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Review paper

The effect of prone positioning on pressure injury incidence in adult intensive care unit patients: A meta-review of systematic reviews

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ABSTRACT

Objective: Numerous systematic reviews have examined the impact of prone positioning on outcomes, including pressure injury (PI). The objective of this meta-review was to synthesise the evidence on the effect of prone positioning on the incidence and location of PIs in adult intensive care unit patients.

Review method: This is a meta-review of published systematic reviews. Five databases were searched; data were extracted by three authors and adjudicated by a fourth. The AMSTAR-2 tool was used to quality appraise the selected articles, which was completed by three authors with a fourth adjudicating.

Results: Ten systematic reviews were synthesised. The cumulative incidence of PI in 15,979 adult patients ranged from 25.7% to 48.5%. One study did not report adult numbers. Only one review reported the secondary outcome of PI location. PIs were identified in 13 locations such as the face, chest, iliac crest, and knees. Using the AMSTAR-2, three reviews were assessed as high quality, six as moderate quality, and one as low quality.

Conclusion: The high incidence of PI in the prone position highlights the need for targeted preventative strategies. Care bundles may be one approach, given their beneficial effects for the prevention of PI in other populations. This review highlights the need for proactive approaches to limit unintended consequences of the use of the prone position, especially notable in the current COVID-19 pandemic.

1. Introduction

Intensive care unit patients experience more pressure injuries (PI) than the general hospital population because of the severity of their underlying condition, treatments they receive, and immobility. Although prone positioning is beneficial for respiratory

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function, it often leads to facial PIs as well as PIs on other weight-bearing areas of the body.

2. Background

Pressure injuries (PIs) are localised areas of tissue damage caused by prolonged pressure and shearing forces, ranging in severity from superficial tissue damage that is assessed visually and staged according to severity, as per the European Pressure Ulcer Advisory Panel (EPUAP), National Pressure Injury Advisory Panel (NPIAP), and Pan Pacific Pressure Injury Alliance (PPPIA) International Guidelines.[1] Among the etiologic factors that cause PI development, tissue ischaemia with or without reperfusion damage and cellular deformation caused by mechanical loading is widely accepted. Besides, it is thought that ischaemia and lymphatic dysfunction due to compression play a role in the formation of PI.[2–4] PI prevention is an international patient safety priority because of the persistently high incidence of PIs, their negative impact on patient outcomes, and associated healthcare expenditure. Despite its priority status, PIs continue to occur in hospitalised patients. In a recent meta-analysis of 35 international studies, the prevalence of PIs in hospitalised patients was 12.8%, with the hospital-acquired PI rate being 8.4%.[5] PIs have negative consequences for patients such as increasing pain, compromising quality of life, social isolation, and even death.[6] Furthermore, the management of PIs is expensive, with the annual costs estimated to be US$11 billion in the United States, £750 million in the United Kingdom, and AUD$1.8 billion in Australia.[7,8] In Europe, PIs account for approximately 4% of the annual health budget, with increasing mortality rates, length of hospital stay, and readmission.[9] Thus, timely identification of a PI is imperative for the delivery of cost-effective care.[10]

Intensive care unit (ICU) patients experience more PIs than the general hospital population because of the severity of their underlying condition, treatments they receive, and immobility. For example, based on a meta-analysis of studies from the ICU setting, the 95% confidence interval (CI) of cumulative incidence and prevalence was 6.6–36.8% and 12.2–24.5%, respectively.[11] A recent study also found that the cumulative incidence of device-related PIs varied between 0.9% and 41.2% in the ICU and prevalence rates from 1.4% to 121%.[12] One particular life-saving treatment, the use of prone positioning in severe respiratory failure, may increase ICU patient risk even more. This is concerning given that over the past decade, prone positioning ventilation has been used more frequently among patients with severe acute respiratory distress syndrome (ARDS).[13–15]

The ARDS Prone Position Network (APRONET) analysis of 6723 patients[16] showed up to 23 h of proning was used for almost one-third of patients ventilated because of serious ARDS. Other researchers found that prone positioning was used for a median of 9 h per session and a median of 18 h per day.[17] They found that the cumulative incidence of PIs in the prone position was 14% of 164 patients. Of the 23 PIs that occurred, 19 (83%) were located somewhere on the face. Although clearly advantageous for oxygenation, a high frequency of PIs has been reported in a randomised controlled trial (RCT) of 466 patients with ARDS nursed in the prone position for 16 h.[18] In this study, the incidence of new PIs was significantly more per 1000 ICU days in the prone group (13.92 versus 7.72 per 1000 ICU days, $p = 0.002$).[18]

There are numerous prone positioning studies with a growing body of systematic reviews in this area mainly exploring PI as a secondary outcome. However, a comprehensive synthesis of this body of research is lacking. Therefore, a meta-review of systematic reviews on the effect of prone positioning on the development of PIs was undertaken.

