of care improvements: daily Braden risk assessment 100%; repositioning: increase from 50% to normal practice 	14/16
Hiser et al. 2006 USA	MICU Sample and sample size: no information	Multidisciplinary, lengthy, educational, and resource re-allocating program <ul style="list-style-type: none"> • PI risk assessment • Role and responsibility clarification of the Certified Wound Ostomy Continence Nurse (CWOCN) • Establishing staff education and training infrastructure 	<ul style="list-style-type: none"> • PI period prevalence: decreased from an average of 29.6% to 0% (significance not reported) • Attitude change: from a belief that pressure ulcers are inevitable among seriously ill patients to a belief that most pressure ulcers can 	10/16

Author Year Country	Sample and setting	PIP Programs and components (in dot points)	Main results (only ICU results are listed here in projects that included non-ICU samples)	QI-MQCS* criteria met
		<ul style="list-style-type: none"> • Changing support surfaces to new products that aimed at PIP 	be prevented if the appropriate measures are instituted proactively	
Padula et al. 2008 USA	A 16-bed medical-surgical critical care unit Sample: all patients admitted to this unit Pre: n=62, Post: n=62	Nurse-focused, comprehensive educational intervention <ul style="list-style-type: none"> • Formalising continuing education • PIP intervention education • Documentation education • Informal education by project nurse • Adding frequently used products to automated medication and supply management system 	<ul style="list-style-type: none"> • PI cumulative incidence: a trend toward improvement (pre 9/12 vs post 8/13). • Care process: skin-specific care plans: increase from 33% pre intervention to 77% to post intervention; using overlays: increase from 37.5% to 100%; skincare documentation: increase from 0.0% to 100%; wound documentation: increase from 25% to 100%. Significance not reported for above results.	14/16
Richardson et al. 2017 UK	4 ICUs in 2 hospitals: (24-bed) Cardiothoracic CCU, 2 (22-bed, and 20-bed) general CCUs, and a neuro/trauma CCU Sample and sample size: no information	An intervention bundle <ul style="list-style-type: none"> • Establishing a multidisciplinary task group • Revising existing nursing care plan and nursing documentation • Developing a new pressure ulcer risk assessment tool • Introducing alternating low pressure mattresses • Developing Bowel Management Assessment Tool • Repositioning • Staff education 	<ul style="list-style-type: none"> • PI cumulative incidence: reduced significantly from 8.08/100 patient admissions (baseline) to 2.97/100 patient admissions (significance not reported) • Average estimated cost: saving £2.6 million (range £2.1-£3.1) calculated by the NHS National pressure ulcer productivity calculator 	14/16
Swafford et al. 2016 USA	A 14-bed medical/surgical ICU Sample: ICU patients Before: n=461, during: n=563	Comprehensive, proactive, collaborative prevention program <ul style="list-style-type: none"> • PI risk assessment • Updating skin care protocol • Using fluidised repositioners • Using silicone gel adhesive dressings • Staff education 	<ul style="list-style-type: none"> • PI cumulative incidence: reduced from 10% (45/461) in 2011 to 3% (17/563) in 2013 (significance not reported) • Estimated cost: reduced from \$1.7 million in 2011 to \$0.66 million in 2013 (based on national database of nursing quality indicator average cost) (significance not reported) 	13/16
Wolverton et al. 2005 USA	3 ICUs with 39 beds (surgical, medical, neurological) Sample: ICU patients n=422	Weekly skin care rounds program <ul style="list-style-type: none"> • Staff education • Reinforcing skin care • PI risk assessment • Discussion point list for rounds 	<ul style="list-style-type: none"> • PI cumulative incidence: decreased from 33% to 13.7% (significance not reported) 	12/16

PU: pressure ulcer, PI: pressure injury, PIP: pressure injury prevention; QI: quality improvement; Quality Improvement Minimum Quality Criteria Set (QI-MQCS): score range 0 - 16 for 16 items. All projects used uncontrolled before and after design.

Table 2. Research studies description and quality assessment (n=9)

