# The incidence and prevalence of medical device-related pressure injuries in intensive care: A systematic review


## ABSTRACT

### Objective

The objective of this review was to synthesize the literature and evaluate the incidence, prevalence and severity of medical device-related pressure injuries in adult intensive care patients.

### Research methodology

Electronic databases and additional grey literature were searched for publications between 2000 and 2017. Outcome measures included cumulative incidence or incidence rate, point prevalence or period prevalence as a primary outcome and the severity and location of the pressure injury as secondary outcome measures. Included studies were assessed for risk of bias using a nine-item checklist for prevalence studies. The heterogeneity was evaluated using $I^2$ statistic.

### Results

Thirteen studies were included in this review. Prevalence was reported more frequently than incidence. Pooled data demonstrated a high variation in the incidence and prevalence rates ranging from 0.9% to 41.2% in incidence and 1.4% to 121% in prevalence. Heterogeneity was high. Mucosal pressure injuries were the most common stage reported in the incidence studies whereas stage 2 followed by stage 1 were most commonly reported in the prevalence studies. In the incidence studies, the most common location was the ear and in the prevalence studies it was the nose.

**Conclusion**

While medical device-related pressure injuries are common in intensive care patients, it is an understudied area. Inconsistency in the staging of medical device-related pressure injuries, along with variations in data collection methods, study design and reporting affect the reported incidence and prevalence rates. Standardisation of data reporting and collection method is essential for pooling of future studies.

Keywords: Critical care; incidence; device-related; pressure injury; prevalence; systematic review.

**Key points**

- MDRPIs are an emergent and evolving area. They are understudied even though they are common in the intensive care setting.
- There is a high variation in the incidence and prevalence rates of MDRPIs reported on studies examining adult patients in intensive care.
- The most common anatomical locations for MDRPIs in intensive care patients were the nose, ear and oral cavity, primarily caused by oxygen tubing, nasogastric tubes and endotracheal tubes.
- There is a lack of standardised data collection methods, study design, sample size, reporting, and staging of MDRPIs.
- To the best of our knowledge this is the first review to synthesize data on the prevalence and incidence of MDRPIs in intensive care settings.

## INTRODUCTION

Pressure injuries (PIs), also referred to as pressure ulcers, are a serious clinical problem and pose a significant burden on the individual and the healthcare system.[1-3] Evidence shows that PIs account for 1.9% of public health expenditure in Australia, totalling $983 million per annum related to treatment costs and prolonged hospital stay.[3] In the United States, PIs cost $2.1 billion per year[4] and in the UK, £2.1 billion per year.[5] Patients who develop a PI in hospital are more likely to have a longer stay than those who do not. [3,6,7]PIs cause pain, physical disability such as immobility, and impact on an individual psychologically.[1,2,8]

Patients in intensive care are at high risk of developing a PI due to immobility, sedation (inability to report pressure or discomfort), and the essential use of medical devices for treatment.[9-11] Medical devices can cause heat, humidity and pressure between the device and the patient's skin, predisposing the patient to develop a medical device-related pressure injury (MDRPI).[12] Although medical devices are a heterogeneous group of varied devices serving varied purposes and located on different parts of the body, the commonality is that all devices are placed over soft tissues and potentially cause pressure or friction related injuries. Patients who have a medical device are 2.4 times more likely to develop a PI than those without a device.[13]

MDRPIs can occur on any anatomical location where the medical device is in contact with the skin. The most frequent locations reported are on the face, neck, ear and extremities.[10,13,14] Commonly reported medical devices that cause PIs include splints, braces[15,16] ETT (endotracheal tubes),[10,15,17] NGT (nasogastric tubes),[15] oxygen tubing,[15] compression stockings[14,18] and CPAP (continuous positive airway pressure).[19] Prevention of MDRPIs includes repositioning, regular skin inspection under the device and correct sizing of

the device. Some pressure redistributing dressings have been shown to reduce MDRPIs,[20-22]however, there is limited evidence to support the use of dressings under medical devices to prevent PIs.

The incidence and prevalence of MDRPIs varies widely depending on the population (adult or paediatric), type of device and the setting. Over the past decade, several studies have reported MDRPI incidence and prevalence. Published prevalence and incidence rates have been largely variable. Reliable estimates of the incidence and prevalence of MDRPIs are important for (i) evaluating the extent of the problem globally and (ii) informing healthcare organisations for policy and guideline development. To date, there has been no formal attempt to systematically review published literature reporting the incidence and prevalence of MDRPIs. Therefore, a systematic review of the literature regarding the incidence, prevalence and severity of MDRPIs in patients in intensive care settings, and the evaluation of the quality of all studies is warranted. The objective of this review was to synthesize the literature and evaluate the incidence, prevalence and severity of MDRPIs in adult intensive care patients. Pooling of such data is necessary to monitor trends in PIs, causes, aetiology and to make recommendations for future research.

**Review question(s)**

1. What is the incidence or prevalence of MDRPIs in patients in adult intensive care units (ICUs)?
2. What is the incidence or prevalence of each stage of MDRPIs in patients in adult ICUs?
3. What are the most common anatomical locations of MDRPIs occurring in patients in adult ICUs?

## METHODS

To reflect best practice and transparency in reporting, this review was developed according to the recommendations described in the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guideline.[23,24] The systematic review protocol was registered in the international prospective register of systematic reviews (PROSPERO)[25] (2017: CRD42017078757).

### Search strategy

An initial search strategy was established in consultation with a university librarian based on identified key words and MeSH terms for MDRPIs (Appendix 1). The words were combined with different Boolean operators, searching title and keywords. To maintain recency, only studies published from 2000 were considered. The lead author (MBJ) searched electronic databases which included Medical Literature Analysis and Retrieval System Online (MEDLINE), Excerpta Medica dataBASE (EMBASE), Cumulative Index of Nursing and Allied Health Literature (CINAHL), Scopus, Web of Science and the Cochrane Library. Additional grey literature, such as dissertations, theses, conference proceedings, publications from national bodies, works indexed in ProQuest, and Google Scholar search results were also examined.

