Title: Effectiveness of preventative care strategies for reducing pressure injuries in children aged 0-18 admitted to intensive care: a systematic review and meta-analysis

Short Title: Pressure injury preventive strategies in paediatrics

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Abstract

Introduction: The development and prevention of pressure injuries is a complex phenomenon, dependent on a wide variety of extrinsic and intrinsic risk factors. Children with critical illness form an extremely vulnerable patient group with an exceptionally high risk of immobility-related and medical device-related pressure injuries. Recent reviews on this subject matter largely been focused on adult patients. The aim of this review is to systematically synthesise the evidence on the most effective interventions to prevent pressure injury development in children admitted to intensive care.

Methods: Four electronic databases; CINAHL, MEDLINE, EMBASE and the Cochrane Central Register of Controlled Trials were searched. Studies were screened at three stages, title, abstract, and full text against the inclusion and exclusion. Quality appraisal was conducted using the Joanna Briggs Institute Critical Appraisal Tools and two authors independently extracted study data from included studies using a predesigned data collection form. A meta-analysis was performed using RevMan 5.

Results: After removal of duplicates, twenty studies met the inclusion criteria. Observed interventions included; use of risk assessment tool, preventative skin regimes, nutrition, repositioning, support surfaces, medical devices care, and staff education and training. A bundle intervention approach was used to implement pressure ulcer preventative strategies. Meta-analysis demonstrated an associated 51% potential reduction in pressure injury post intervention (pooled OR 0.49 (95% confidence Interval (CI) 0.39 – 0.62) $P < 0.0001$).

Conclusion: Pressure injury preventative strategies are more likely to reduce the number and severity of pressure injuries. Paediatric nurses are pivotal members of the direct care multidisciplinary team with unique expertise and influence over the risk assessment, implementation and maintenance of pressure injury preventative strategies for children admitted to intensive care.

Key words: paediatrics, pressure ulcers, intensive care, prevention, intervention

Introduction

The development and prevention of pressure injuries (PIs) is a complex phenomenon, dependent on a wide variety of extrinsic and intrinsic risk factors. Typically PIs have been defined by the National Pressure Injury Advisory Panel (NPIAP), European Pressure Ulcer Advisory Panel (EPUAP) and Pan Pacific Pressure Injury Alliance (PPPIA) as a localised injury to the skin and/or underlying tissue as a result of immobility-related pressure or pressure in combination with shear [1, 2]. Children with critical illness who require an intensive care admission form an extremely vulnerable patient group with an exceptionally high risk of immobility-related PIs [3]. Growing evidence suggests that medical devices, particularly in paediatric populations, are also a leading cause of PI [4-6]. The notable difference between immobility-related and medical device-related PIs is that the latter will mimic the shape of the medical device itself and be caused as a result of sustained pressure that is usually attributed to the rigid materials of the device or the tight dressings that may be used to secure it [5, 7]. These injuries are particularly of challenge to prevent because medical devices are often an essential therapeutic or diagnostic component of life sustaining treatment [4, 5, 8]

The scale of the problem is global. Early prevalence studies published before 2010 did not always separate medical device-related PIs from immobility-related PIs, or specify whether device-related PIs were included or excluded [9]. However, PI prevalence estimates among hospitalised paediatric patients after 2010 ranged from 1.4% to 8.2% [8] and paediatric critical care areas have reported prevalence as high as 43.1% [10]. A huge emphasis is currently being placed on patient safety issues and harm free care initiatives, particularly in the fundamental aspects of nursing care such as PI prevention, at local and international level [11, 12]. The urgency to reduce physiological and psychological burden on patients and their caregivers, lessening the financial liability on health care providers, and decrease the risk of subsequent co-morbidities and infection is crucial for advancing PI prevention research [13].

A systematic review that evaluated the effectiveness of preventative care strategies for reducing PIs among critically ill adult patients concluded that rigorously designed

randomised controlled trials are necessary to further the evidence base [14]; while another recent systematic review concluded that nurses caring for critically ill patients are well qualified to lead in the prevention of PIs and they must plan and implement evidence-based care to prevent all types of PIs, including medical device-related PIs [15]. Much has been learned since 2001, when initial efforts to elucidate the problem of PIs in children was published in an international guideline [16]. With progress being made in paediatric-specific, medical device sensitive, PI risk assessments [3], this systematic review aims to identify the effectiveness of PI prevention strategies on the development of hospital-acquired PIs among children aged 0-18 admitted to intensive care.

Methods

A systematic review protocol for this study was registered with the International Prospective Register of Systematic Reviews (PROSPERO; CRD42021245169) in March 2021. The Preferred Items for Systematic Reviews and Meta-Analysis (PRISMA) [17] guidelines were used to report the review process.

Search Strategy

A comprehensive search strategy (Appendix 1) was devised and executed on the following four databases: Cumulative Index to Nursing and Allied Health (CINAHL), MEDLINE, EMBASE and the Cochrane Central Register of Controlled Trials (CENTRAL). Google Scholar and the National Institute for Health and Care Excellence (NICE) were also searched for sources, plus the reference lists of included studies. The search terms included: child* (OR) adolescent (OR) infant (OR) baby (OR) babies (OR) pediatric* (OR) paediatric* (OR) neonat* AND pressure injur* OR pressure ulcer* OR pressure sore OR bed sore OR decubitus ulcer AND intensive care OR critical care OR PICU OR ICU OR PCCU OR NICU OR high depend* AND reduc* OR prevent* OR sever* OR duration OR develop* OR worsen*. An asterisk (*) wildcard symbol was added to truncate certain search phrases to ensure more comprehensive identification of the relevant studies. Medical subject headings ‘intensive care’, ‘pressure ulcer’ and ‘pediatric’ were used in addition to key search terms. Consultation with two independent subject librarians regarding the

search strategy occurred prior to completing the search for sources. Database searches were conducted up to December 2022.

Eligibility Criteria

Articles were included and reviewed based on whether they were experimental study designs - including randomised controlled trials (RCTs), non-randomised controlled trials, quasi-experimental studies, and comparative studies - and evaluated the effectiveness of any PI prevention strategies that have been conducted in intensive care settings providing services to children aged 0-18. Studies published in the English language, and at any time, were considered for inclusion in this review.

Study Selection

Articles were initially screened by title and abstract, by the primary author, to ensure they met the inclusion criteria. All full text papers for inclusion were individually assessed for eligibility by two independent authors (Setchell and Nelson). Both authors used a spreadsheet to store information about the papers, which was then cross checked for accuracy. Any discrepancies were discussed amongst the two reviewers until they reached agreement. In this instance, there was no need for a third reviewer, as a consensus could be reached.

Quality assessment

Quality assessment for included studies was undertaken independently by two reviewers (Setchell and Marufu), and discrepancies were resolved by agreement. The Joanna Briggs Institute (JBI) critical appraisal tools for Quasi-Experimental Studies, RCTs [18] and Prevalence Studies were used according to the corresponding methodology. Following appropriate guidance, each item in the critical appraisal tool was scored (1 for ‘yes’, or 0 for ‘no’ or ‘unclear’) and a total for each study was converted to a percentage. The authors rated the studies as high quality (>80%), moderate quality (50%–80%) and low quality (<50%).

Data Extraction

Two authors (Setchell and Nelson) independently extracted study data from included studies using a predesigned data collection form. Data extraction was done independently and agreed using consensus. No disagreements occurred in this

process. A summary table was created to include study details (authors, year and country), study aim, participants, details of the interventions and findings from each study.