Author, Year country	Design	Sample and setting	PIP program and components (in dot points)	Main results	Quality assessment (MMAT)*				
					D1	D2	D3	D4	D5
Anderson et al. 2015 USA	Uncontrolled before-after study	3 ICUs: trauma/neurological ICU, medical/surgical ICU, and cardiovascular ICU unit Patients ≥ 18 years, without PU and LOS ≥ 24 hours n=327 (pre: n=181, post: n=146)	Universal pressure ulcer prevention bundle (UPUPB) with wound ostomy and continence (WOC) nurse rounds <ul style="list-style-type: none"> • Standardising skin emollient products • Skin assessment • Elevating heels • Using pressure redistribution surfaces • Repositioning • Semi-weekly WOC nurse rounds 	<ul style="list-style-type: none"> • PI cumulative incidence: significant decrease from 15.2% to 2.1% • Adherence to repositioning: significant increase (0.792$\pm$0.236 vs 0.852$\pm$0.207 $t(325)=-2.441$ $p=0.015$) Adherence to heel elevation: significant increase (Phase 1: 0.116 $\pm$ 0.184 vs Phase 2: 0.205 $\pm$ 0.227; $t_{276.666}=-3.819$, $p<0.001$) <ul style="list-style-type: none"> • Adherence to composite prevention interventions, use of skin emollients, conducting skin assessments, and pressure redistribution surfaces: no significant difference (significance not reported) 	Y ^a	Y ^a	Y ^a	Y ^a	Y ^a
Avsar and Karadag. (2018) Turkey	Controlled before-after study.	Cardiovascular surgical ICU and the chest disease ICU Adult patients at the middle- and high-risk of PU (Braden Scale) n=154 (Intervention group: 77, Comparison group: 77)	Evidence-based nursing initiatives program <ul style="list-style-type: none"> • Skin assessment • Skin cleaning • PI risk assessment • Nutrition assessment • Elevating bed head at 30 degree or less • Repositioning • Early mobilisation • Using support surface 	<ul style="list-style-type: none"> • PI cumulative incidence: significant decrease (control group: 33.8%; intervention group: 13.0%, $p=0.002$). • The average cost to increase tissue tolerance : significantly higher in intervention group than in the control group (\204.34\pm$41.07 vs \$138.90$\pm$1.70, $p<0.001$) 	Y ^a	Y ^a	Y ^a	Y ^a	Y ^a
Coyer et al. (2015) Australia	Controlled before-after study	A 36-bed general adult ICU Patients ≥ 18 years without community acquired loss of skin integrity on admission or pressure injuries	Interventional patient skin integrity (InSPiRE) protocol <ul style="list-style-type: none"> • Staff education • Skin assessment and documentation • Skin care • Repositioning 	<ul style="list-style-type: none"> • PI cumulative incidence: significant reduction from 30.4% (31/102 patients) to 18.1% (19/105 patients) ($p=0.04$) • Time to develop PI: delayed in the intervention group (log rank=11.842, $p\leq 0.001$) • Number of PIs per patient: significant reduction (>3 PIs/patient: 1/105 vs 10/102, $p=0.02$) 	Y ^a	Y ^a	Y ^a	Y ^a	Y ^a

Author, Year country	Design	Sample and setting	PIP program and components (in dot points)	Main results	Quality assessment (MMAT)*				
					D1	D2	D3	D4	D5
		diagnosed within 24 hours of ICU admission n=207 (Intervention: n=105;Control: n=102)	<ul style="list-style-type: none"> • Using support surface • Repositioning devices • Skin protection • Elevating heels • Maintaining stable skin temperature • Optimising nutrition • Mobilising patients 	<ul style="list-style-type: none"> • PI severity: significant reduction in stage II-IV from 4/105 to 17/102 (significance not reported) • Mucous injuries: significant reduction from 15 injuries in 19 patients to 39 injuries in 31 patients (p<0.001) • Significant increased compliance to protocol: repositioning devices increased from 28% to 76% (p<0.001); Repositioning patients increased from 51% to 83% (p<0.001); Using heel protector: increased from 27% to 41% (p=0.02) • Mobilisation: no difference 					
de Laat et al. (2007) Netherlands	Prospective cohort study	<p>A 28-bed intensive care department with 4 units: 2 general ICU, 1 neurological ICU, and 1 thoracic and cardiac surgical ICU</p> <p>Patients ICU stay ≥48hrs, no PI at admission n=399 (baseline: n=110; 3-6 months: n=130; 12-15 months: n=159)</p>	<p>Hospital-wide PIP and treatment guideline</p> <ul style="list-style-type: none"> • Staff education • Using a specific pressure-reducing mattress in case of nonblanchable erythema or an expected immobility of >72 hrs 	<ul style="list-style-type: none"> • PI grade II-IV incidence density: significant decrease, from 54/1000 days baseline to 46/1000 days in the second period and 32/1000 days in the third period (p=0.001) • PI cumulative incidence of grade II-IV: decrease from 43% in the baseline period to 37% in the second period and 28% in the third period (p=0.04) • Median PI-free time: increase from 12 days to 19 days (hazard rate ratio=0.58; p=0.02) • Frequency of preventive transfers to a specific pressure-reducing mattress: increase from 28% in the baseline period to 40% in the second period 60% in the third period (p=0.003) 	Y ^a	Y ^a	Y ^a	Y ^a	Y ^a
Loudet et al. (2017) Argentina	Uncontrolled before-after study	<p>A 14-bed medical-surgical ICU</p> <p>ICU adult patients ≥ 15 years requiring mechanical ventilation (MV) ≥ 96 hours without pre-existent PUs n= 124 (pre: n=55, post:</p>	<p>Multifaceted educational program</p> <ul style="list-style-type: none"> • Multidisciplinary team involvement • Skin assessment • Family participation in prevention bundle during open visitation 	<ul style="list-style-type: none"> • PI cumulative incidence: significant decrease from 41(75%) to 37(54%) (p=0.016) • PI cumulative incidence of grade III- IV: significant decrease from 27(49%) to 7(10%) (p=0.0000) • PI locations including the sacral, heel and others: significant decrease (p=0.0083, p=0.0001, p=0.014) • Onset of new lesions: significant delay from a median of 4.5 to 9 days (p=0.0001) • Presence of PI at ICU discharge: significant decrease 	Y ^a	Y ^a	Y ^a	N ^a	Y ^a