### Selection of studies

Each search was limited to English, Spanish and Chinese studies reporting the incidence, prevalence and severity of MDRPIs in patients in adult ICUs. Spanish and Chinese studies were chosen because translation could be performed by research colleagues. Three reviewers (MBJ, FC, TW) screened study titles and abstracts against the eligibility criteria (Table 1).

**Table 1.** Eligibility criteria

| Characteristics | Criteria |
|---|---|
| Study Design | Observational, cross-sectional, cohort, case-control intervention studies, pre and post design, systematic reviews and meta-analyses (randomised control trials, single and multiple arm and quasi-experimental studies have been excluded because they focus on the effect of an intervention). |
| Population | Includes patients in adult intensive care unit/service. |
| Exposure | The prevalence and incidence of medical device-related pressure injuries in patients in the adult intensive care unit/services. |
| Outcomes | ***Primary***<br>1. Incidence rate of medical device-related pressure injuries in adult intensive care unit/services.<br>2. Point prevalence of medical device-related pressure injuries in adult intensive care unit/services.<br>3. Period prevalence of medical device-related pressure injuries in adult intensive care unit/services.<br><br>***Secondary***<br>1. Severity of the injury (reported stage).<br>2. Anatomical location of the pressure injury.<br>3. Device attributed to the injury. |

Five reviewers (MBJ, FC, TW, MLai, KW) independently assessed full-text studies identified during the screening process for their suitability for inclusion. Discrepancies were resolved by discussion and consensus. Figure 1 shows a PRISMA diagram of the study selection process.

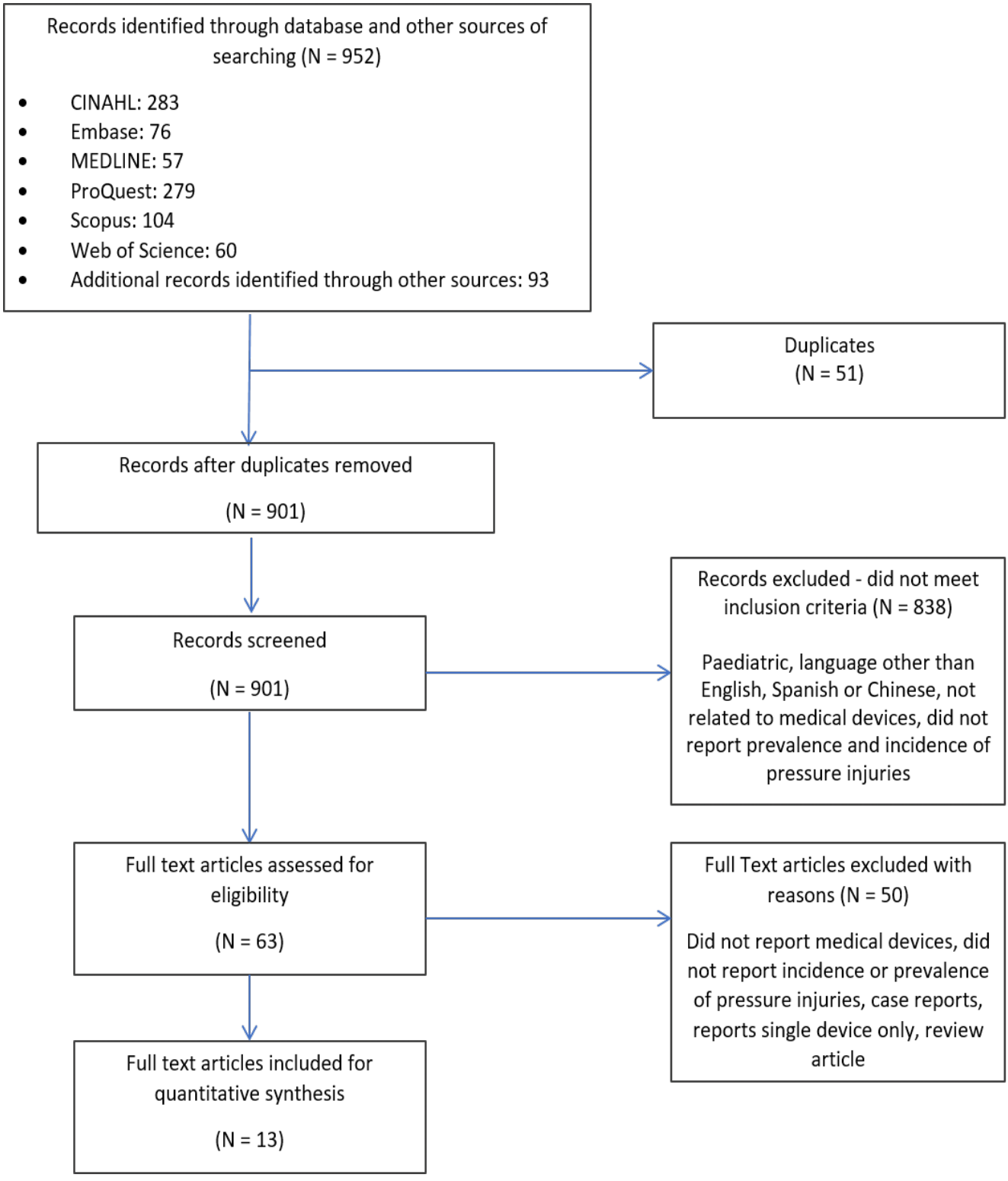


**Figure 1.** PRISMA flow diagram of the study selection process

**Data extraction and risk of bias assessment**

Table 2. Risk of bias assessment tool

| **Risk of bias item** |
|---|
| External Validity |
| 1. Was the study's target population a close representation of the adult intensive care population in relation to relevant variables? (Studies in high dependency units will be excluded). |
| 2. Was the sampling frame a true or close representation of the adult intensive care population? |
| 3. Was some form of random selection used to select the sample, OR, was a census undertaken? (Check if the study included all intensive care patients admitted to the intensive care unit during the specified time frame (period/ point) in their sample). |
| 4. Was the likelihood of non-response bias minimal? (Did the authors describe the reasons for patient withdrawals appropriately?). |
| Internal validity |
| 5. Were data collected directly from the subjects (as opposed to a proxy)? (If pressure injury outcomes are measured from medical charts/ records, this is secondary source of data and therefore high risk). |
| 6. Was an acceptable case definition used in the study? (For example, low risk is use of clinical practice guidelines for pressure injury identification and grading). |
| 7. Was the study instrument that measured the parameter of interest (for example, clinical practice guidelines for skin assessment for pressure injuries) shown to have reliability and validity? Were those involved in data collecting trained or educated in determining and reporting study outcomes? |
| 8. Was the same mode of data collection used for all subjects? |
| 9. Was the length of the shortest prevalence period for the parameter of interest appropriate? |
| 10. Were the numerator(s) and denominator(s) for the calculation on prevalence/incidence of MDRPIs appropriate? |