3. Review questions

1. What is the effect of prone positioning on the incidence and prevalence of PIs in adult ICU patients?
2. What are the stages of PIs in adult ICU patients placed in the prone position?
3. What are the locations of PIs in adult ICU patients placed in the prone position?
4. What is the time to develop a PI in adult ICU patients placed in the prone position?

4. Methods

A meta-review of systematic reviews was conducted. Meta-reviews aggregate the reviews of a number of systematic reviews and are used to inform policy and practice decision-making.[19] Similar to systematic reviews, meta-reviews include the selection of the studies and quality appraisal of the reviews, provide results, and give an overview of results for practice and research-related implications.[20] Using the PICO Framework[21] as a guide, this meta-review appraised existing systematic reviews that measured the incidence and prevalence of prone position–induced PIs in adult ICU patients. The components of the PICO were as follows:

- Population: adult ICU patients.
- Intervention: prone position (irrespective of its duration or frequency).
- Comparison: all other positions.
- Outcome: primary, incidence of PI (cumulative and/or rate/density) and prevalence (point and/or period); secondary, PI stage, PI location, and time to PI.

The author team followed the standard approach advocated for systematic reviews and used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[22] to guide the conduct and reporting of the meta-review. The PRISMA refers to present records identified through all databases searched and is presented in Fig. 1. The study protocol was preregistered with the International Prospective Register of Systematic Reviews (PROSPERO; CRD42020191963).

4.1. Search strategy

The following inclusion criteria were used:

- Published systematic reviews, published in English since 2005 with no geographic restriction for study sites to ensure more contemporaneous proning practices were captured.
- PI in included studies could be a primary or secondary outcome.
- Adults (older than 16 years), inpatient in an ICU, with no restrictions on the length of stay, diagnosis, comorbidities, or concurrent treatments. If a review included both adults and paediatrics, only adult data were extracted unless there was no difference between the adult and paediatric data, in which case we used the complete data set.
- ICU of any type such as general, surgical, medical, mixed, cardiac surgery, trauma, burns, neurological conditions.
- Prone positioning irrespective of its duration or frequency.