Author, Year country	Design	Sample and setting	PIP program and components (in dot points)	Main results	Quality assessment (MMAT)*				
					D1	D2	D3	D4	D5
		n=69)		from 38 (69%) to 18 (26%) (p=0.0000) • Family participation: significant increase from 5(9%) to 39(57%) (p=0.016) • Using support mattresses: significant increase from 48% to 85% (p=0.0000)					
Rogenski and Kurcgant. (2012) Brazil	Uncontrolled before and after study	Adult ICU (including 12 intensive care beds and 8 beds reserved for semi-intensive care) Patients at risk of developing PUs (Braden score ≤16 n=78	PU prevention protocol • PI risk assessment • Skin assessment • Repositioning • Using a pneumatic mattress for patients at risk • Elevating bed head 30° • Nutritionist consultation • Protecting bone prominences • Moisture prevention • Skin cleaning • Patient education	• PI cumulative incidence: decrease from 41.0% before the protocol to 23.1% (significance not reported)	Y ^a	Y ^a	Y ^a	N ^a	Y ^a
Tayyib et al. (2015) Saudi Arabia	Two-arm cluster randomized experimental control trial	Two ICUs in two hospitals Patients ≥18 years and expected to stay in the ICU for more than 24 hour without existing PU on admission and in the first 24 hours of admission to the ICU n=140 (Intervention: n=70; Control: n=70)	PU prevention bundle • PI risk assessment • Skin assessment • Skin care • Nutrition assessment • Repositioning • Elevating foot of the bed by 20° • Elevating heels • Mobilising patients • Using support surface • Securing and repositioning devices • Staff education	• PI cumulative incidence: significantly different between intervention group (7.1%) and control group (32.9%) (p<0.001) • Time to first PI development: delayed in the intervention group (p<0.001) • Number of PIs: significant difference between the intervention (12/70) and control (37/70) groups (p<0.001) • PI severity: Stage I (control 19/70 vs intervention 7/70, p=0.002) and II (13/70 vs 5/70, p=0.026) PI development significantly decreased • No difference in both groups in admission skin assessment and documentation within required time frames (100%), daily ongoing assessment (100%), patients bed-bathed (100%)	Y ^b	N ^b	Y ^b	Y ^b	Y ^b

Author, Year country	Design	Sample and setting	PIP program and components (in dot points)	Main results	Quality assessment (MMAT)*				
					D1	D2	D3	D4	D5
				<ul style="list-style-type: none"> • Reposition patients: significant increase in intervention group (every 3 hrs: 85%), than the control group (every 2 hrs 20%) • Using heel protectors: significant increase from 0 to 97% (p<0.001) 					
Tayyib et al. (2016) Saudi Arabia	Prospective observational study (this is the findings from the intervention arm of the study above)	A general 24-bed ICU RNs working in the ICU n=11	As above	<ul style="list-style-type: none"> • High level compliance towards the PU prevention bundle protocol: 22.43/30 (78.1%) • Time has a significant effect on the intervention compliance (p<0.016), however, it has no significant effect on the intervention compliance of some key elements, such as skin assessment (p=0.069), skin care (p=0.076), nutrition (p value not reported), patient repositioning (p=0.548) and medical device care (significance not reported) • Time has a significant effect on the intervention compliance for risk assessment (p=0.015) 	Y ^a	Y ^a	N ^a	N ^a	Y ^a
Uzun et al. (2009) Turkey	Controlled before-after design	2 general medical and surgical ICUs, a neurosurgical, and the post anaesthesia care unit ICU patients, ≥18, and ICU stay ≥ 48 hrs n=186 (Control: n=93, Intervention: n=93)	Education intervention regarding preventive care <ul style="list-style-type: none"> • Staff education • Skin assessment • PI risk assessment • Repositioning • Elevating heels 	<ul style="list-style-type: none"> • PI cumulative incidence of stage II: significant decrease from 37% to 17% (p<0.01) 	Y ^a	Y ^a	Y ^a	Y ^a	Y ^a

*The Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018); a: section 3 of the MMAT for quantitative non-randomised studies; b: section 2 of the MMAT for randomised controlled trials; PU: pressure ulcer; PIP: pressure injury prevention; PI: pressure injury. D1, D2, D3, D4 and D5 denotes the quality assessment domains under each study design.