Adapted from the quality assessment and risk of bias tool for prevalence studies by Hoy et al. (2012).[26]
MDRPIs=Medical device-related pressure injuries

The data extracted were managed in Microsoft Excel. After eligible studies for inclusion were selected, all reviewers independently extracted data using a standardised data collection form. Data extraction variables included citation, year, country, study design, aim/purpose, sample size, sample characteristics, prevalence or incidence, medical devices and pressure injury staging and locations. All authors critically appraised the methodological quality of each study with a tool by Hoy et al. (2012)[26] (Table 2). This risk of bias assessment tool was also used recently in a systematic review of the prevalence and incidence of PIs in adult ICU patients.[27] Each item was assigned a score of 1 = Yes or 0 = No. Scores were then summed across items to produce an overall quality score ranging from 0-10, with risk of bias assessed as: 8-10 (low) 5-7 (moderate) and 0-4 (high). Disagreements about quality assessment were discussed until consensus was reached.

**Data analysis and synthesis**

All data were analysed and synthesized using R version 3.5.0. A meta-analyses on single proportions using Freeman-Tukey double arcsine transformation was conducted to answer each of the three review questions, with the proportions defined according to the context of each question. For research question two, analysis could only be conducted on prevalence as only one incidence study reported staging. The prevalence and incidence rate estimates from studies were pooled and calculated using the mixed effect model to account for (i) heterogeneity and (ii) the small number of studies. A fixed effect model was used when the

heterogeneity was sufficiently low. Further, the incidence and prevalence figures are reported with corresponding standard error and 95% confidence intervals using the exact binomial method as described by Clopper and Pearson.[28] Statistical heterogeneity between studies was assessed using $I^2$ statistic. A value of 25% indicates low heterogeneity, 50% moderate heterogeneity and 75% high heterogeneity.[29] For intervention studies, a measure of intervention effects was calculated for each study using a risk ratio (RR). The incidence ranged from 0.69% to 8.33%.[30]

**RESULTS**

Thirteen studies met the inclusion criteria and were included in this review (Table 3). The risk of bias for the individual studies are shown in Table 4. The studies were conducted from 2007 to 2017. Most of the prevalence studies used a cross-sectional design (N = 5). Incidence studies included, prospective observational (N = 2), before and after design and retrospective data analysis (each N = 2). With regards to quality assessment, nine were classified as having low risk of bias and four were classified as having moderate risk of bias. Moderate risks of bias items were common for item 2 (target population), item 3 (random selection or census undertaken of ICU patients in the specified time frame), item 4 (efforts to reduce potential bias) and item 6 (case definition). Three of the studies[13,17,31] had disparities between reported MDRPI numbers in figures or tables and text and/or disparity between numbers and percentages. The primary authors were contacted for clarification and additional information, however, no authors responded to the request. Several studies[11,31-34]did not report stages of MDRPIs which could not be included in the analysis of the incidence or prevalence of each stage of MDRPI.

**Table 3. Summary of included studies (N = 13)**

| First Author (Year) | Country | Study design | Study Type | Setting | Overall MDRPI incidence % (N) | Overall MDRPI prevalence % (N) | Sample size | Medical device (N) | Bias |
|---|---|---|---|---|---|---|---|---|---|
| Amirah[35] (2017) | Saudi Arabia | Retrospective, cross-sectional | Prevalence | 116 beds, four ICUs | | 29.7% (128) | 431 | ETT (47), Foley catheter (47), NGT (16), neck collar (12), traction (2), other (4) | Moderate |
| Barakat-Johnson (2017)[10] | Australia | Prospective observational | Incidence | 50 bed ICU | 0.9% (34) (per OBD) | | 3730 | ETT (10), $O^2$ tubing (9), anti-embolism stocking (4), NGT (3), CPAP (3), saturation probe (2), nasal prong (2), epistaxis balloon (1) | Low |
| Black (2010)[13] | USA | Retrospective, cross-sectional | Prevalence | Medical-surgical ICU | | 1.9% (39) | 2079 | Not reported | Low |
| Cooper (2015)[36] | USA | Cross-sectional | Prevalence | Cardiac surgery ICU | | 9.0% (12) (2012)<br>1.5% (2) (2013)<br>1.4% (2) (2014) | 134 (2012)<br>135 (2013)<br>141 (2014) | Salem pump (4), tracheal flange (3), ETT (3), urinary catheter (1), CPAP (1), surgical bra (1), nasal cannula (1), FMS (1), SCD (1) | Moderate |
| Coyer (2014)[15] | Australia and USA | Cross-sectional | Prevalence | Australia (36 bed general ICU)<br>USA (77 beds, five ICUs) | | 4.1% (20) | 483 | NGT (8), ETT (7), $O^2$ tubing (2), tracheal tube (2), rectal thermometer probe (1) | Low |

**Table 3. Summary of included studies (N = 13) continued**

| First Author (Year) | Country | Study design | Study Type | Setting | Overall MDRPI incidence (%) | Overall MDRPI prevalence (%) | Sample size | Medical device (N) | Bias |
|---|---|---|---|---|---|---|---|---|---|
| Coyer (2015)[37] | Australia | Before and after | Incidence | 36 bed general ICU | Control 41.2% (42)<br><br>Intervention 14.3% (15) | | 102 (control)<br><br>105 (intervention) | Control - NGT (22), ETT (16) $O^2$ tubing (1) pulse oximetry (1), restraint (1), plastic needle hub (1)<br><br>Intervention - ETT (9), NGT (4), $O^2$ tubing (2) | Low |
| Coyer (2017)[33] | Australia | Secondary data analysis | Prevalence | 18 hospitals (Five level 1 ICUs, eight level II ICUs, and five level III ICUs) | | 7.1% (21)[a] | 296 | Not reported | Low |
| Guimil (2007)[31] | Spain | Prospective cohort | Prevalence | 12 bed ICU | | 9% (46) | 511 | ETT (23), NGT (19), Other (4) | Moderate |
| Hanonu (2016)[17] | Turkey | Prospective review | Prevalence | Five ICUs | | 121% (211) | 175 | ETT (95), CPAP (22), saturation probes (17), $O^2$ mask (15), nasal cannulas (14), NGT (10), ECG leads (7), anti-embolism stockings (5), vascular lines (3), Foley catheter (6), BP cuff (2), ECG electrodes (2), other (13) | Low |