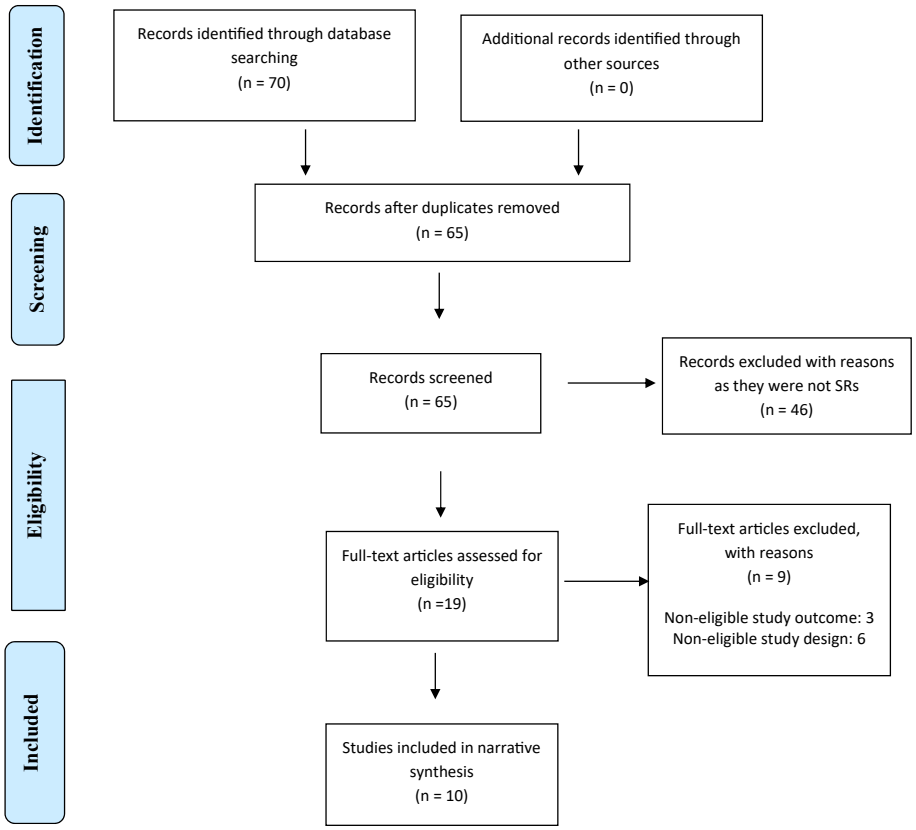

Fig. 1. PRISMA flow diagram for study selection. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; SR, systematic review.

- Study designs within systematic reviews: RCTs, Quasi RCTs, crossover trials, and observational studies.

The exclusion criteria were as follows:

- Published systematic reviews focused on only paediatric ICU patients.
- Coronary care units, step-down or high-dependency units.

The search was conducted on May 13, 2020, with an updated search completed on June 8, 2020, by a health sciences librarian. Two independent searches were completed. Five databases were searched: MEDLINE (Ovid), EMBASE (Ovid), EBM Reviews, and Cochrane Library (Ovid), Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science. To identify further published systematic reviews, the search included the following:

- reference lists of all included reviews;
- grey literature using OpenGrey (www.opengrey.eu);
- conference proceedings, research reports.

The keywords used in the search included the following:

#1 Pressure Ulcer OR Ulcer, Pressure OR Ulcers, Pressure
#2 Bedsore OR Bedsores OR Bed Sores OR Bed Sore OR Sore, Bed OR Sores, Bed
#3 Pressure Sore OR Pressure Sores
#4 Decubitus Ulcer OR Decubitus Ulcers OR Ulcer, Decubitus OR Ulcers, Decubitus
#5 Pressure Injury OR Pressure Injuries
#6 #1 OR #2 OR #3 OR#4 OR #5
#7 Prone
#8 #6 AND #7
#9 Intensive Care Unit
#10 #8 AND #9

4.2. Screening

The article titles and abstracts of existing systematic reviews were assessed independently by four team members. The full-text versions of potentially relevant reviews were then independently screened against the inclusion/exclusion criteria by the same four team members. Consensus was obtained through discussion, with a fifth member adjudicating if disagreements occurred.

4.3. Data extraction

For each review, three authors extracted data independently. Data were extracted according to a purpose-built and piloted data extraction table. The data extracted related to the review type, types of studies reviewed, sample, intervention, control, how PI events were assessed, and the pooled analysis of PI events across studies. A fourth author adjudicated on disagreements or discrepancies.

4.4. Quality assessment

The 16-item AMSTAR-2 tool was used for the quality assessment. It was developed specifically to carry out a reliable and swift quality appraisal of systematic reviews.[23] The 16 questions relate to the review question, methods, search strategy, data extraction, data analysis, and risk of bias. The AMSTAR-2 tool was completed by three authors, with a fourth intervening where disagreements or discrepancies occurred. Although not giving an overall score, the AMSTAR-2 tool allowed the group to determine an overall quality rating for each included review.

Table 1
Characteristics of included reviews.