The included quality improvement projects and research studies were conducted in various types of ICUs including medical, surgical, neurological, trauma, cardiac, or mixed ICUs. Two quality improvement projects did not specify the type of ICU. Email queries to the corresponding authors were unanswered (Donovan et al., 2016, Gage, 2015). Among the 12 quality improvement projects, six were multisite (Baldelli and Paciella, 2008, Ballard et al., 2008, Donovan et al., 2016, Gage, 2015, Richardson et al., 2017, Wolverson et al., 2005), and six were single site (Azuh et al., 2016, Elliott et al., 2008, Gill, 2015, Hiser et al., 2006, Padula et al., 2008, Swafford et al., 2016). Among the eight research studies, five were multisite (Anderson et al., 2015, Avsar and Karadag, 2018, de Laat et al., 2007, Tayyib et al., 2015, Uzun et al., 2009), and three were single site (Coyer et al., 2015, Loudet et al., 2017, Rogenski and Kurcgant, 2012). We considered the Tayyib et al. (2016) study as multisite as it reports the findings from the implementation site of the two arm RCT (Tayyib et al., 2015).

Geographically, one quality improvement project was conducted in a developing country (United Arab Emirates) (Gill, 2015), and the remaining 11 were conducted in developed countries including one in Australia (Elliott et al., 2008), two in United Kingdom (Gage, 2015, Richardson et al., 2017), and eight in the United States (US) (Azuh et al., 2016, Baldelli and Paciella, 2008, Ballard et al., 2008, Donovan et al., 2016, Hiser et al., 2006, Padula et al., 2008, Swafford et al., 2016, Wolverson et al., 2005). Four of the eight studies (5 papers) were conducted in developing countries, including Saudi Arabia (Tayyib and Coyer, 2016, Tayyib et al., 2015), Brazil (Rogenski and Kurcgant, 2012), Turkey (Avsar and Karadag, 2018, Uzun et al., 2009), Argentina (Loudet et al., 2017), and three were conducted in developed countries including the US (Anderson et al., 2015), Australia (Coyer et al., 2015), and the Netherlands (de Laat et al., 2007).

All quality improvement projects used uncontrolled before and after design. Of the eight research studies, one study used a cluster randomised trial design with two clusters (Tayyib et

al., 2015); one used a prospective cohort design (de Laat et al., 2007), three used controlled before and after design (Avsar and Karadag, 2018, Coyer et al., 2015, Uzun et al., 2009), and three were uncontrolled before and after design studies (Anderson et al., 2015, Loudet et al., 2017, Rogenski and Kurcgant, 2012). Sample size varied in these studies from 78 to 399 patients with a median of 202, and interquartile range (IQR) of 170.

Among the 12 quality improvement projects, most of the included papers (n=8, 62%) met ≥ 13 of 16 QI-MQCS criteria (81%), and the remaining met 10-12 of 16 criteria. Among the eight research studies, seven were assessed against the items for quantitative non-randomised studies of the MMAT (2018). Five of these met all five MMAT criteria (Anderson et al., 2015, Avsar and Karadag, 2018, Coyer et al., 2015, de Laat et al., 2007, Uzun et al., 2009), and two of studies met all but the “are the confounders accounted for in the design and analysis” criteria (Loudet et al., 2017, Rogenski and Kurcgant, 2012). One study (two papers) was assessed against items for randomised trial of the MMAT (Tayyib et al., 2016, Tayyib et al., 2015), which did not meet the “are the groups comparable at baseline” criteria but met all other criteria.

Pressure injury prevention programs and components

Most (n=20/21) of the included papers explicitly described the pressure injury prevention programs (see Tables 1 and 2). Generally, they were better described in the research studies than in the quality improvement papers. Seven research papers (6 studies) (Anderson et al., 2015, Avsar and Karadag, 2018, Coyer et al., 2015, de Laat et al., 2007, Rogenski and Kurcgant, 2012, Tayyib et al., 2016, Tayyib et al., 2015) and 10 quality improvement projects (Baldelli and Paciella, 2008, Ballard et al., 2008, Donovan et al., 2016, Elliott et al., 2008, Gage, 2015, Hiser et al., 2006, Padula et al., 2008, Richardson et al., 2017, Swafford et al., 2016, Wolverton et al., 2005) implemented a multicomponent pressure injury prevention

program. Two research studies (Loudet et al., 2017, Uzun et al., 2009) and one quality improvement project (Gill, 2015) implemented a multicomponent education program with skin assessment, pressure injury risk assessment, repositioning, and support surfaces use as sub-components. Azuh et al. (2016) implemented a multicomponent early mobility program, which used pressure injury prevention interventions as sub-components.