Data Analysis

Included studies presented outcome results in various formats including odds ratio (OR), relative risk (RR) and percentage rates. Using pre and post pressure ulcer prevention intervention figures, OR and 95% confidence intervals (95% CI) for the likelihood of pressure ulcer reduction after the intervention (exposure) was calculated. A meta-analysis was conducted using Rev.Man 5 [19] using the random effect method for a pooled size effect of implementing a pressure ulcer prevention strategy. For the studies where OR could not be calculated and/ or OR results were for a specific part of the intervention a qualitative synthesis is provided.

Results

The online search identified a total of 1173 studies, 265 duplicates were removed, and 58 studies were sort for retrieval after title and abstract sifting stages. Twenty-five papers were abstracts that had been submitted to conferences without a published full text paper, 33 full texts were retrieved and screened for eligibility and only 20 met the inclusion criteria, Table 1. Figure 1 is a flow chart showing an overview of the search process.

Table 1 Characteristics of included studies

Figure 1 PRISMA Flow chart

Out of all the included studies, six were randomised control trials (RCTs) [20-25] and nine were quasi-experimental [26-34] all with a combined sample size of 9287 participants. Four studies were before and after intervention [35-38] of which three [36-38] did not have specified sample size and one was a prospective cohort study [39] with a total sample size of 65 participants. Nine studies were conducted in the United States of America [27-29, 32-34, 36-38], three in Spain [26, 30, 39], two in China [20, 24], and one in each of the following countries; Australia [21], India [22]

Indonesia [23], Iran [25], Argentina [35] and Turkey [31]. Most settings were single centre tertiary hospitals, only two studies were multicentre trials with larger population samples [28, 30].

Methodology Quality Assessment

Fifteen studies were high quality, scoring > 80% on the JBI assessment tool and the other five studies had moderate scores [23, 25, 32, 37, 39]. No studies were assigned a low-quality ranking and therefore, no studies were excluded on methodological quality. Due to the nature of interventions, three out of the five RCTs commented on the difficulties of blinding healthcare providers [20-22]. However, to mitigate this, one study blinded the nurses before allocation [20], one study blinded an investigator who was analysing patient photographs [21] and one study blinded the statistician [22]. Only one study mentioned blinding participants and their guardians [20], in comparison two of the five RCTs did not describe their blinding or randomisation procedures at all [23, 24].

Interventions

All interventions used in the studies included are largely in line with the NPUAP, EPUAP and PPPIA guidelines [1] for PI prevention. Interventions were used as part of bundle interventions (that involves concurrent implementation of multiple interventions). These included; skin risk assessment, preventive skin care regimes, nutrition status, repositioning, support surfaces (pressure relieving equipment), medical device related assessments and staff education and training. These interventions are briefly summarised below with a narrative synthesis of studies not included in the meta-analysis.

Skin risk assessment; thirteen studies used a variety of validated risk assessments as part of their bundle of preventative strategies and generally assessed patients using them every 24 hours. Predominantly the Braden Q Scale [39] was used in eleven of these studies [23, 26-29, 31, 333-35, 38, 39], which is the former version of the updated Braden QD Scale [17] used in one recent study [32]. The Neonatal Skin Risk Assessment Scale [41] was used in three studies: as the only tool in one study [30], and in addition to the Braden Q Scale depending on the age of patients in two studies [23, 26]. Of these studies, which incorporated a risk assessment tool, six

studies included additional training for nursing staff on how to use them as part of the preventative strategy [27, 29, 31, 34, 35, 38]. None of the studies reported reduction on PI due to the use of the assessment tool alone. However all these studies reported an overall reduction in PI incidence rates by ensuring those at risk were identified early by daily risk assessment as part of bundle intervention.

Preventative skin care regimes; seven studies described the use of barrier cream to moisturise and protect the skin after episodes of incontinence [26-29, 31, 32, 36], with one detailing the use of foam dressings [26]. Similar to the skin risk assessment, none of the studies outlined the effectiveness of barrier cream use alone. All studies also reported a reduction in overall PI.

Nutrition; eleven studies in this review acknowledged the crucial element of adequate nutritional support for patients in intensive care at risk of PIs [26-33, 36-38], however four of these studies did not implement interventions to support this [30, 33, 36, 37]. The remaining seven studies all specified how nutrition consultations formed part of their preventative strategy [26-29, 31, 32, 38], with two of these studies using a high risk Braden Q Score <16 to trigger this consultation [27, 38]. By making this process automatic, one study was able to achieve a 100% compliance score for every high risk patient receiving a nutritional review by a dietician during the study period [27, 46]. In a large multicentre study, the three institutions with the lowest rates of pressure ulcers used preventative nursing strategies such as nutrition consultations [28], and another study reported that early nutritional intervention can prove an effective prevention strategy if patients with a higher risk of developing PI are identified [26]. Parenteral nutrition was found to be a significant risk factor in one study [30].

Repositioning; Variation in repositioning frequency was observed across included studies. Nine studies acknowledged that repositioning paediatric patients in intensive care every two to three hours is associated with a lower risk of PIs [26, 28-33, 36, 38]. In one study, turning the patient every two, four and eight hours were associated with lower risk for PI development (OR 0.27, 95% CI, 0.21 - 0.35, p <.001), (OR 0.355, 95% CI, 0.267 - 0.472, p <.001), (OR 0.63, 95% CI, 0.42 - 0.93, p .02)

respectively [28]. However one multicentre study reported two hourly frequency of repositioning as non-significant [30].
One study observed that measuring frequency of repositioning is not always feasible in intensive care if hemodynamic and/or respiratory instability conditions contraindicate it [26], but the NPIAP recommends slow, gradual turns in this patient group to allow time for stabilisation of hemodynamic and oxygenation status [1]. In addition, small shifts in body position for critically ill patients who are too unstable to maintain a regular repositioning schedule should supplement regular repositioning [1], which one study in this review credited as a successful intervention [32].
To improve repositioning compliance, one study found that appointing a project leader to track the frequency of repositioning daily increased compliance from 36% to 67% [38], which resulted in a 63% PI reduced from baseline. Similarly, another study implemented a family-centred approach, which encouraged family members to remind and assist nursing staff with repositioning their child [32]. The study reported a 17% reduction in PI rates post-intervention.

Support surfaces; nine studies describe the use of pressure redistributing support surfaces [26-30, 32, 33, 35, 36], however the extent of their use is often variable. One study reported the following interventions did not demonstrate statistical significance in reducing pressure ulcer development; egg-crate and foam-mattress overlays, gel pads, cushions, and specialty pressure redistributing mattresses [28]. Two studies used pressure redistributing mattresses that were limited to adult sized beds or were only suitable for patients who weighed >22kg [29, 33], and one study reported having an insufficient amount of pressure redistributing mattresses on site which caused some eligible patients to be excluded if they were already in use [39] and cautioned using pressure redistributing mattresses among haemodynamically unstable patients. Historically, the use of dynamic pressure management surfaces was not widespread among paediatric intensive care units, as traditionally these surfaces were considered more suitable for adults [27, 39], but centres are now incorporating algorithms that guide nurses to allocate paediatric-specific surfaces appropriately [26, 39]. Three studies detailed the use of support surfaces other than pressure redistributing mattresses, these included polymer gel positioners and cushions [27, 29, 35]. One of these studies failed to measure the adherence to these

interventions [35], whereas the other two studies reported a high compliance to their use [27, 29].