Author, year	Types of studies in the SR, setting & population	Sample	Intervention (prone position)	Control	Approach to PI assessment
Abroug et al. (2008)[a,38]	Six RCTs comparing positioning in ALI/ARDS. Five studies included only adults	Five RCTs (1322 adult patients) PI as an adverse event in prone patients = 296/719 patients (not clear which studies were included in the PI calculation).	Duration of ventilation in prone position for adults varied from 4 hr to 17 hr per day	Supine	Not reported
Bloomfied et al. (2015)[32]	RCTs that examined the effects of prone position versus supine/ semirecumbent position during conventional mechanical ventilation in adult participants with acute hypoxemia	Ten trials (2185 patients) PI as an adverse event = 3 trials (366 patients) and one additional study of 791 participants and 10,944 event days presented results on PIs as events per day	Mean daily application of prone ventilation for the nine included studies was 16.3 h (range: 7–24 h/d) given over a mean of 6.2 days (range: 1–11.9 days). Mean total hours of prone ventilation for participants in each study ranged from 24 h, with a mean of 100 h across included studies	Supine and semirecumbent	Not reported
Kopterides et al. (2009)[40]	Four multisite RCTs • Adult population (≥16 years) mechanically ventilated with hypoxemic respiratory failure • ICU mortality was the primary outcome • ICU	Four trials (1271 patients) PI as an adverse event = 3 trials (1135 patients)	Time in the prone position in the four studies ranged from 7 to 17 h, and there was wide variation in the number of days that were included	Supine	Not reported
Lee et al. (2014)[41]	RCTs comparing overall mortality of prone versus supine positioning in patients with acute respiratory distress syndrome Excluded were RCTs conducted on paediatric patients and randomised crossover trials that assigned patients to both prone and supine groups	Eleven trials (2246 patients) PI as an adverse event = 6 trials with 1344 patients	Patients received mechanical ventilation in the prone position for a median of 12 h per day (range: 4–24 h), and proning manoeuvres continued either for a prespecified period or until prespecified clinical improvement occurred (median duration of proning was 4 days, range was 1–10 days)	Supine	Not reported
Munshi et al. (2017)[33]	RCTs comparing prone with supine positioning in mechanically ventilated adults with ARDS An updated systematic review to identify the most recent systematic reviews (following systematic review published in 2010) Secondary outcomes included PaO_2/FIO_2 ratio on day 4 and an evaluation of adverse events	Eight trials (2129) patients PI as an adverse event = 3 trials with 1109 patients	Intervention = ventilation in the prone position Time in the prone position in the eight studies ranged from 7 to 24 h	Supine	Not reported
Sud et al. (2014)[34]	RCTs that compared prone and supine positioning during mechanical ventilation in patients with ARDS	Ten trials (2239 adult patients PI = 818/1765. It is not clear which studies were involved in PI meta-analysis. The number of patients in the SR and in the PI analysis was not reported	Duration of adult ventilation in prone position varied from 4 hr daily for 6.0 for to 24 h daily for 4.4 d.	Supine	Not reported
Sud et al. (2010)[35]	RCTs Adult and postneonatal children (no difference when paediatrics excluded therefore both groups in the analysis) Acute hypoxemic respiratory failure and severe hypoxemia	Ten trials (1867 pts) PI as an adverse event = 6 trials (620 events/1279 patients)	Patients in the included trials were ventilated in the prone position for a median of 14 h per day (range: 4–24 h), and prone ventilation was continued either for a prespecified duration or until prespecified clinical improvements (median duration of proning = 4.7 days, range = 4–10 days)	Supine	Not reported

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Table 1 (*continued*)

Author, year	Types of studies in the SR, setting & population	Sample	Intervention (prone position)	Control	Approach to PI assessment
Sud et al. (2008)[36]	RCT and Quasi randomised trials (alternating fashion or hospital registry number) Adult and postneonatal children (no difference when paediatrics excluded therefore both groups in the analysis) Acute hypoxemic respiratory failure No restrictions on types of ICUs (but not neonatal)	Eleven adult trials (1433 adult patients) PI as an adverse event = 5 trials (204 adult proned patients in total).	All patients received mechanical ventilation in the prone position for a median of 12 h per day (range: 4–24 h), and proning manoeuvres continued either for a prespecified period or until prespecified clinical improvement occurred (median duration of proning: 4 days, range: 1–10 days)	Positions except prone	One trial classified PI using standardised criteria (stage II, III, or IV according to the classification of the National Pressure Ulcers Advisory Panel)
Suegnet et al. (2008)[37]	Randomised controlled trials (RCTs) as well as comparative, nonrandomised, and observational studies as evidence. Selected studies included a population of adult or paediatric subjects that were ventilated and turned into the prone position Setting = ICU	Forty-two adult studies 13 RCTs. Overall PI incidence of 25.7%, adults and paediatric groups not separated in this calculation.	Prone position (PP) for all patients Min duration of PP = 6.4 h Max duration of PP = 20.7 h	Supine	Not reported
Tiruvoipati et al. (2008)[39]	Prospective RCTs comparing prone position ventilation with supine ventilation in managing patients with acute severe respiratory failure, requiring intubation, and mechanical ventilation were included Adult patients (aged 18 years) with ALI or ARDS requiring intubation and mechanical ventilation were included	Five trials (1287 patients) PI as a secondary outcome = 4 trials Three studies included PIs in MA = 480 patients	Duration of prone ventilation was different (17 h per day for a period of 10 days in the study by Mancebo et al., 7 h per day for a period of 10 days in the study by Gattinoni et al., and 8 h per day for 4 days in the study by Guerin et al.)	Supine	Not reported