The number of components included in each pressure injury prevention program varied, ranging from 2 to 11. Common components of pressure injury prevention programs included: clarification of staff roles/introducing new roles dedicated to pressure injury prevention, repositioning/positioning of patients' pressure areas, staff and patient education, support surfaces use, pressure injury risk assessment, skin assessments, nutrition needs assessment, documentation, multi-disciplinary team involvement, and mobilisation (Table 1 and 2).

Implementation strategies

The implementation strategies used in the included papers were presented in Table 3. Detailed information on what strategies was used in each of the studies is presented in Supplementary Table 2.

Table 3 Six classification of pressure injury prevention (PIP) implementation strategies used in included papers

Classification of implementation strategies*	Categories within each classification	Actors (who enacted the strategies)	Number of papers used the strategy (N) and number of papers mentioned the actors (n) N(n)
Dissemination strategies	Staff education: including lectures, seminars, meeting, teach-back method, video, case study	Dedicated team/staff including wound care team, dermatologist, product educators, and researchers.	12(11) Avsar and Karadag, 2018; Baldelli and Paciella, 2008; Coyer et al., 2015; de Laat et al., 2007; Gill, 2015; Hiser et al., 2006; Loudet et al., 2017; Padula et al., 2008; Richardson et al., 2017; Swafford et al., 2016; Tayyib et al., 2015; Uzun et al., 2009
	Staff education using print materials, including poster, brochure, handout, laminated slide	Dedicated staff including wound care specialists, and researcher.	6(2) Avsar and Karadag, 2018; Coyer et al., 2015; Gage, 2015; Richardson et al., 2017; Tayyib et al., 2015
	Events	No information	1(0) Hiser et al, 2006
	Media	Researcher	1(1) de Laat et al, 2007;
	Champion	No information	1(0) Coyer et al, 2015
	Patient/ family education	Staff who provided skin care	3(3) Azuh et al., 2016; Loudet et al., 2017; Rogenski and Kurcgant, 2012
Implementation process strategies	Using tools to assess skin PI status and PI risk regularly, including Braden Scale, Waterlow Scale, the CALCULATE tool, a redesigned wound chart, and a PI staging tool	Bedside nurses	11(11) Anderson et al., 2015; Avsar and Karadag, 2018; Azuh et al., 2016; Baldelli and Paciella, 2008; Coyer et al., 2015 ; Gage, 2015; Gill, 2015; Hiser et al., 2006; Padula et al., 2008; Richardson et al., 2017; Swafford et al., 2016; Tayyib et al., 2015; Wolverton et al., 2005
	Using skin care products, tools and equipment to protect patients' skin, keeping skin dry, repositioning, mobilising, using support surfaces, nutrition management	Bedside nurses	11(11) Anderson et al., 2015; Avsar and Karadag, 2018; Azuh, 2016; Baldelli and Paciella, 2008; Coyer et al, 2015; Gage, 2015; Gill, 2015; Loudet et al, 2017; Rogenski and Kurcgant, 2012; Tayyib et al., 2015; Uzun et al., 2009
	audit, and feedback	Research and project team members, ICU leadership team, or PIP dedicated staff	14(10) Azuh et al., 2016; Baldelli and Paciella, 2008; Ballard et al., 2008; Coyer et al., 2015; Donovan et al., 2016; Elliott et al., 2008 ;Gage, 2015; Gill, 2015; Hiser et al., 2006; Padula et al., 2008; Richardson et al., 2017; Swafford et al., 2016; Tayyib et al., 2015; Wolverton et al., 2005
Integration strategies	Standardising and improving documentation, including creating standardized documentation, increasing documentation frequency, and adding documentation content.	Mostly nurses, some by dedicated team	7(7) Ballard et al., 2008; Coyer et al., 2015; Donovan et al., 2016 ; Gage, 2015; Hiser et al., 2006; Loudet et al., 2017; Tayyib et al., 2015