Medical device-related interventions; in total, thirteen studies in this review utilised interventions to reduce PIs from medical devices [20-25, 28-32, 34, 36, 37]. Two studies commented on the difficulty in conducting skin assessments under critical devices that are difficult to reposition, for example endotracheal tubes, non-invasive positive pressure ventilation facemasks, and tracheostomies [29, 30]. Both studies reported > 50% of PIs being attributed to medical devices despite twelve-hourly daily skin checks, whereas two other studies also included this intervention with greater success [31, 36]. One of these studies included the additional removal of respiratory devices every four hours as part of their preventative strategy, however they acknowledge this was the least compliant element of their overall bundle [36]. Specifically investigating continuous positive airway pressure (CPAP) devices, one RCT showed that Bubble CPAP with its nasal interface had higher and more serious incidence of nasal injuries in comparison to Jet CPAP device, risk ratio (RR) 0.6 (95% CI, 0.5 – 0.8, $p < 0.001$) [22]. In contrast another study reported that the implementation of a Bubble CPAP Skincare Protocol was successful at reducing nasal PIs over the 24-month post implementation period [37].

Similarly, another study was able to significantly decrease the number of patients who developed a tracheostomy PI from 8.1% during the pre-intervention period, to 0.3% after the interventions were implemented [32]. They achieved this by using extended-style tracheostomy tubes in children with anatomy that caused the neck to not be clearly exposed in the neutral position or those with behaviours that repeatedly drove the tube down into the sternum, performing tracheostomy assessments every 8 hours, and by placing hydrophilic polyurethane foam under tracheostomy tubes to wick moisture from the stoma away from the skin surface. They also used a hydrocolloid barrier dressings under the flanges of tracheostomies, which is another intervention recommended by the NPIAP [1]. Five other studies also used this intervention effectively [20, 21, 24, 25, 34].

Three demonstrate that prophylactic use of a nasal barrier dressing was effective at reducing nasal PI for infants receiving nasal CPAP [21, 24, 25]. One of these studies focused on the first 48 hours of commencing treatment in very preterm or very low

birth weight infants and observed that skin damage occurred to 34% of those who had a hydrocolloid barrier dressings compared to 56% of those without the barrier dressing, P = .02 [21]. A similar study reported infants in the intervention study having significantly lower incidence and severity of nasal injury compared with those having standard care 37.5% versus 92.5% respectively, P <0.001 [25]. The other study, used the chi-squared test, to show a statistically significant difference (*P*=0.01) in the incidence of nasal injury between infants who received a prophylactic hydrocolloid barrier dressing and those who did not [24]. One study noted that hydrocolloid dressings does not only reduce the rate of nasotracheal tube-related PI in the child with long-term nasotracheal intubation, but also improve the endurance of the nasal skin significantly [20].

Staff education and training; sixteen studies included some form of staff training and development as part of their preventative strategy [20, 22, 26-39]. Four studies opted for an online training module or podcast [27, 31, 33, 34, 38], two studies utilised face-to-face training either for new nurses [27] or in small groups [26], and two studies focused on family member training [32, 36]. The rest of the studies did not specify how the training was delivered, but most modules included information about using risk assessment tools, the preventative interventions that were going to be studied, and methods of data collection. In one study skin care champions were appointed who received extra training [29], and in another study the knowledge of nurses was tested before and after an education intervention; the authors found that the knowledge was improved [38]. Continual, real-time feedback about PIs during weekly skin rounds was also found to be an effective intervention in one study [36].

Meta-analysis of interventions to reduce pressure ulcers

Ten studies were included in a meta-analysis of interventions to reduce pressure ulcers (Figure 2). For all studies included in the meta-analysis [20, 21, 24, 26-27, 29, 31-32, 35, 39] intervention data and pressure ulcer events provided in the studies was used to calculate corresponding OR. Calculated OR for individual studies are presented in Table. The meta-analysis showed a pooled OR 0.49. 95% confidence interval (CI) (0.39 – 0.62), p = 0.001 for test of overall effect. The analysis demonstrates an associated 51% reduction in pressure ulcer development in PICU admitted patients post intervention. Moderate heterogeneity (I^2 = 59%) was observed

demonstrating medium variation in study outcomes between included studies. No sub-group analysis was performed.

Figure 2 Meta-analysis of interventions to reduce pressure ulcers

Publication bias

Publication bias was visually assessed using funnel plot developed using Rev.Man5. The plot was asymmetrical indicating a possible risk of publication bias (Figure 3 Funnel plot).

Figure 3 Funnel plot

Discussion

While other systematic reviews have investigated PI prevention strategies for adult patients [14, 15, 42], this paediatric review is novel research and the first review of its kind. This review has identified that preventative strategies from the NPIAP guideline [1] are effective to reduce the number and severity of PIs among critically ill children admitted to intensive care. Given the inclusion of RCTs and quasi-experimental studies, this review can be relatively certain that PI preventative strategies lead to reductions in the number and severity of PIs, but the effect size is varied depending on the interventions included. As a complex phenomenon, a multifaceted approach to PI prevention that includes multiple interventions (also known as bundles) has demonstrated effectiveness for reducing PIs for adults admitted to intensive care [42].

Further evidence suggests that some interventions are being used in practice, but a standard is lacking. In a recent point-prevalence study in a large tertiary children's hospital, 44% of patients were reported as not receiving PI preventive strategies aligned to their risk assessment. Despite this, the overall incidence of PIs was low [11]. This paper recommends that randomised, controlled, multicentre studies with larger samples and standardised, multicomponent PI prevention strategies for children admitted to intensive care are therefore necessary.

In comparison, having a medical device is consistently associated with an increased risk of developing PI [5, 6, 11, 17]. Most studies in this review acknowledged the difficulty of preventing device-related PIs, and the effectiveness of prophylactic hydrocolloid barrier dressings to prevent nasal PIs for infants receiving respiratory support was demonstrated [24]. The NPIAP (working with international partners) has recently launched an initiative to develop evidence-based standards for using prophylactic dressings to prevent PIs, as none currently exist despite their widespread use [43]. Not only does this amplify the contemporaneity of this issue, but it encourages clinical academic professionals to research the use of prophylactic barrier dressings among children of all ages. Paediatric medicine uses a whole spectrum of, often invasive, medical devices [5, 6, 17], and the future of PI prevention for children is synonymous with device risk mitigation. There is an opportunity for health professionals and device manufacturers to work closely with biomedical and biomechanical engineers to develop designs for existing and new

devices that will reduce the risk of device-related PIs [5]. Through effective clinical academic research, children's nurses should clearly articulate their clinical goals in order to drive innovation measured against standardised quantitative performance outcomes. Nurses are well qualified to lead in the prevention of PIs [15].
Although PI prevention is a fundamental aspect of nursing care and a nursing quality indicator, most centres employ a multidisciplinary approach to their strategy. Notably, a nutritional expert is considered beneficial to this process. Among adult research, there is a moderate statistical association between nutrition status and developing a PI [44]. While impaired nutrition and its relationship to PI development has not been as rigorously studied in children, this review was able to highlight that early nutritional intervention, by a qualified expert, is an effective strategy to prevent PIs in those children who have been identified as higher risk. In addition, audit and feedback strategies were found to be effective at ensuring compliance in a recent adult systematic review [42]. While only one study in this review demonstrated that real time, multidisciplinary, audit and feedback was useful for maintaining compliance to the preventative strategy, other research in this area has determined that information technology can be incorporated into daily work flow to improve patient care and safety in a children's intensive care unit [45]. As technology in hospitals advances, consideration should be given to the dissemination of patient safety data such as PI prevention via systems that are accessible to all direct care members of the multidisciplinary team.