Abbreviations: ALI, acute lung injury; ARDS, acute respiratory distress syndrome; ICU, intensive care unit; ITT, intention-to-treat; MA, meta-analysis; PI, pressure injury; RCT, randomised controlled trial.

[a] One study in this systematic review (Curley et al.) recruited only paediatric patients, and the study by Gattinoni et al. included patients older than 16 years. It is not clear which trials report PI as an adverse event.

4.5. Synthesis

This meta-review enabled an examination of the effect of prone positioning as a risk factor for PI development in adult ICU patients. Initially, it was thought that some groups were more susceptible than others and that this would have allowed for subgroup analysis; however, this was not the case. A network analysis was also planned if different prone regimes were outlined and specified, but this did not arise. Rather, a synthesis of findings was performed. In determining PI incidence, data from each study included in every review were extracted and analysed. After removing duplicate data from studies included in multiple reviews, the range of cumulative incidence in the reviews was determined.

5. Results

Fig. 1 outlines the flow of article screening and selection through the review. Following an initial screening of 70 articles, 51 were excluded as they were not systematic reviews. Subsequently, after an in-depth review of the remaining articles, a further nine were excluded for various reasons including noneligible study outcome,[24–26] and noneligible study design: a questionnaire survey,[27] a clinical guideline,[28] and a literature review.[29–31] This left 10 systematic reviews that met the inclusion criteria.

6. Review characteristics

Ten systematic reviews, published from 2008 to 2017, all of which included meta-analyses,[32–41] were included in this meta-review. Table 1 provides a summary of the review characteristics. Review authors were from several countries, but the most frequently represented country was Canada (N = 4, 40%).[33–36]

All reviews focussed on the ICU setting, and prone position PI incidence was a secondary outcome in all reviews. Nine reviews included only RCTs, and one review included RCTs as well as comparative, nonrandomised, and observational studies as evidence.[37] The mean sample size across nine reviews was 1775 (±440) and ranged from 1278 patients[40] to 2246 patients[41] across the reviews. One review did not report adult number.[37] Five reviews included some overlapping studies.[32,33,36,39,40] Therefore, when data were pooled, the overall mean incidence was calculated by including each trial only once.

The duration of ventilation in the prone position differed in each review. The minimum duration of ventilation in the prone position in a single day was reported by Kopterides et al[40] and varied from 7.0 ± 1.8 h/day for a minimum of 10 days and a maximum of 17 h/day for 10.1 ± 10.3 days. The maximum duration of ventilation in the prone position in 1 day was reported by Sud et al[34] which was a median of 17 h per day (range: 4–24 h) for 4.6 days (range: 4–10

Table 2
Incidence and location of pressure injury.