**Table 3. Summary of included studies (N = 13) continued**

| First Author (Year) | Country | Study design | Study Type | Setting | Overall MDRPI incidence (%) | Overall MDRPI prevalence (%) | Sample size | Medical device (N) | Bias |
|---|---|---|---|---|---|---|---|---|---|
| Hobson (2017)[18] | USA | Observational | Prevalence | 49 beds, 3 surgical ICUs | | 3% (54) | 1787 | Compression stockings (40), medical devices that were not compression stockings (14) | Low |
| De Medeiros (2017)[38] | Brazil | Cross-sectional | Prevalence | 37 beds, four ICUs | | 3.4% (1) | 29 | Not reported | Moderate |
| Swafford (2016)[34] | USA | Retrospective data analysis | Incidence | 12 bed, combined medical/surgical ICU | 2% (9) (2011)[a]<br>0.7% (3) (2012)[a]<br>0.4% (2) (2013)[a] | | 461 (2011)<br>434 (2012)<br>563 (2013) | Not reported | Low |
| Tayib (2016)[32] | Saudi Arabia | Prospective, observational | Incidence | Two 24 bed ICUs | 9.5% (8) | | 84 | Not reported | Low |

[a]Prevalence/incidence rate was calculated using the number of patients with MDRPI instead of the number of MDRPI as this data was not reported by the authors.
Abbreviations: BP (blood pressure), CPAP (continuous positive airway pressure), ECG (electrocardiography), ETT (endotracheal tube), FMS (fecal management system), ICU (intensive care unit), NGT (nasogastric tube), $O^2$ (oxygen), OBD (occupied bed days), SCD (sequential compression device).

Table 4. Risk of bias for individual studies (N = 13)

| | External validity | | | | Internal validity | | | | | | Overall bias rating (Low/moderate/high bias) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| First author (Year) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| Amirah (2017)[35] | ✓ | ✓ | ✓ | ✓ | X | X | X | ✓ | ✓ | ✓ | Moderate |
| Barakat-Johnson (2017)[10] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Black (2010)[13] | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Cooper (2015)[36] | ✓ | X | ✓ | X | ✓ | X | ✓ | ✓ | ✓ | ✓ | Moderate |
| Coyer (2014)[15] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Coyer (2015)[37] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Coyer (2017)[33] | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Guimil (2007)[31] | ✓ | X | X | X | ✓ | X | ✓ | ✓ | ✓ | ✓ | Moderate |
| Hanonu (2016)[17] | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| Hobson (2017)[18] | ✓ | ✓ | X | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |
| De Medeiros (2017)[38] | ✓ | ✓ | ✓ | X | ✓ | X | X | ✓ | ✓ | ✓ | Moderate |
| Swafford (2016)[34] | ✓ | ✓ | ✓ | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | Low |
| Tayyib (2016)[32] | ✓ | ✓ | X | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | Low |

✓ = Yes, X = No; Scoring: Low risk = 8 to 10 yes responses, Moderate risk = 6 - 7 yes responses, High risk ≤ 5 yes responses.

Publication bias was determined using Egger's regression test for funnel plot asymmetry. The funnel plot of seven studies on the overall MDRPI prevalence is presented in Figure 2. Egger's test for asymmetry was not significant ($p = 0.8674 > 0.05$), therefore we can conclude the plot is symmetrical (no bias). However, assessment is difficult because the number of studies is not large. In general, funnel plots are thought to be unreliable methods of investigating publication bias, particularly if the number of studies is small (less than 10).[39] Additonally, limitations of some of the studies included incidence and prevalence estimates, missing values on the number of PIs or number of patients with PIs, missing information on the location and staging of the MDRPIs and the responsible medical devices.