Finally, the education and training of direct care nurses will always remain a fundamental aspect of PI prevention. The evidence suggests that online training modules or podcasts are a popular method of delivery, presumably because they can be distributed and accessed easily, however some centres prefer to provide face-to-face training. The limited number of studies in this review, and in adult literature [14, 42, 43], that examines the effectiveness of PI prevention training indicates the necessity for further research in this area. Similarly, the inclusion of non-professional carers and family members has a specific place in paediatric healthcare. Nurses are uniquely positioned to foster relationships with families who have a child admitted to intensive care; however the challenges of restrictive family presence and poor understanding of family needs were highlighted as key findings from a systematic review [46]. A small number of studies in this review discovered

that educating family members about the risks of PIs, including how to inspect for signs of PI and to notify the direct care nurse with concerns was a useful component of the preventative strategy. This type of family-centred care philosophy is recommended in the International Consensus Document about device-related PIs [5], however further empirical research is required to substantiate how effective and appropriate this is as a PI preventative strategy – especially in a critical care environment.

Study strengths and limitations

A comprehensive search strategy was used to identify potential studies for inclusion and the PRISMA guidelines were used as a review process and reporting mechanism. All studies included in the review had low risk of bias when assessed for methodological quality, giving some assurance on data quality and review results. However, results in studies that met the inclusion criteria for this review were reported in various formats with a limited number, (ten) of studies included in a meta-analysis. Furthermore for some studies OR were calculated from reported data, and therefore were not adjusted for any potential confounders. This has the potential to influence data quality of the meta-analysis and limit the generalisability of our study findings. However, considering bundle intervention approach used, the results observed in this review are more generalisable, highly relevant, timely and supported in clinical practice [42].

Conclusion

In this systemic review, strategies to prevent PIs in children admitted to intensive care settings have been analysed. Following international policy guidance, the review provides evidence on the use of risk assessment, preventative skin care regimes, nutrition, repositioning, pressure relieving equipment, medical devices care, and education and training as interventions to prevent PIs. Children's Nurses are the pivotal members of the direct care multidisciplinary team with unique expertise and influence over the risk assessment, implementation and maintenance of PI preventative strategies for children admitted to intensive care. The quality of the research is varied; which demonstrates requirements of further research to advance the empirical data. A particular focus on standardising strategy protocols, compliance

to interventions, data collection and the complexity of device-related PI prevention is crucial moving forward.

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Table 1 Characteristics of included studies

Authors	Type of Study	Country	Aim	Participants	Details of interventions	Findings
Bargos-Munarriz et al [26]	Quasi-Experimental	Spain	To evaluate a prevention strategy implemented to reduce incidence and severity of positioning related pressure injuries affecting paediatric patients in a paediatric critical care unit. Secondary objective was to evaluate compliance with preventive recommendations.	Paediatric patients up to 14 years old at risk of suffering from pressure injuries and who were admitted more than 48 h in a paediatric intensive care unit. n=110 [50 control grp, PI 8 participants, cumulative 14PIs and 212 days of PICU admission; Cumulative incidence 16% [CI95: 8.33%–28.51%] [60 intervention grp, PI 8 participants cumulative 11 PIs, 70 days PICU admission Cumulative incidence 13.33% [CI95: 6.91% to 24.16%].In prolonged hospitalisation patients cumulative incidents of PI was 55.55% [CI95: 26.66%–81.12%] in control grp and 20% [CI95: 5.66% to	The intervention group was attended using the prevention care plan which included the main evidence-based recommendations of NPUAP/EPUAP and focused on: skin assessment (from head to toe during cleaning or care procedures), skin moisturizing, repositioning (including heel offloading), limiting head-of-bed elevation to 30 degrees, allocating pressure-redistributing support surfaces using a standardized algorithm, and localized pressure relief (with different types of devices). Interventions: Skin assessment – Twice a day, hyperoxygenated fatty acids (HFA) application – Twice a day, pressure-redistributing support surfaces (PRSS) – daily, Head-of-bed	The cumulative incidence in paediatric patients exposed to the risk of pressure injuries was reduced from 16% to 13.3%, OR 0.58 95% CI (0.23 – 1.42)*; and in the subgroup of patients with prolonged stay (≥28 days), the incidence was reduced from 55.55% to 20%. In the intervention group, category III and IV pressure ulcers were completely reduced. In addition, the total number of pressure injuries decreased by 21.43%

				50.98.0%] in the intervention grp.	elevation maximum 30◦ -daily, Barrier cream application – daily, Floated heels – daily, Full body/head repositioning – 8 times a day.	
Chen et al [20]	RCT	China	To investigate the efficacy of hydrocolloid dressing in reducing the occurrence rate and severity of nasotracheal tube-related pressure injury	Paediatric patients received invasive mechanical ventilation via nasotracheal tubes. N=122 [n= 62 control grp, n= 60 intervention grp. Mean duration of nasotracheal intubation 150.10 ± 117.09 hours intervention grp, 161.75 ± 120.72 hours control grp.	The participants in the experimental group received hydrocolloid dressing to protect nasal skin from the beginning of nasotracheal intubation, while the participants in the control group received the current care procedure (without hydrocolloid dressing) unless pressure injuries occurred. The hydrocolloid dressing was changed daily to assess the nasal skin. The pressure injury staging system that was redefined and updated by the NPIAP in 2016 was used.	45 participants had nasotracheal tube-related pressure injuries in control group, compared to 26 patients in the experimental group (72.6% vs 43.3%; absolute difference, 29.3%, 95% CI, 12.5–46%; p = 0.001), OR 0.29 95% CI (0.14 – 0.62)*. The median survival times of the nasal skin integrity were 95.5 hours in the control group and 219.5 hours in experimental group (p < 0.001). Conclusions: Hydrocolloid dressing can not only reduce the occurrence rate of nasotracheal tube-related pressure injury in the child with long-term nasotracheal intubation but also improve the endurance of the nasal skin significantly.
Imbulana et al [21]	RCT	Australia	To determine whether the use of a	Eligible infants were born <30 weeks of gestation and/or	Infants were randomly allocated to receive either a hydrocolloid	Infants in the barrier group had a significantly lower rate of nasal

			hydrocolloid nasal barrier dressing during binasal continuous positive airway pressure (CPAP) therapy, compared with no barrier dressing, reduces the rate of nasal injury in very preterm and/or very low birth weight infants.	with birth weight <1250 g, and had received ≥4 hours, but <48 hours, of CPAP. A total of 108 preterm infants were enrolled: 53 infants in the barrier group and 55 infants in the no barrier group.	nasal barrier dressing during CPAP (barrier group), or no barrier dressing (no barrier group).	injury compared with the no barrier group: 18 of 53 (34%) vs 31 of 55 (56%), OR 0.40, 95% CI (0.18 – 0.87)* Summary: Prophylactic use of a nasal barrier dressing within 48 hours of commencing treatment with binasal CPAP in very preterm or very low birth weight infants reduces nasal injury.
Khan et al [22]	RCT	India	To report and compare the incidence, severity and type of nasal injury, and nasal comfort (pain scores, displacements) between two types of nasal interfaces with different CPAP delivery systems [variable flow device (Jet CPAP) versus continuous flow bubbling device	Preterm neonates of < 34-week gestation, who received nasal CPAP as primary support as part of a randomized trial comparing Jet device with Bubble device for delivery of CPAP, both through nasal prongs of different structure, make and fixation methods. n=170 [J-CPAP n= 80, B-CPAP n=90, overall nasal injury J-CPAP n= 36, B-CPAP n=67:	The neonates allocated to the experimental group received Jet-CPAP (J-CPAP; Phoenix Medical Technologies Ltd., Chennai, India) with short bi-nasal prongs at a flow rate just enough to generate desired CPAP. Standard group neonates received CPAP using a stand-alone bubble CPAP device with short bi-nasal prongs (Fisher and Paykel Healthcare, New Zealand) and were connected to the Fisher	103 (61%) developed nasal injury, moderate 18 (11%), severe 8 (5%). Septum was the most common injury site. Bubble CPAP device with its nasal interface had higher and more serious incidence of nasal injuries in comparison to Jet CPAP device [RR 0.6 (95% C.I. 0.5–0.8); p < 0.001]. Similarly, neonates in Jet group had lesser average [median (IQR): 3 (3,4) vs. 4 [8, 14]; p = 0.04] as well as peak N-PASS pain scores [median (IQR): 4 [8, 14] vs.