	Staff role clarifications	No information	1(0) Azuh et al, 2016
	Establishing new structures such as new teams and new roles on PIP	No information	9(0) Baldelli and Paciella, 2008; Ballard et al., 2008; Coyer et al., 2015; de Laat et al., 2007; Donovan et al., 2016 ; Gage, 2015 ; Hiser et al., 2006; Loudet et al., 2017; Richardson et al., 2017
	New protocols	Interdisciplinary team	1(1) Hiser et al., 2006
	Adding new equipment	Hospital	2(2) Donovan et al., 2016; Hiser et al., 2006
	Using technology in decision making	Team leaders	1(1) Loudet et al., 2017
	Reminder system	Dedicated team or bedside nurses	6(5) Baldelli and Paciella, 2008; Coyer et al., 2015; Donovan et al., 2016; Elliott et al., 2008 Gill, 2015 ; Tayyib et al., 2015
	Communication and education checklist	Multidisciplinary team and dedicated PIP team	2(2) Donovan et al., 2016; Wolverton et al., 2004
Capacity building strategies	Multidisciplinary rounds	Dedicated team such as ICU leadership team, and PI team	3(3) Ballard et al., 2008; Gage, 2015; Wolverton et al., 2004
	Education events	No information	1(0) Hiser et al., 2006
	Education: e-learning modules, learning credits	All staff	2(1) Gage, 2015; Hiser et al., 2006
	Mentoring	Dedicated staff such as research nurse, and educators.	7(7) Anderson et al., 2015; Avsar and Karadag, 2018; Baldelli and Paciella, 2008; de Laat et al., 2007; Elliott et al., 2008; Padula et al., 2008; Tayyib et al., 2015
Sustainability strategies	Ongoing tools use; Ongoing audit and feedback; Ongoing staff education; Engaging staff; Putting systems in place to track progress.	No information	1(0) Gage, 2015
Scale up strategies not mentioned in any papers			

*We used a modified implementation strategy classification system (Leeman et al., 2017); PI: pressure injury; PIP: pressure injury prevention

Staff education was the main *dissemination strategies* used in the included papers. Target audiences were mostly clinical staff, with content commonly focused on staff knowledge on pressure injury prevention, pressure injury assessment and pressure injury risk assessment, and documentation. The education strategies used included posters, booklets, e-learning modules, videos, photographs, seminars and regular conferences. Return demonstrations and teach-back by participants were used in one quality improvement project (Swafford et al., 2016). Staff education was predominantly conducted by skin care/wound management specialist or staff in education roles in most of the papers, with one study using a champion (Coyer et al., 2015). Some papers did not report who enacted certain elements of the education strategy such as who presented the education PowerPoints and poster and who conducted the orientation for nurses (Coyer et al., 2015, Gage, 2015, Hiser et al., 2006).

Common *implementation process strategies* used in the included papers were: using tools to assess skin pressure injury status or pressure injury risk regularly in all quality improvement projects and research studies except Padula et al. (2008); protecting patients' skin during care by using skin barrier products and cleaning agents; using tools and equipment; repositioning patients regularly following protocols; reviewing patients' pressure injury status and documentation regularly; audit; and feedback. Some of these strategies were enacted by bedside nurses who provided direct patient care, with an exception of audit and feedback which were mostly conducted by the research/project team members, ICU leadership team, or dedicated pressure injury prevention staff. Specific details for each paper are shown in Table 3.

Integration strategies included standardising and improving documentation (in most papers), using reminder systems (six papers), clarification of roles (Azuh et al., 2016), establishing new structures such as new teams and new roles on pressure injury prevention (10 papers),

pressure injury prevention protocol development (Hiser et al., 2006), adding new pressure injury prevention equipment to hospital product list (Donovan et al., 2016, Hiser et al., 2006), and developing/using technology such as smartphone apps to manage pressure injury management decisions (Loudet et al., 2017). Some of these strategies were carried out by project team members and bedside nurses, however, most of the papers did not specify who enacted the strategies.

Multidisciplinary ward rounds (Ballard et al., 2008, Gage, 2015, Wolverton et al., 2005), staff education (Hiser et al., 2006), and mentoring (Baldelli and Paciella, 2008, Elliott et al., 2008, Gage, 2015, Tayyib et al., 2015) were the strategies used for *capacity building*. These strategies were mostly enacted by research/project team members or staff members in leadership roles with an aim to improve capacity.

None of the included projects stated plans or activities to spread the implementation to other sites or settings, which is called *scale-up strategies*.

Only one quality improvement project (Gage, 2015) reported using *sustainability strategies* including ongoing use of tools, ongoing staff education, continuous staff engagement, and ongoing audit and feedback on compliance to new practice. However, there was no information on who enacted these strategies.