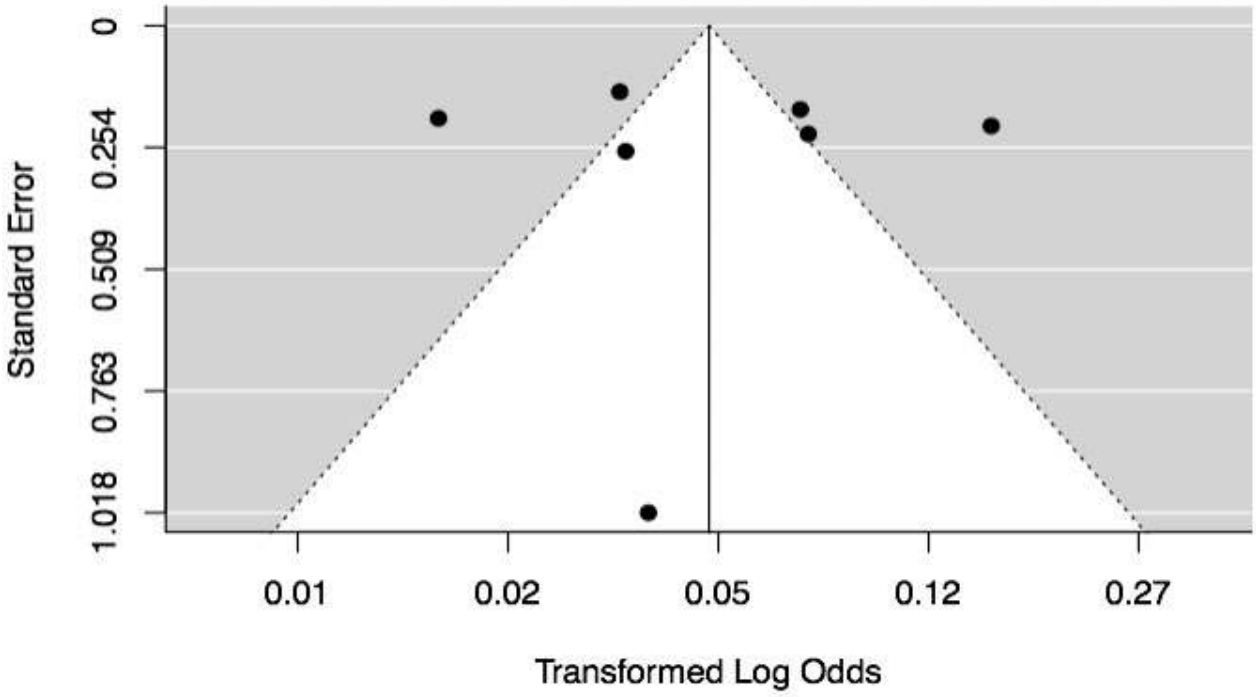


**Figure 2.** Funnel plot of seven prevalence studies

**Incidence**

***Overall incidence of MDRPI***: Four studies reported the incidence rate of MDRPI in ICU patients[10,32,34,37] which ranged from 0.69% to 8.33%. There were two intervention studies[34,37]and two prospective observational studies[10,32] with a sample size ranging from 34 to 563. Heterogeneity among the prospective incidence studies was considerably high ($I^2$ = 94%) and was moderate for the intervention studies ($I^2$ = 67%). The pooled estimate of the incidence of MDRPI over sample size for the prospective studies was 3.85% (95% CI: 0%, 16.71%). The two intervention studies resulted in a relative risk ratio of 0.32 (0.20, 0.53) for ICU patients, suggesting a reduced risk in the intervention group for ICU patients.

***Incidence of MDRPI in number of hospital-acquired pressure injuries (HAPIs)***

Two of the four incidence studies[10,32]reported the incidence rate of MDRPI in the

number of HAPIs. Heterogeneity among these studies was considerably high ($I^2$ = 93%) and the pooled estimate was 3.36% (CI: 0%, 14.41%).

***Staging***

A minimum of two incidence studies was needed from each study design to pool staging. Both Coyer et al[10 37] and Barakat-Johnson et al[9] had reported mucosal PIs to be the most common MDRPI, followed by stage 2 and then stage 1. Staging in the incidence studies could not be pooled as two of the studies[32,34] did not report staging.

***Anatomical location***

The locations of MDRPIs included in the two prospective reviews comprised the nose/nare, oral cavity, ear and legs. The most common location for a MDRPI to occur was the ear, with a pooled incidence of 30.33% (95% CI: 16.53%, 45.92%). The oral cavity (27.55%, 95% CI: 14.40%, 43.13%) was the second most common location for MDRPI to occur, followed by the nose/nare (15.78%, 95% CI: 5.33%, 29.43%) and the leg (10.88%, 95% CI: 2.23%, 23.33%).

In the intervention studies, the locations of MDRPIs and responsible devices could not be pooled due to one study[34] not reporting on these two areas. The devices causing MDRPIs in the study by Coyer et al[37] included ETTs, anti-embolic stockings, NGTs, CPAP masks, saturation probe, nasal prongs, and an epistaxis balloon.

**Prevalence**

***Prevalence of MDRPI***: Seven studies[13,15,18,31,35,36,38]reported the overall prevalence of MDRPIs in ICU patients, which ranged from 1.88 % to 29.70% (Figure 3). Heterogeneity among these studies was substantial ($I^2$ = 98%). The pooled estimate of

the prevalence of MDRPIs in ICU patients was 6.46% (95% CI: 1.97%,13.11%).