			(Bubble CPAP)] used for the management of respiratory distress with onset within 6 h of birth in preterm infants < 34-week gestation.		and Paykel bubble CPAP system using Fisher and Paykel 'Flexi Trunk Midline Interface' (BC 191–70 mm) and appropriately sized Fisher and Paykel 'Infant Bonnet' depending on the head circumference	5 [13, 16]; p = 0.01] in comparison to Bubble group. However, Jet group neonates had significantly more common prong displacements.
Schindler et al [27]	Quasi-Experimental	USA	To determine whether a pressure injury prevention bundle was associated with a significant reduction in pressure ulcer development in infants in the paediatric intensive care unit.	399 infants aged 0 - 3 months admitted to intensive care at a large tertiary care medical centre. [n= 149 control grp, n=250 intervention grp. PI developed 28 participants (18.8%) control grp, 17 participants (6.8%) intervention grp]	A Pressure Ulcer Prevention Program (PUPP) was implemented in this PICU, the components of which included: assuring patients were maintained on the correct support surface in order to decrease tissue interface pressure - Delta-202Warmer Overlay (29″ x 23.75″x 2.25″, frequent turning supported with Gel-filled pillows, incontinence management - zinc-based barrier cream was used with each diaper change and use of non-alkaline cleansing agents, appropriate nutrition - any child who scored a "1" in the Braden	Implementation of the care bundle was associated with a significant drop in pressure ulcer incidence from 18.8 to 6.8%, OR 0.32, 95% CI (0.17 – 0.60)*. In this study, effective nursing care with targeted interventions reduced the incidence of pressure injuries in critically ill infants. Study participants who developed pressure injuries were extremely young, stayed in the PICU for extended periods of time, and had heavy disease burdens with the need for invasive mechanical support. In this study, the PUPP bundle appeared to be associated with improved outcomes.

					Q required dietician input, and education - nursing staff participated in an online educational module about the Braden Q pressure ulcer risk assessment, pressure ulcer identification and grading, as well as education on the components of the PUPP intervention, Skin champions. The infants in the control group were part of a previous study conducted to determine the incidence of pressure ulcer development in the PICU. During this study, the nurses received education about the Braden Q risk assessment scale and pressure ulcer staging, but they did not receive any education about skin care or pressure ulcer prevention in hospitalized children. There was no set standard for bathing, use of barrier creams, or moisturizing of infants. Nurses	

					used their own nursing judgment to address these components of care. Infants were turned or were repositioned every 4 hrs and there were no skin care champions. In the intervention group, in addition to the PUPP bundle, skin care champions were identified and received extra training to help facilitate bundle compliance.	
Visscher et al [29]	Quasi-Experimental	USA	To develop and implement a quality-improvement (QI) intervention to reduce pressure injuries by 50% in PICUs.	Sample size 1425 [before bundle implementation n = 754 (PICU 293, NICU 461), after bundle implementation 671 patients across PICU (391) and NICU (280).PUs associated with medical devices before bundle implementation n=62 (PICU 51, NICU 11), after bundle implementation n = 53 (PICU 35, NICU 18)	Implement a pressure injury prevention bundle with the following components: daily risk assessment, daily skin assessment, examine under each medical device every 12 hours, reposition every 2 hours, float heels, check common moisture areas every 2-4 hours, apply barrier cream to nappy area, use slide sheets to reposition, optimise nutrition with ongoing dietician reviews for all high risk patients, educate all	The pressure injury rate in the PICU was 14.3/1000 patient-days during the QI development and 3.7/1000 patient-days after QI implementation (P<.05), achieving the aim of 50% reduction, OR 0.96, 95% CI (0.65 – 1.40)*. The PICU rates of stages I, II, and III conventional and device-related pressure injuries decreased after the QI intervention. The pressure injury rate in the NICU did not change significantly over time but

					nurses with focused training modules, actively engage family members, implement skin champions and conduct collaborative skin rounds, share results of skin assessments with all staff every 2 weeks.	remained at a mean of 0.9/1000 patient-days.
Widlati et al [23]	RCT with a cross-over design	Indonesia	To determine the effectiveness of injury prevention guidance about children who need to have medical devices attached to their bodies as part of their treatment	50 children admitted to intensive care aged between 1 day and 18 years	The control group received injury prevention treatment following the hospital routines, while the intervention group was given precautionary treatments based on Kiss and Heiler's guidelines. Assessment of skin that had medical devices attached was done by taking photos and was conducted on three consecutive days.	Although, statistically, there were no significant differences between the control and intervention groups, the results of the study did uncover a notable decrease in the incidence rate of pressure injuries on the third day, compared to the first day (in the intervention group). Day 1: OR (95% CI) - 1.5 (0.3; 7.7), Day 2: OR (95% CI) 0.5 (0.04; 6.2), Day 3: OR (95% CI) 0.8 (0.2; 3.9).
Garcia-Molina et al [39]	Prospective Cohort Study	Spain	Are continuous and reactive low pressure special surfaces (CRLPSS) i.e. pressure redistributing mattresses effective at preventing immobility-related pressure	N= 65 [2008 PU incidence 20% (n =7) children with support surface-related n= 35). Current study PU incidence 3.3% (n= 1) children with CRLPSS n= 30.]	To assess the effect of two paediatric-specific, continuous and reactive low-pressure mattresses on the incidence of pressure injuries, an observational, descriptive, prospective, longitudinal (2009–2011) study was conducted	The incidence of pressure injury development not related to the use of a medical device was low (3.3%) 95% CI 0.08% - 17.2%, much lower than the rate of similar ulcers in a previously conducted incidence study (20%) 16.7% difference p = 0.0021 at the same

			injuries for children admitted to intensive care	30 eligible patients were ages 1 day to 10 years old, admitted to the PICU for more than 24 hours for whatever reason, at risk of developing pressure injuries according to the Braden-Q scale (for children >1 month old) or the neonatal skin risk assessment scale (NSRAS) for children <1 month old.	among PICU patients. The two paediatric mattresses — one for children weighing between 500 g and 6 Kg and another for children weighing more than 6 Kg — were provided to patients at risk of pressure injuries. The aim was to see whether these mattresses decreased the number of immobility-related pressure injuries compared with a previous incidence study at the same PICU prior to the mattresses being used.	facility. The mattresses were believed to be particularly beneficial for patients who cannot be repositioned OR 0.14, 95% CI (0.02 – 1.19)*. Additional controlled clinical studies are warranted to help develop evidence-based protocols of pressure injury prevention in high-risk paediatric patients.
Aprea et al [35]	Before and after intervention study	Argentina	To assess the impact of a health care quality improvement intervention on the development of pressure injuries at the paediatric intensive care unit.	A total of 152 patients were included: 74 before the intervention (PUs 51.35% (n= 38) and 78 after the intervention PUs 23.08% (n= 18). Patients' median age was 7 months old.	Uncontrolled, before and after study. Pre-intervention: measurement of pressure injuries; post-intervention: implementation of a bundle of measures (staff training, identification of patients at risk, and pressure relief by using anti-bedsore mattresses and polymer gel positioners) and the same measurements.	A lower incidence of pressure injuries was observed after the implementation of the health care quality improvement intervention (pre-intervention: 50.60%; post-intervention: 23.08%; p= 0.001) OR 0.28, 95% CI (0.14 – 0.57)*. No changes were detected in the number of pressure injuries or the severity staging. The most common pressure injury location was the lower occipital region, followed by