Effectiveness of the pressure injury prevention programs

Patient outcomes reported included pressure injury prevalence and incidents, and pressure injury severity. In four of the eight research studies and one of the 12 quality improvement projects, the pressure injury prevention programs resulted in significant decreases in pressure injury cumulative incidence (Anderson et al., 2015, Azuh et al., 2016, Coyer et al., 2015, Loudet et al., 2017, Tayyib et al., 2015); a decrease in pressure injury cumulative incidence

with no statistical significance in one study (Rogenski and Kurcgant, 2012); a significant decrease in pressure injury period prevalence in one study (Avsar and Karadag, 2018); and two reported significant decrease in the incidence stage II and above Pressure injuries (de Laat et al., 2007, Uzun et al., 2009). Family participation in pressure injury prevention significantly increased from 9-57% in one study (Loudet et al., 2017). One quality improvement project reported increased patient satisfaction to the implementation of an early mobilisation project (Azuh et al., 2016).

Process outcomes reported in one quality improvement project and four research studies included significant increase in compliance/adherence to pressure injury prevention protocols and strategy use (Anderson et al., 2015, Azuh et al., 2016, Coyer et al., 2015, Gill, 2015, Tayyib et al., 2016, Tayyib et al., 2015), family participation (Loudet et al., 2017), patient satisfaction (Azuh et al., 2016), and nurses satisfaction (Tayyib et al., 2016).

Organisational outcomes measured included increased cost in the intervention group (Avsar and Karadag, 2018). Two quality improvement projects reported estimated reduced costs, with one reported a saving of US\$1 million after the implementation focused on education and adherence to protocols in one 14-bed ICU (Swafford et al., 2016), and another with a saving of £2.6 million after implementing **pressure injury** care bundles in 4 ICUs (Richardson et al., 2017).

Discussion

This review of pressure injury prevention programs identified a variety of both quality improvement projects and research studies. The wide geographic origin of the articles may indicate pressure injury prevention a world-wide priority for ICUs. There were considerable similarities across the programs, however, the implementation strategies varied, particularly,

who implemented the strategies. The majority of the studies found a significant decrease in pressure injury cumulative incidence and period prevalence, however given the types of study designs used, there may be other reasons for these results.

Programs and their components

The multicomponent programs were associated with decreased pressure injury incidence in critically ill patients. A review of strategies used in implementing clinical practice guides in ICU suggested that multi-faceted interventions such as care bundles were more effective than single component interventions (Jordan et al., 2017). However, a recent systematic review found that research evidence on the effectiveness of care bundles were mostly of low quality (Lavalley et al., 2017).

Pressure injury risk assessment was used in 60% of all papers, however, how to accurately assess pressure injury risk in the ICU population remains as an issue, as concluded in a literature review by Cox (2017). For example, the Braden Scale has been recommended to use for critically ill patients, however, research evidence on the relationship between the Braden score and pressure injury incidence in the ICU population from different authors has been inconsistent (Cox, 2017). This calls for future research exploring a pressure injury assessment tool that is more sensitive and appropriate for the ICU population.

Other components such as skin assessment, use of a skin barrier product, repositioning, and support surface use were commonly used in included papers, which is consistent with the recommendations from international clinical practice guidelines (National Pressure Ulcer Advisory Panel et al., 2014). In addition, staff and patient education, nutrition needs assessment and support, and multidisciplinary ward rounds were also common components in some pressure injury prevention programs. Consistent with research evidence, there are variations in the components used in different programs. For example, for the repositioning

component, the frequency of the repositioning ranged from one to three hours. This may be because there is no high quality evidence to suggest which frequency is better (Gillespie et al., 2014). Further, repositioning frequency is often determined by patients' clinical condition and organisational policies regarding pressure injury prevention.

Implementation strategies

A wide variety of implementation strategies were used in the included papers. Although staff education strategies, including seminars, posters, brochures, PowerPoints (which can be used face to face or for self-paced study), were commonly used in most of the included papers, no study examined their effectiveness. Current literature suggests that education will not contribute to behaviour change unless it is targeted and tailored to the specific context, and education focused on application of knowledge rather than feeding staff with knowledge is more meaningful for clinicians (Baker et al., 2015). Further, reminder systems such as the “turn clock” strategy used by Coyer et al. (2015) can be used to prompt busy clinicians to adhere to pressure injury prevention protocols. Audit and feedback, strategies that have found to be effective to ensure compliance, are commonly used in the quality improvement projects and research studies. However, only one paper (Gage, 2015) explicitly stated that an ongoing audit and feedback practice was put in place for long term sustainability.