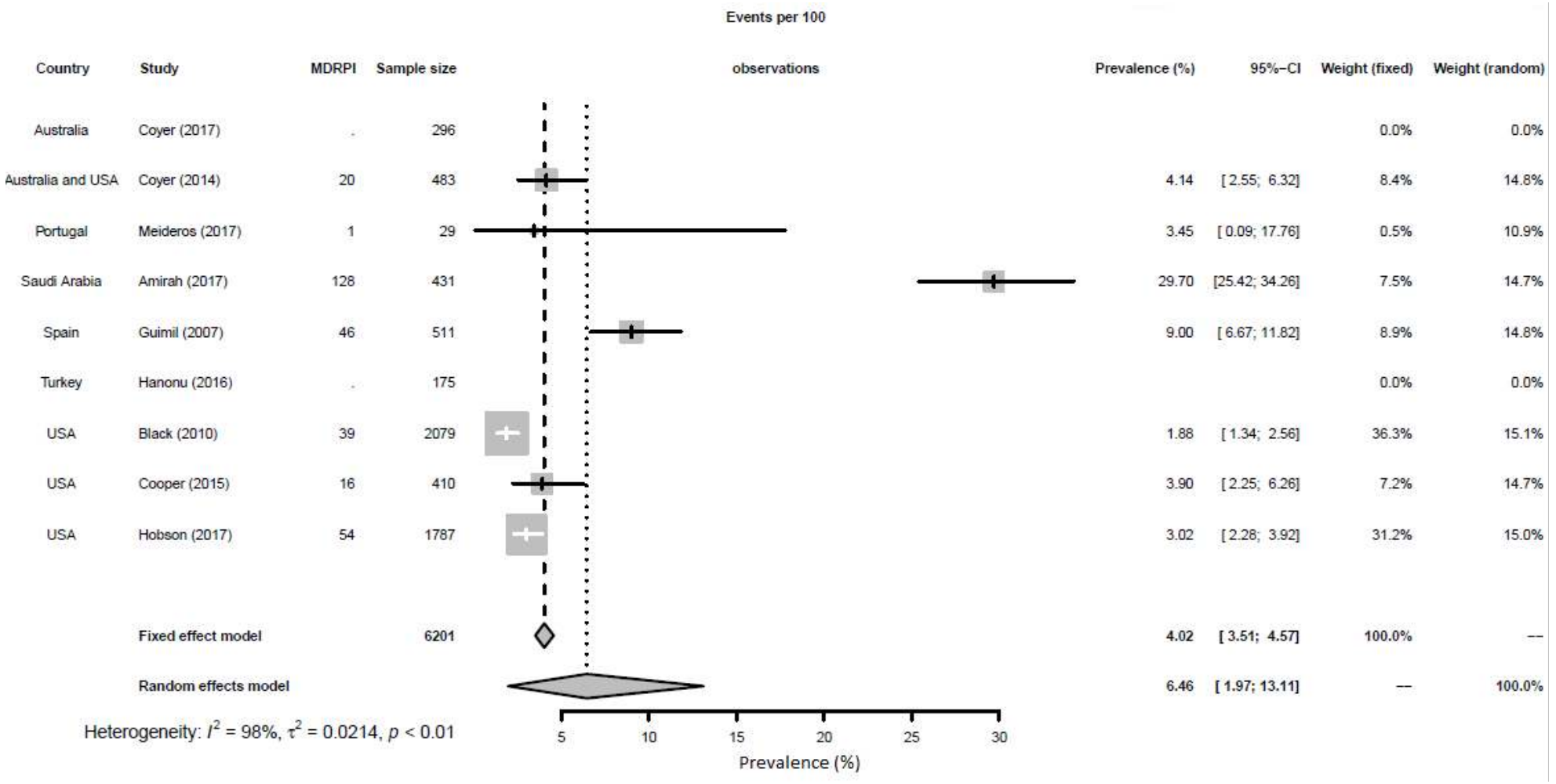


**Figure 3**. Random effects meta-analysis of nine studies providing overall prevalence of MDRPI in intensive care patients.

***Prevalence of patients with MDRPI:*** Seven studies[13,15,17,18,30,33,38] reported the prevalence of patients with MDRPI which ranged from 1.30% to 15.43%. The pooled estimate of the prevalence of patients with MDRPIs in ICU patients was 4.97% (95% CI: 2.27%, 8.58%).

***Prevalence of patients with MDRPI in the number of patients with HAPIs***

Seven studies[13,15,18,31,33,38]reported the prevalence of patients with MDRPI in the number of patients with HAPI, which ranged from 5 to 53.85%. The pooled estimate was 33.73% (95% CI: 22.61%, 45.8%).

***Staging***

Three studies[15,17,18] reported the staging of MDRPI. A meta-analysis could only be performed for stage 1, 2 and deep tissue PIs. Stage 1 MDRPIs ranged from 10% to 45%. There was high heterogeneity among these studies ($I^2$ = 77%). The pooled estimate was found to be 36.39% (95% CI: 30.62%, 42.34%). Stage 2 MDRPIs ranged from 15% to 42%. There was also high heterogeneity among these studies ($I^2$ = 84%). The pooled estimate was found to be 37.43% (95% CI: 31.62%, 43.41%). Only two studies reported deep tissue MDRPIs ranging from 1.9% to 40%. Heterogeneity was found to be substantial ($I^2$ = 97%). The pooled estimate was 15.1% (95% CI: 0%, 65.8%). Two studies reported the prevalence of deep tissue MDRPIs in overall MDRPIs which ranged from 1.9% to 40%.

***Anatomical location***

Four studies[31,33,37,38]included the locations of MDRPIs. The most common location for a MDRPI to occur in prevalence studies was the nose, with a pooled prevalence of 38% (95% CI: 25.75%, 50.99%). The oral cavity was the second most common

location for MDRPIs to occur, with a pooled estimate of 22.86% (95% CI: 12.25%, 34.92%) followed by the ear, with a pooled estimate of 13.04% (95% CI: 4.56%, 23.79%). Finally, two studies reported on the prevalence of MDPRIs on the neck, which ranged from 8% to 10%. There was no heterogeneity found ($I^2$ = 0%). The pooled estimate was found to be 2.5%, (95% CI: 0%, 11.35%).

**Discussion**

This is the first review to systematically report the incidence and prevalence of MDRPIs in patients in adult ICUs. The results of this review highlight a number of disparities with regards to published incidence and prevalence data on MDRPIs, where studies did not report complete data, including total number of MDRPIs, or total number of HAPIs, number of patients with MDPRIs, or number of patients with HAPIs. With these data missing, the pool of studies from which incidence and prevalence rates could be calculated was small.

There was also high variation in the incidence and prevalence rates of MDRPIs, leading to substantial heterogeneity between studies. There was considerable variability in data collection methods, study design, sample size, reporting, and staging of MDRPIs. There was a broad array of study designs employed including secondary data analysis, cross sectional or observational design and various types of prospective studies. Sample sizes also varied from 29 to 2079 patients.

Another explanation for the variability in the data is that MDRPIs are an emergent and evolving area. For example, it is only recently that the National Pressure Ulcer Advisory Panel international staging guidelines have included mucosal injuries as a category of PI.[40] As guidelines change, it is reasonable to assume that how studies

report findings and what they report on will also change.

Based on this systematic review, the most common anatomical locations for MDRPIs in ICU patients were the nose, ear and oral cavity, primarily caused by oxygen tubing, NGTs and ETTs. Many critically ill patients require medical devices that are placed in the mouth, nose or around the ear for monitoring and therapeutic purposes. Damage can occur on insertion of the device, or if it is poorly fixated, [13] if regular offloading or rotating the device does not occur.[9] Damage can be caused by adhesive tapes that irritate skin and cause friction or with ETT ties that are too tight and cause pressure and friction. A few studies reported that a reduction in incidence and prevalence can be achieved by rotating, off-loading the device and regular inspection of the skin.[9, 12]

In relation to staging of MDRPIs, patients presented with differences that did not allow for comparability. Analyses for staging in this review could only be conducted on three prevalence studies,[15,17,18] which can explain some of the high heterogeneity. There was a combination of mucosal and skin injuries identified, with the most common staging being stage 2 followed by stage 1. However, given the low number of studies, it makes it difficult to draw meaningful conclusions. Interestingly, mucosal injuries were reported in the most recent incidence studies.[9, 35 10,37]As the new mucosal category becomes more widely used, we may see an increase in mucosal injuries being reported.