Author	Sample N across groups	Pooled MA results	Location of PI
Abroug et al. (2008)[38]	Not reported	PI reported with prone positioning: in 296 (41%) of 719 patients in the prone group.	Not reported
Bloomfied et al. (2015)[32]	Prone group: 184 patients Supine group: 182 patients	Three studies reported an event rate of 41.3% for participants ventilated prone and 29.7% for those ventilated supine, with a risk ratio of 1.37 (95% CI: 1.05 to 1.79; p-value = 0.02) Pressure injury (three trials; 366 participants) with a pooled risk ratio of 1.37 [10.5, 1.79, (p = 0.65) I^2 = 0.0%], the analysis supports the supine position **Total incidence of prone PI**=41.3% (76/184) Individual study results (n/N): 1. Gattinoni et al 2001: **55/152** 2. Voggenreiter et al 2005: **19/21** 3. Chan et al 2007: **2/11** A single study (Guerin 2004) reported events per day (and therefore not part of the quantitative meta-analysis), reporting pressure sores on 3.6% of event days in prone groups and 3.0 % in supine groups, with an odds ratio of 1.20 (95% CI: 0.97 to 1.48; value = 0.09). Both analyses favoured the supine position to avoid this adverse event	Not reported
Kopterides et al. (2009)[40]	Prone Group: 662 patients Supine Group: 609 patients	Prone positioning was associated with a higher risk of PI than the supine position (OR, 1.49; 95% CI, 1.17–1.89) **Total incidence of Prone PI** = 48.1% (282/586) Individual study result: Prone PI ratio (n/N) Gattinoni et al.(2001): **55/152** Guerin et al. (2004): **208/413** Voggenreiter (2005) et al.: **19/21**	Not reported
Lee et al. (2014)[41]	Not reported	This is meta-analysis of six studies' results. Prone positioning was significantly associated with PIs (odds ratio, 1.49; 95% CI, 1.18–1.89; p = 0.001; p = 0.0%). PI was not separately reported for each study In general: PI as an adverse event/prone **Total incidence of prone PI**=: 42.1% (294/698)	Not reported
Munshi et al. (2017)[33]	Prone group: 572 patients Supine group: 541 patients	This is a meta-analysis of three studies' results. PIs (RR, 1.22; 95% CI, 1.06–1.41; I2, 0%; three studies **Total incidence of prone PI**=: 43% (246/572) Individual study result: prone PI ratio (n/N) Gattinoni et al. (2001): **36/148** Guerin et al. (2004): **208/413** Chan et al. (2007): **2/11**	Not reported
Sud et al. (2014)[34]	Not reported	PI reported with prone positioning: 46% (818/1765)	Multiple diverse sites
Sud et al. (2008)[36]	Not reported	PI was reported as an effect of secondary outcomes: **Total incidence of prone PI**=: 38.7% (79/204) Individual study result: prone PI ratio (n/N) Leal et al. (1997): **1/8** Gattinoni et al. (2001): **55/152**	Not reported.

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Table 2 (*continued*)

Author	Sample N across groups	Pooled MA results	Location of PI
		Beuret et al. (2002): **2/12** Voggenreiter et al. (2005): **19/21** Chan et al. (2007): **2/11**	
Sud et al. (2010)[35]	Not reported	Cumulative incidence 48.5% (620 PI/1279 pts) Pooled risk ratio 1.29 (95% CI: 1.16–1.44, $p < 0.00001$, I^2 0%)	Not reported
Suegnet et al. (2008)[37]	Prone group: 204 patients Supine group: 199 patients	PI as a complication that occurred in the prone position was reported as 25.7% (It is not able to be differentiated adult and pediatric population PI rates.).	Not reported.
Tiruvoipati et al. (2008)[39]	Prone group: 698 patients Supine group: 609 patients	This is a meta-analysis of four studies' results. Pooled analysis show a trend towards increased incidence of pressure sores (OR = 1.95; 95% CI, 0.09–4.15; P = 0.08) **Total incidence of prone PI = :** 42.8% (299/698) Four RCTs reported PI outcome but data from one study not suitable for MA Prone PI ratio (n/N) Gattinoni et al. (2001): **70/188** Mancebo et al. (2006): **2/76** Voggenreiter et al. (2005): **19/21** Guerin et al. (2004): **208/413**	Not reported

Abbreviations: CI, confidence interval; MA, meta-analysis; OR, odds ratio; PI, pressure injury; RCT, randomised controlled trial; RR, risk ratio.

days) and continued until prespecified criteria for clinical improvement were met (9 trials), or after a prespecified duration (2 trials) (see Table 1).

7. Synthesis of findings

The primary outcome of this meta-review was PI incidence and/or prevalence in ICU patients treated in the prone position. Prone position PI incidence was reported as a secondary outcome in all reviews and prevalence in no reviews. From participants enrolled (N = 15,979), the cumulative incidence of prone position ranged from 25.7%[37] to 48.5%[35] (see Table 2).

PI stage, PI location, and time to PI were the secondary outcomes of this review. Only one review reported PI location as the secondary outcome,[37] which were reported in a wide variety of locations (see Table 2). No other secondary outcomes were reported on.