						the lateral malleolar and the upper occipital regions. Very few pressure injuries corresponded to stage III or higher.
Simsic et al [36]	Before and After intervention study	USA	This quality project was aimed to reduce the incidence of pressure injuries > stage II in the paediatric cardiothoracic intensive care unit.	Not specified	Interventions included: implementing a pressure injury bundle (April 2010, revised January 2013). This bundle included barrier cream, pulse oximeter probe rotation, turning schedule, pressure reduction surfaces, heel pressure release, head of the bed elevation, a head-to-toe skin assessment every 12 hours, removal of each respiratory device every 4 hours to monitor for pressure injury or skin breakdown; and skin inspection around each medical device including all lines, tubes, and drains every 12 hours. Multidisciplinary huddles for pressure injuries > stage II was also implemented (October 2011) along with multidisciplinary weekly skin	Between 2010 and 2014, pressure injuries decreased from 15.7 events per 1,000 patient days to a new baseline of 2.9 events per 1,000 patient days. The hospital has sustained this rate for 3 years. Pressure injuries related to immobility decreased from 35 in 2010–2011 to 4 in 2016–2017. Pressure injuries related to medical devices decreased from 34 in 2010–2011 to 15 in 2016–2017. Conclusions: Institution of pressure injury bundle, multidisciplinary weekly skin rounds, and huddles for pressure injuries > stage II reduced injuries related to immobility, allowed for earlier identification of stage II injuries and reduced stage III injuries. Challenges remain in reducing pressure injuries related to medical

					rounds (March 2010, revised August 2012), unit specific workgroup (October 2012), and a caregiver input form (December 2012). A bulletin board with actual photographs of pressure injuries in patients (with parental approval) was updated regularly in the staff-only area as a visual tool to raise staff awareness and engagement.	devices. Importantly, the hospital sustained this improvement over the past 3 years. The non-punitive huddle process and the bulletin board with actual photographs of pressure ulcers in our patients as a visual tool are effective in raising staff awareness and engagement.
Lawrence et al [37]	Before and After intervention study	USA	The purpose of this inter-professional team–driven quality improvement project was to implement a Bubble continuous positive airway pressure (BCPAP) Skincare Protocol proactively to prevent potential device-related pressure injuries.	Not specified	The BCPAP Protocol included: 2-hourly skin checks by 2 members of staff, nurses could escalate to a wound specialist without the need to go through the medical team, BCPAP 'tip of the week' was handed out to retain knowledge, signs on doors of patients involved in data collection, and reconfigured rooms to ensure nurses could always see the bubble apparatus	During the first 3 months post-protocol implementation period, one stage 2 nasal injury was noted and immediately treated and healed without incident. During the next 24-month, post-implementation period, there were zero nasal pressure injuries reported

Cummins et al [38]	Before and after intervention study	USA	The aim of this quality improvement project was to implement evidence-based paediatric pressure injury prevention strategies to decrease the incidence of pressure injuries by reducing the rate from 8% to 6% during a 6-week time period	All patients admitted to the PICU between May 7, 2017, and June 30, 2017, were included in the project. PICU patients older than 18 years were excluded from the project.	To implement the following three evidence-based pressure injury prevention strategies: educating PICU nurses on risk factors for paediatric pressure injuries and prevention strategies, turning PICU patients every 2 hours, and ordering nutrition consultations on all patients with a Braden Q score less than 16. Several multidisciplinary groups were involved in the quality improvement project including the hospital executive team, clinical informatics, nursing education, nutrition support team, quality and safety leaders, and the PICU patient care team.	The quality improvement project improved the quality of care being delivered to patients in the PICU by increasing nurses' knowledge of paediatric pressure injury risk factors and evidence-based prevention strategies, improving turning compliance, and implementing an electronic trigger to enhance nutrition support for patients at risk of developing pressure injuries. The quality improvement project also decreased preventable patient harm to PICU patients by decreasing the pressure injury incidence rate. PICU pressure injury incidence rate reduced from 8% pre-intervention to 3%, which is a 63% decrease from baseline.
Garcia-Molina et al [30]	Quasi-Experimental	Spain	This work was developed to determine the incidence of pressure injuries in hospitalised infants admitted to	A sample of 268 infants was included. 34 infants developed PU	A multi-centre, prospective, observational study, evaluating the incidence of pressure injuries, risk factors, and preventive measures in 6 public neonatal units, was performed.	Cumulative incidence of PUs was 12.70% (95%, CI 95% = [8.95%-17.28%]). Cumulative incidence in the intermediate 1.90% (CI95% = [0.39%-5.45%]), intensive care unit 28.18% (CI95% = [20.02%-

			intensive and intermediate care units, along with relevant risk factors and preventive measures.		The data were collected between January 25, 2013 and December 17, 2013. The skin of each infant was examined every day by clinical nurses. In addition, a member of the research team—blinded to the clinical nurse's diagnosis—evaluated the skin of each infant every 48 hours until discharge or up to 30 days from the day of birth. Predefined risk factors and preventive measures were collected through observations. The medical and nursing records were reviewed 3 times per week by the same researcher. The data consisted of demographic information, including gender, size, and weight at birth, as well as head circumference and gestational age.	37.56%]). PUs by category; stage I, 57.10%; stage II, 31.70%; and stage III, 11.10%. The multivariate analysis found the following to be risk factors: low scores in the Spanish version of the Neonatal Skin Risk Assessment Scale (e-NSRAS) (Relative Risk (RR) 0.80; CI95% = [0.66-0.97]), the use of non-invasive mechanical ventilation (RR 12.24; CI95% = [4.02-37.32]), and the length of stay (RR 1.08; CI95% = [1.02-1.15]) The kangaroo care method was the only measure that yielded a significant protective effect from PU development (RR 0.26; CI95% = [0.09-0.71]). Repositioning every 2 or 3 hours and support surfaces (SS vs standard) as well as changes in the location of the pulse oximeter sensor were non-significant preventive measures. Parenteral nutrition was found to be a

						significant risk factor. Postural changes (every 2 to 3 hours) RR 0.74 95% CI [0.36-1.54 .43] Support surfaces (SS vs standard) RR 2.67 95% CI [0.48-14.88 .26] Pulse oximeter changes (every 2 to3 hours) RR 6.40 95% CI [0.53-76.35 .14]
Schindler et al [28]	Quasi-Experimental	USA	To determine the incidence of pressure injuries in critically ill children, to compare the characteristics of patients in whom pressure injuries do and do not develop, and to identify prevention strategies associated with less frequent development of pressure injuries	Characteristics of 5346 patients in paediatric intensive care units, admitted from March 2006 – December 2007, in whom pressure injuries did and did not develop, were compared.	The nurses in all 9 PICUs completed education on the Braden Q Scale score and pressure ulcer staging before the study began. Although the participating hospitals were currently using the Braden Q Scale, the education was implemented to ensure that the nurses had a review of the risk assessment tool and knew how to use the tool properly. The study was retrospective, so no intervention was assigned based on the Braden Q Scale score. Each day, nurses at each participating PICU documented the specific strategies used to	The aggregate incidence of pressure ulcers was 10.2%. Nursing interventions that were associated with lower risk for PU development: turning the patient every 2 hours OR 0.271 (95% CI, 0.209 - 0.352, p <.001), every 4 hrs OR 0.355 (95% CI, 0.267 - 0.472, p <.001), every 8 hrs OR 0.625)95% CI, 0.423 - 0.926, p .02). Use of blanket rolls OR 0.267 (95% CI, 0.205 - 0.348, P <.001), draw sheets OR 0.575 (95% CI, 0.403 - 0.820, P = .002), pillows for positioning OR 0.430 (95% CI, 0.322 - 0.573, P <.001), sheep skin OR 0.448 (95% CI, 0.325 - 0.618, P <.001), use of body lotion