Finally, despite growing interest in the impact of MDRPIs, and the wide ranges of incidence and prevalence reported in this review, MDRPIs are an emergent understudied area that require routine observation and a consistent process for

measurement and data collection. Possible explanations for the varied prevalence and incidence rates of MDPRIs reported in the studies included in this review are that MDRPIs may be under-reported or under-detected to varying extents. MDRPIs are an existing clinical problem, which, until recent years, have been overlooked. The findings of this review have clinical implications. MDRPIs are area of practice which require more attention and prioritization by clinicians at the bedside. This includes regular assessment and frequent repositioning. Further education may be of benefit to clinicians to focus greater attention on MDRPIs, particularly in recognizing and diagnosing MDRPIs. Future work should develop and validate a standardized methodology for measuring and reporting MDRPI incidence and prevalence worldwide. When estimates of incidence and prevalence are reported, they should include the country, overall MDRPI rate, number of patients with MDRPIs, severity and location of MDRPIs and the responsible device. Such efforts would minimize heterogeneity and allow results to be pooled and compared.

**Strengths and Limitations**

Strengths of this review include the importance of MDRPI as an emergent topic, a librarian guided comprehensive search strategy, and this review being the first systematic review to synthesise the literature on the incidence and prevalence of MDRPI in intensive care patients.

Limitations include the high heterogeneity between studies; summary prevalence and incidence measures should be interpreted with caution. There were only two intervention studies and two incidence studies. This restricts any meaningful analysis to be conducted on these four studies. Another limitation is that the risk of bias tool used in this systematic review was applied to both incidence and prevalence studies

when it was designed for the assessment of prevalence studies. However, a recent systematic review by Chaboyer et al.[27] also used this tool to assess the risk of bias of prevalence and incidence studies examining HAPIs in adult ICU patients. Further, there may have been studies published before 2000 or studies that were not published in English, Spanish or Chinese that were not reviewed, which could have provided important information on MDRPIs.

## Conclusion

The incidence and prevalence of MDRPIs is an understudied area that varies widely. Inconsistency in the staging and reporting of MDRPIs, along with other variations in data collection methods, study design, as well as reporting, affect the reported incidence and prevalence rates. Standardisation of best data reporting and collection method is essential for pooling of future studies.

## Reflective questions

1. Describe why the incidence and prevalence rates of MDPRIs in intensive care patients vary.
2. Where are the most common locations for MDPRIs to occur? Which devices are most commonly associated with MDPRIs in these locations?
3. How can future studies be conducted to ensure that data can be pooled?

**References**


1. Gorecki C, Brown JM, Nelson EA et al. Impact of pressure ulcers on quality of life in older patients: A systematic review: Clinical investigations. *J Am Geriatr Soc*. 2009;57(7):1175-83.

2. Gorecki C, Nixon J, Madill A et al. What influences the impact of pressure ulcers on health-related quality of life? A qualitative patient-focused exploration of contributory factors. *J Tissue Viability*. 2012;21(1):3-12.

3. Nguyen KH, Chaboyer W, Whitty JA. Pressure injury in Australian public hospitals: a cost-of-illness study. *Aust Health Rev*. 2015;39(3):329-36.

4. Agency for Healthcare Research and Quality. Preventing Pressure Ulcers in Hospitals. 2014. https://www.ahrq.gov/professionals/systems/hospital/pressureulcertoolkit/putool1.html (accessed 18 July 2018).

5. Bennett G, Dealey C, Posnett J. The cost of pressure ulcer in the UK. *Age Ageing*. 2004;33(3):230-5.

6. Independent Hospital Pricing Association. National Hospital Cost Data Collection, Public Hospitals Cost Report, Round 20 (Financial year 2015-16). 2018. https://www.ihpa.gov.au/sites/g/files/net4186/f/publications/nhcdc_cost_report_round_20_financial_year_2015-16_0.pdf (accessed 18 July 2018).

7. Barakat-Johnson M, Lai M, Wand T, White K, De Abreu Lourenco R. The cost and consequences of an intervention-based programme to reduce hospital-acquired pressure injuries in one health district in Australia. *Aust Health Rev.*2018. In press.

8. Bale S, Dealey C, Defloor T et al. The experience of living with a pressure ulcer. *Nurs Times*. 2007;103(15):42-3.

9. Baharestani M. Medical Device Related Pressure Ulcers: The Hidden Epidemic Across the Lifespan. 2012. http://www.npuap.org/wp-content/uploads/2012/01/pdf.-Baharestani-Medical-Device-Related-Pressure-Ulcers-1The-Hidden-Epidemic-Across-the-Lifespan.pdf (accessed 18 July 2018).

10. Barakat-Johnson M, Barnett C, Wand T, White K. Medical device-related pressure ulcers: An exploratory descriptive study in an acute tertiary hospital in Australia. *J Tissue Viability*. 2017;26(4):246-53.

11. Cooper KL. Evidence-based prevention of pressure ulcers in the intensive care unit. *Crit Care Nurse*. 2013;33(6):57-66.

12. Black J, Kalowes P. Medical device-related pressure ulcers. *Chronic Wound Care Manag Res*. 2016;3:91-9.

13. Black JM, Cuddigan JE, Walko MA et al. Medical device related pressure ulcers in hospitalized patients. *Int Wound J*. 2010;7(5):358-65.

14. Apold J, Rydrych D. Preventing Device-Related Pressure Ulcers: Using Data to Guide Statewide Change. *J Nurs Care Qual*. 2012;27(1):28-34.

15. Coyer FM, Stotts NA, Blackman VS. A prospective window into medical device-related pressure ulcers in intensive care. *Int Wound J*. 2014;11(6):656-64.

16. Arnold-Long M, Ayer M, Borchert K. Medical Device-Related Pressure Injuries in Long-term Acute Care Hospital Setting. *J Wound Ostomy Continence Nurs*. 2017;44(4):325-30.

17. Hanonu S, Karadag A. A Prospective, Descriptive Study to Determine the Rate and Characteristics of and Risk Factors for the Development of Medical Device-related Pressure Ulcers in Intensive Care Units. *Ostomy Wound Manage*. 2016;62(2):12-22.

18. Hobson DB, Chang TY, Aboagye JK et al. Prevalence of Graduated Compression Stocking Associated Pressure Injuries in Surgical Intensive Care Units. *J Crit Care*. 2017;40:1-6.