Among the 14 papers that reported using integration strategies, only seven reported who enacted the strategies (Ballard et al., 2008, Coyer et al., 2015, Donovan et al., 2016, Gage, 2015, Hiser et al., 2006, Loudet et al., 2017, Tayyib et al., 2015). Integration strategies aim to change individual practitioner's behaviour and organisational factors that impact on them (Leeman et al., 2017). Clarity on who should be responsible to enact the integration strategies in the organisation is essential for it to happen, as ownership in translating research evidence

into practice is important. Using new care teams and clarifying existing staff members' roles and responsibilities in pressure injury prevention was mentioned in six papers. The benefits of new roles or clarified roles can be three-fold. Firstly, staff in these roles can be champions, which has been found to be an effective strategy to enhance CPG implementation in ICU (Jordan et al., 2017) and to lead and reinforce research evidence uptake and improve compliance to protocols (Miech et al., 2018). Secondly, this helps to build capacity in promoting evidence-based practice. And lastly, established role structures may contribute to better sustainability over time.

Sustainability has been important concern of implementation scientists in recent years. Although a number of papers had systems put in place that may contribute to better sustainability, sustainability was only explicitly mentioned in one paper (Gage, 2015). To ensure new practices are embedded in clinical practice, and continued improvements are made, strategies that aim to reinforce adherence, such as ongoing audit, feedback, and regular review of practice to make change continuously, need to be in place as suggested by the Knowledge to Action framework (Field et al., 2014).

Effectiveness of the programs

Most of the pressure injury prevention programs were associated with significant decreases in pressure injury incidents and prevalence. Structured and multi-faceted approach to pressure injury prevention has been shown to be effective and are recommended by international practice guidelines (National Pressure Ulcer Advisory Panel et al., 2014). While ICU patients are at high risk of pressure injury, their clinical condition can preclude the use of some pressure injury prevention strategies. Thus, multicomponent programs allow ICU nurses to enact appropriate components according to the patients' situation. However, most of the

studies used a before and after design which are considered less rigorous in the level of research evidence hierarchy (Centre for Evidence Based Medicine, 2009) and have the potential for the Hawthorn effect (Lewis-Beck et al., 2004). The designs of both the research studies and the quality improvement projects have various weaknesses, which means that causation inferences need to be tentative. That is, there are numerous threats to internal validity in before and after and other descriptive designs (Polit and Beck, 2016). As a result, there may be reasons other than the pressure injury prevention programs that explain improvements on outcomes. Thus, better designed future studies such as adequately powered randomised controlled trials are needed to provide higher quality evidence.

In this review, the success or outcome of the pressure injury prevention programs did not seem to have a relationship with the number of components or complexity of their implementation, which supports findings from current literature (Shanbhag et al., 2018). Program success may be related to the tailored intervention approach used in the studies or projects. For example, a study that implemented a 3-component program (Loudet et al., 2017) reported similar findings (significant decrease in pressure injury incidence) as the studies that implemented programs with 6 to 11 components (Anderson et al., 2015, Avsar and Karadag, 2018, Coyer et al., 2015, Tayyib et al., 2015). These results may suggest that interventions designed to suit the local contexts and individual patient characteristics may be important for meaningful outcomes (Baker et al., 2015).

Only two projects estimated significant cost savings (Richardson et al., 2017, Swafford et al., 2016). These findings are noteworthy because pressure injury is one of the most costly adverse events in hospitalised patients (Padula et al., 2018, Padula et al., 2018). However, one before and after study with only 154 patients found an increase in cost in the intervention group (Avsar and Karadag, 2018). But, without a proper economic evaluation that includes the potential beneficial savings, focusing on costs alone may be misleading. Thus more

research is needed to investigate the cost savings of pressure injury prevention programs; what components are crucial to decrease cost; and identify what components or implementation strategies are not effective in improving patient outcomes but contribute to higher cost in pressure injury prevention implementation.

Limitation

Before and after designs were used in most of the quality improvement projects and research studies therefore the resulting level of research evidence was generally low. Additionally, we did not assess risk of bias in the research studies but instead assessed the quality of reporting. Therefore, the benefits of pressure injury prevention programs in this review should be interpreted with caution. Due to the complexity of ICU patients' clinical conditions, and the multiple components implemented in the projects and studies, it was impossible to determine which components worked to what degree. Last, there could be possibility of publication bias when non-positive quality improvement projects or studies are not reported or published.

Conclusion

The majority of the quality improvement projects and research studies implemented a comprehensive pressure injury prevention program which was congruent with recommended by international clinical practice guidelines. Much of this work on multicomponent pressure injury prevention programs has been undertaken as quality improvement projects, and before and after research studies with limited rigorous, high quality research. However, positive outcomes and strong theoretical rationales for the components in the programs suggest they are beneficial. pressure injury prevention programs can often be labour intensive, and the equipment and tools used are often costly to healthcare organisations. This calls for future

high-quality research such as randomised controlled trials to test the effectiveness of multicomponent interventions and their implementation strategies.

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