					prevent pressure ulcers in each patient.	OR 0.655, (95% CI (0.478 - 0.897, P = .008), Breathable waterproof transparent dressing OR 0.713 (95% 0.516 - 0.985, P = .04), Using urinary catheter strap 0.663 (95% CI, 0.496 - 0.885, P = .005), Using endotracheal holder OR 0.592 (95% CI, 0.422 - 0.832, P = .003), disposable underpants, OR 0.345 (95% CI, 0.252 - 0.473, P <.001), Specialty bed OR 0.226 (95% CI, 0.167 - 0.306, P <.001, Nutrition consultation OR 0.206 (95% CI, 0.156 - 0.272, P <.001), Physical or occupational therapy consultation 0.486 (95% CI, 0.354 - 0.668, <.001). The following interventions did not demonstrate statistical significance in reducing PU development; egg-crate and foam-mattress overlays, gel pads. Pressure ulcers were more likely to develop in children younger than 2 years at the time of PICU admission than in older children but patients in whom

						pressure ulcers developed did not differ from those in whom the ulcers did not develop in sex or race/ethnicity. Pressure ulcers were more likely in children who remained in the PICU at least 4 days than in children who remained in the PICU less than 4 days. Therapeutic interventions that increased the risk for pressure ulcers included use of BiPAP, CPAP, conventional mechanical ventilation, HFOV, and ECMO
Xie [24]	RCT	China	This study aimed to compare the incidence of nasal injury secondary to nasal continuous positive airway pressure (nCPAP) protected with or without hydrocolloid dressing in preterm infants.	A total of 65 infants, Control grp n= 32, PUs observed in 9 participants, intervention grp n= 33 PUs observed in 2 participants	Paraffin oil was smeared around the infants' nostrils before inserting the nCPAP prongs in the control group; and the infants' nostrils in the intervention group were covered with hydrocolloid dressing 1.8 mm thick with a size of 2–3 cm cutting two holes adapted to the nose and nostrils. The nostrils of those infants were inspected daily during nCPAP support until they were weaned off nCPAP.	7 infants in the control group and 2 infants in the intervention group developed nasal injury during nCPAP support, OR 0.16, 95% CI (0.03 – 0.84)*.

Uysal et al [31]	Quasi-Experimental	Turkey	The aim of this study was to determine the effectiveness of a pressure injury prevention guide used in a paediatric intensive care unit (PICU) on the occurrence of pressure injuries.	Children aged 0 - 18 years who were able to be accepted to the PICU, who had no pressure injuries at admission, were included in the sample. Patients whose PICU admission was under 48 hrs were excluded. n = 181 for control group, PUs occurred in 17 (9.4%) participants. n= 165 intervention group, PUs occurred in 6 (3.6%) participants.	Prevention guide included: risk assessment, skin examinations (The skin was examined and palpated before each shift change, monitored for temperature, rash, induration, and edema, and evaluated for pressure-induced pain), Position change (Prevented from remaining in the same position for more than 2 hr according to the skin status and comfort level of the child, Protectors were used for heels and elbows, and a position-tracking form was used.) assessment of nutrition (Independent feeding and dietary pattern status, Weight loss Dehydration, Adequate and balanced nutrition)	Pressure injuries occurred on 9.4% of children in the nontreatment group, and in 3.6% of children in the treatment group, OR 0.36, 95% (0.14 – 0.95)*. There was a statistically significant difference in the occurrence of pressure injuries between the nontreatment group and the treatment group. The results show that the risk of pressure injuries was reduced, and pressure injuries occurred later when an evidence-based pressure injury prevention guide was used. Pressure injury prevention guides can be considered effective in preventing pressure injuries or reducing the risk of their occurrence. There remains a need for randomized, controlled, multicentre studies with larger samples because the number of studies on the prevention of pressure injuries in children in PICUs is limited.

Pasek et al [32]	Quasi-Experimental	USA	Will a nurse-driven interdisciplinary pressure injury prevention protocol that is tiered according to the day of ECMO therapy and predicted patient stability reduce the prevalence of immobility- and device-related pressure injuries among patients receiving ECMO in the PICU?	29 patients. Before intervention n=8, number of patients developed PUs n= 3 observed PUs 12. During intervention n = 21, number of patients developed PUs n = 4 PUs observed 11.	The purpose of the protocol was fourfold: (1) to improve proactive prevention measures before or concurrent with the initiation of ECMO; (2) to standardize prevention throughout the course of therapy for this patient population; (3) to improve patient safety by reducing the number of pressure injuries, or eliminating them, in patients receiving ECMO; and (4) to enhance the family's participation in their child's skin care while the child is receiving ECMO. Interventions include: foam dressings between cannulas and skin, 2 nurses head to toe assessment on day one to establish baseline, off loads heels, fluidized positioner under occiput, turning 2 hourly, consider support mattresses, semi-weekly skin care rounds.	The study was able to reduce the number of pressure injuries in patients receiving ECMO by implementing a tiered pressure injury prevention protocol in the PICU. The rate of pressure injuries per 100 days of ECMO therapy decreased from 6.78 to 4.49 during the project. Before implementation, 3 of the 8 patients (36%) receiving ECMO had 1 or more pressure injuries. After implementation, however, such injuries occurred in only 4 of the 21 patients (19%) receiving ECMO—an improvement of 17%, OR 0.39 95% CI (0.06 – 2.37)*. The study found more device-related injuries after implementation (63%) than before implementation (8%); the authors attribute this increase to the use of the new Braden QD Scale, which improved our awareness and

						assessment of medical device–related injuries.
Kiss and Heiler [33]	Quasi-Experimental	USA	To decrease skin breakdown in the PCICU patient population through the standardization of nursing practice. The specific objectives of the study were to create and implement a practice guideline for PCICU nurses and providers, so that they could execute proper interventions for potential skin-breakdown issues in PCICU patients during the acute time period from intubation to extubation, using the best possible practices identified to date.	The study population for the first chart review was obtained through a random selection of 100 patients that were admitted to the PCICU between May 2012 and October 2012; 100 subjects for the post-implementation chart review were randomly selected from patients admitted between January, 2013 and June, 2013.	Create a practice guideline which guided nurses on the interventions to be implemented as preventative measures. An educational podcast was also created and was mandatory for all 41 PCICU nurses to watch prior to the study. Adherence to the guideline was documented in the patient's notes. Interventions included: skin assessment, specific medical device care, pressure relief and repositioning.	The skin-care guideline was useful in decreasing skin breakdown and pressure ulcers in the PCICU during the acute time period. OR 0.387 95% CI [0.16 -0.95] P= 0.03

Boesch et al [34]	Quasi-Experimental	USA	To develop and test potential interventions for tracheostomy-related pressure injury prevention, condense them into a clinical bundle, and then implement the bundle into standard practice and measure its effectiveness.	Patients aged 13 months – 9 years were included in this study. All tracheostomy-dependent patients admitted to the 18-bed ventilator unit from July 2008 through December 2010 were included. N=834.	Once effective interventions were identified by a literature review, they were incorporated into a pressure injury prevention bundle and implemented with the use of quality improvement methodology. These included: pressure ulcer risk and skin assessment, moisture-free device interface, and pressure-free device interface. In addition, full body assessments took place daily with Braden Q risk assessments, tracheostomy assessments took place every 8 hours, and hydrocolloid barrier dressings were placed under the flanges of tracheostomies. Nurses received training about pressure injuries and the intervention bundle online and face-to-face. Consultation with device manufacturers also occurred to redesign the tracheostomies	There was a significant decrease in the rate of patients who developed a pressure injury from 8.1% during the preintervention period, to 2.6% during bundle development, to 0.3% after bundle implementation.