8. Quality appraisal

Table 3 shows the results of the methodological quality appraisal. Three reviews[32,34,41] were assessed as high quality, whilst most of the reviews (N = 6)[33,35,36,38–40] were assessed as moderate quality, and one[37] was assessed as a low-quality review. Of the 16 AMSTAR-2 items, nine were met by eight or more studies. The criteria most often addressed were including the research question in PICO format (Q1 = 100%) and completing subgroups and sensitivity analysis (Q11 = 100%). Risk of bias and how it affected results were addressed in eight reviews, as were the completion of data selection and extraction in duplication, and the provision of an explanation for heterogeneity. Eight of the 10 reviews detailed why they included the studies they did. The criteria least often addressed were items 2 and 10. The review methods were established before the review in two studies, and the source of funding was reported in one study.

9. Discussion

A meta-review of 10 published systematic reviews that measured the incidence and prevalence of prone position–induced PIs in adult ICU patients was conducted. Our synthesised findings showed the cumulative incidence of PI ranged from 25% to almost 50% of ICU patients, higher than the range of 3.0%–34.4% in the primary studies included in another recent ICU review.[11]

Only one review reported PI location as the secondary outcome.[37] Although only one review addressed this, it is clear that PIs occur where there is a pressure point and vulnerable tissue. Although prone positioning is beneficial for respiratory function, it often leads to facial PIs as well as PIs on other weight-bearing areas of the body.[18,34,42] Many studies report PI as an adverse event in patients undergoing prone positioning.[18,43] A recent clinical case report on facial PIs in patients treated in the prone position during the COVID-19 pandemic has found that a high patient ICU throughput and care delivered by non-ICU nurses played a role in facial PIs.[44] All of this makes this meta-review important, particularly in the current climate, considering the prominent role ventilation and proning play in the treatment of ICU patients with COVID-19.

The number of times each day and the time span for each prone position varied in the reviews, yet a significant proportion of patients developed a PI, irrespective of the proning duration. The prone position clearly places patients at risk of being exposed to prolonged pressure on various parts of the body, enhancing the potential for the development of ischaemic lesions.[17] Therefore, there is a clear need for ICU clinicians to implement PI preventative measures. Focusing on skin assessment and care, regular relieving or redistributing pressure of at-risk areas and prophylactic dressings may be beneficial; however, robust evidence of their effect is mostly lacking.[44] However, in accordance with this same clinical review, skin assessment should happen before proning and before repositioning to the supine position.[44] Additionally, keeping the

Table 3
Quality assessment of the included reviews using the AMSTAR-2 tool (n = 10).

ID	Authors, year	AMSTAR-2 Items																Rating
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	
1	Abroug (2008)[38]	Y	**N**	Y	**PY**	Y	Y	**PY**	Y	**Y**	N	Y	Y	**Y**	Y	Y	N	Moderate quality
2	Sud (2008)[36]	Y	**N**	Y	**Y**	Y	Y	**Y**	Y	**Y**	N	Y	Y	**Y**	Y	Y	Y	Moderate quality
3	Suegnet et al. (2008)[37]	Y	**PY**	N	**PY**	N	N	**N**	N	**PY**	N	Y	N	**N**	N	N	N	Low quality
4	Tiruvoipati (2008)[39]	Y	**PY**	N	**PY**	Y	Y	**PY**	PY	**Y**	N	Y	N	**Y**	Y	N	Y	Moderate quality
5	Kopterides (2009)[40]	Y	**N**	Y	**PY**	Y	Y	**Y**	Y	**Y**	N	Y	Y	**Y**	Y	N	N	Moderate quality
6	Sud (2010)[35]	Y	**N**	Y	**Y**	Y	Y	**y**	Y	**Y**	N	Y	N	**Y**	Y	Y	Y	Moderate quality
7	Lee (2014)[41]	Y	**Y**	Y	**PY**	Y	Y	**PY**	Y	**Y**	Y	Y	Y	**Y**	Y	Y	N	High quality
8	Sud (2014)[34]	Y	**PY**	Y	**Y**	Y	Y	**Y**	Y	**Y**	N	Y	Y	**Y**	Y	Y	Y	High quality
9	Bloomfield (2015)[32]	Y	**Y**	Y	**Y**	Y	Y	**Y**	Y	**Y**	N	Y	Y	**Y**	Y	Y	Y	High quality
10	Munshi (2017)[33]	Y	**N**	Y	**Y**	Y	Y	**Y**	Y	**Y**	N	Y	Y	**Y**	Y	Y	Y	Moderate quality
	Percentage of reviews completely meeting each criterion	**100**	**20**	**80**	**50**	**90**	**90**	**60**	**80**	**90**	**10**	**100**	**70**	**90**	**90**	**70**	**60**	