19. Seyedhejazi M, Hamidi M, Sheikhzadeh D, Aliakbari Sharabiani B. Nasogastric tube placement errors and complications in pediatric intensive care unit: a case report. *J Cardiovasc Thorac Res*. 2011;3(4):133-4.

20. Black J, Alves P, Brindle CT et al. Use of wound dressings to enhance prevention of pressure ulcers caused by medical devices. *Int Wound J*. 2015;12(3):322-7.

21. Boesch RP, Myers C, Garrett T et al. Prevention of tracheostomy-related pressure ulcers in children. *Pediatrics*. 2012;129(3):e792-7.

22. Turjanica MA, Clark L, Martini C et al. Incidence, correlates, and interventions used for pressure ulcers of the ear. *Medsurg Nurs*. 2011;20(5):241-6.

23. Liberati A, Altman DG, Tetzlaff J et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *J Clin Epidemiol*. 2009;62(10):e1-e34.

24. Shamseer L, Moher D, Clarke M et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ*. 2015;350.

25. Booth A, Clarke M, Dooley G et al. The nuts and bolts of PROSPERO: an international prospective register of systematic reviews. *Syst Rev*. 2012;1:2.

26. Hoy D, Brooks P, Woolf A et al. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. *J Clin Epidemiol*. 2012;65(9):934-9.

27. Chaboyer WP, Thalib L, Harbeck EL, et al. Incidence and Prevalence of Pressure Injuries in Adult Intensive Care Patients: A Systematic Review and Meta-Analysis. *Critical care medicine.* 2018;46(11):e1074-e1081.

28. Zieliński W. The Shortest Clopper-Pearson Confidence Interval for Binomial Probability. *Commun Stat Simul Comput*. 2009;39(1):188-93.

29. Higgins Julian P. T, Thompson Simon G. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002;21(11):1539-58.

30. Baharestani MM, Black JM, Carville K et al. Dilemmas in measuring and using pressure ulcer prevalence and incidence: an international consensus. *Int Wound J*. 2009;6(2):97-104.

31. Güimil JAE, Castelo CA, Quiñones AIE et al. Monitorization of pressure ulcers in a critical care unit. *Gerokomos*. 2007;18(3):142-50.

32. Tayyib N, Coyer F, Lewis P. Saudi Arabian adult intensive care unit pressure ulcer incidence and risk factors: a prospective cohort study. *Int Wound J*. 2016;13(5):912-9.

33. Coyer F, Miles S, Gosley S et al. Pressure injury prevalence in intensive care versus non-intensive care patients: A state-wide comparison. *Aust Crit Care*. 2017;30(5):244-50.

34. Swafford K, Culpepper R, Dunn C. Use of a Comprehensive Program to Reduce the Incidence of Hospital-Acquired Pressure Ulcers in an Intensive Care Unit. *Am J Crit Care*. 2016;25(2):152-5.

35. Amirah MF, Rasheed AM, Parameaswari PJ et al. A cross-sectional study on medical device-related pressure injuries among critically ill patients in Riyadh, Kingdom of Saudi Arabia. *WCET J*. 2017;37(1):8-11.

36. Cooper DN, Jones SL, Currie LA. Against All Odds: Preventing Pressure Ulcers in High-Risk Cardiac Surgery Patients. *Crit Care Nurse*. 2015;35(5):76-82.

37. Coyer F, Gardner A, Doubrovsky A et al. Reducing pressure injuries in critically ill patients by using a patient skin integrity care bundle (InSPiRE). *Am J Crit Care*. 2015;24(3):199-209.

38. de Medeiros LNB, da Silva DR, da Silva Guedes CDF et al. Prevalence of pressure ulcers in intensive care units. *JNUOL*. 2017;11(7):2697-703.

39. Sterne JAC, Sutton AJ, Ioannidis JPA et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ*. 2011;343.

40. The National Pressure Ulcer Advisory Panel. National Pressure Ulcer Advisory Panel (NPUAP) announces a change in terminology from pressure ulcer to pressure injury and updates the stages of pressure injury. 2016. http://www.npuap.org/national-pressure-ulcer-advisory-panel-npuap-announces-a-change-in-terminology-from-pressure-ulcer-to-pressure-injury-and-updates-the-stages-of-pressure-injury/ (accessed 18 July 2018).

**Appendix 1: SEARCH STRATEGY STRING**

The incidence and prevalence of medical device-related pressure injuries in intensive care: A systematic review

OR
Bed sore*
Bed-sore*
Decubitus ulcer*
Pressure ulcer*
Pressure injur*
Skin injur*

AND

OR
Ankle Band
Anti-embolism stocking*
Anti-embolic stocking*
Arterial line/cannula/tub*
BiPAP
Bilevel Positive Airway Pressure
Bowel Management System*
Brace*
Bracelet
Calf Compressor*
Catheter
Cervical Collar*
Continuous Renal Replacement Therapy
Compression stocking*
Continuous Positive Airway Pressure
CPAP
CRRT (cannula/line/tub*)
Central Venous /line/cannula/tub*
Device-related
Device*
Extracorporeal membrane oxygenation cannula/line/tub*
ECMO Cannula/line/tub*
Epistaxis Balloon
ET tub*
Endotracheal tub*
Endotracheal tube attachment device
ETAD
EVD (cannula/line/tub*)
External Fixator*
External Fixator Device
External Fixator Frame*
External Fixator Pin*
Ex-fix Pin*
External Ventricular Drain/line/tub*

Face mask*
F$cal Containment Device*
Femoral line/cannula/tub*
Forehead Saturation Probe
High flow nasal prong*
HFNP
ID Band
Nasal prong*
Nasal Cannula*
Nasogastric tub*
NGT
OGT
Oral Gastric Tub*
Orthop$dic external fixation
Oxygen tub*
Patient identification band
Pelvic Ex-fix
PICCO
Pulse Contour Cardiac Output Monitor
Respiratory mask*
Sequential Compression Device*
Saturation probe/tub*
Sengstaken Blakemore tub*
Splint*
Surgical Drain
Tape
TED stocking*
Temperature probe
Vascath*
Vas catheter

AND

OR
Prevalence
Incidence

AND

OR
Intensive care
Intensive care unit
Critical care
Critical care unit
CCU
ICU
Intensive care service*