Rezaei et. al [25]	RCT	Iran	To examine the effect of a hydrocolloid nasal dressing on the incidence and severity of nasal injury in preterm infants receiving nasal CPAP (N-CPAP)	Eighty (80) eligible infants were born at 32 weeks of gestation or younger and/or with a birth weight of 1,500 g or less and had received between 4 and 72 hours of CPAP.	Infants were randomly assigned to two groups; the intervention group used a protective dressing, and the control group received routine care.	Main study outcome – incidence and severity of nasal injury in preterm infants undergoing N-CPAP. Infants in the intervention group had a significantly lower incidence and severity of nasal injury compared with the control group: 15 of 40 (37.5%) versus 37 of 40 (92.5%; P < .001). Overall, the injuries identified in this study were mostly mild and moderate, with only three severe injuries in the intervention group and five in the control group.
Abbreviations: PICU – Peadiatric Intensive Care Unit, OR – Odds Ratio, RCT – Randomised Control Trial, ECMO - Extracorporeal membrane oxygenation, CPAP – Continuous Positive Pressure airway pressure, N-CPAP – Nasal Continuous Positive Pressure airway pressure, BCPAP - Bubble continuous positive airway pressure, PRSS - pressure-redistributing support surfaces, NPUAP - National Pressure Injury Advisory Panel, EPUAP- European Pressure Ulcer Advisory Panel, PPPIA - Pan Pacific Pressure Injury Alliance, *OR – Odds ratios calculated from reported raw data.						

Figure 1 PRISMA Flow Diagram

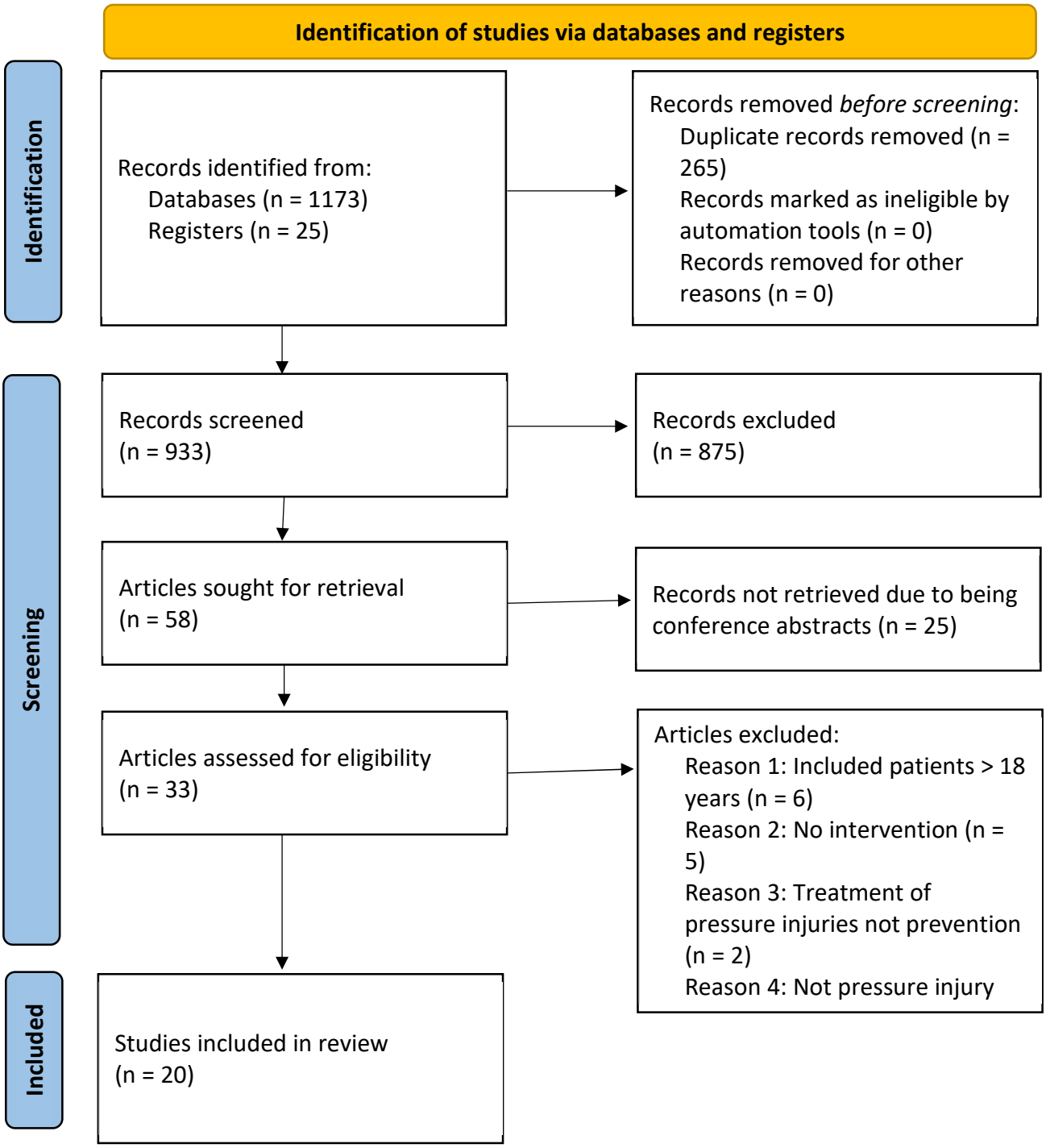

Figure 2

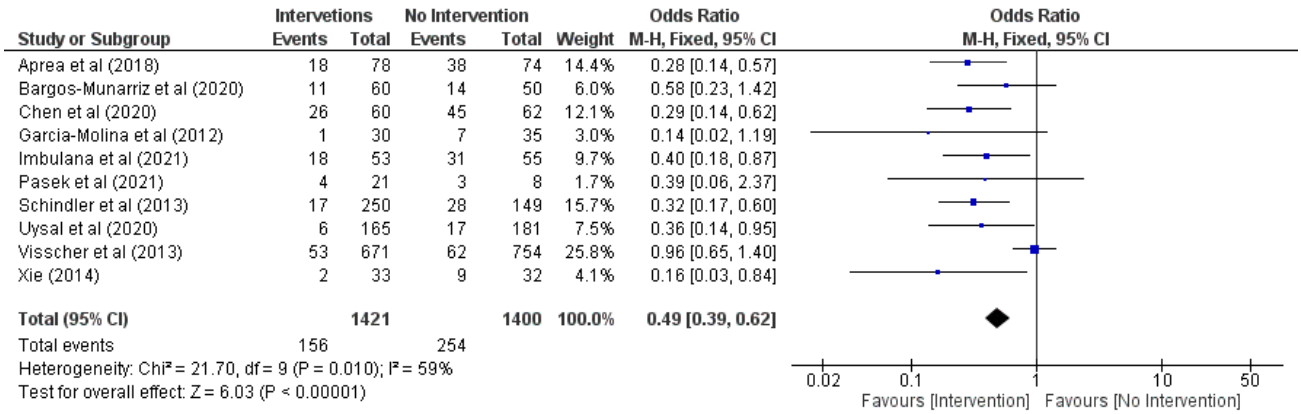

Figure 3