Note: N, no; PY, partial yes; Y, yes.
Bold items are AMSTAR-2 critical domains.

patient's skin clean, dry, and moisturised, with a pH balanced moisturiser and cleanser, is currently one of the main recommended preventative strategies.[45–47] It is important to recognise that this evidence is related to the supine position, highlighting the critical need for similar research in prone position patients. Some suggest positioning devices can relieve pressure points on the face and body and could therefore be part of any PI prevention strategy.[48–50] Furthermore, although there is no strong evidence available at this time, regular use of protective coatings such as hydrocolloids, clear film, and silicone appears to have some benefits in reducing facial skin degradation An area for clinical development is the use of dedicated care bundles, given their beneficial effects for the prevention of PIs in other populations. As with other individual preventative strategies, high-quality evidence on their effectiveness in the ICU setting is lacking. However, until more research is undertaken, clinicians are faced with the challenge of providing quality care, which may require a reliance on theoretically sound, biologically plausible but not evidence-based prevention practices.

In terms of the AMSTAR-2, the quality assessment varied across the systematic reviews.

Most of the systematic reviews (n = 6, 60%) were of moderate quality, and one review was of low quality. It is interesting to see that most of these systematic reviews were published in earlier years, meaning that a possible explanation for these results is that reviews were published before the AMSTAR-2 quality assessment tool was conceived. Therefore, researchers did not have this quality guide available to them when writing their review. Another possible explanation is that systematic review methodology has advanced greatly in the past two decades, so it is not surprising that some of the older reviews did not score as highly as well as more recent ones. What is clear is that researchers need to consider all quality assessment criteria when they are conducting a systematic review.

10. Recommendations

Given the high incidence of PI in the prone position, there is a clear need to undertake high-quality effectiveness trials to test various interventions such as the use of prophylactic dressings on pressure points, head positioners, and micropositioning changes. Because a multitude of factors contribute to PIs, it will also be important to ensure data are collected on various risk factors and cointerventions used for each patient in the trial. Future trials should seek to adequately describe the proning regime each patient receives and consider adjusting for differences in analysis if indicated.

11. Limitations

A number of important limitations need to be considered when reading this meta-review. The quality appraisal of the studies demonstrated that most of the systematic reviews were of moderate quality and one review was of low quality. This meta-review is limited to adult patients only, so findings cannot be generalised to a paediatric population. Furthermore, a lack of data on the specific cumulative incidence in the primary studies reported in the systematic reviews meant a meta-analysis could not be completed.

12. Conclusion

This meta-review found from about 25% to almost 50% of adult ICU patients placed in the prone position developed a PI, irrespective of the duration of proning. Because of this high incidence, it is important that clinicians regularly assess patients' skin and PI risk and proactively implement PI prevention strategies. But because there is limited evidence on the effectiveness of various preventative strategies in the ICU population, high-quality trials are needed in this area.

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CRediT authorship contribution statement

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References

[1] European Pressure Ulcer Advisory Panel, National Pressure Injury Advisory Panel And Pan Pacific Pressure Injury Alliance. Prevention and Treatment of pressure ulcers/injuries: clinical practice guideline. The International Guideline; 2019.
[2] Clark M, Black J, Alves P, et al. Systematic review of the use of prophylactic dressings in the prevention of pressure ulcers. Int Wound J 2014;11:460–71. https://doi.org/10.1111/iwj.12212. 2014/01/30.
[3] Schwartz D, Gefen A. The biomechanical protective effects of a treatment dressing on the soft tissues surrounding a non-offloaded sacral pressure ulcer. Int Wound J 2019;16. https://doi.org/10.1111/iwj.13082.
[4] Levy A, Gefen A. Computer modeling studies to assess whether a prophylactic dressing reduces the risk for deep tissue injury in the heels of supine patients with diabetes. Ostomy/Wound Manag 2016;62:42–52 [Article].

[5] Li Z, Lin F, Thalib L, et al. Global prevalence and incidence of pressure injuries in hospitalised adult patients: a systematic review and meta-analysis. Int J Nurs Stud 2020;105:103546. https://doi.org/10.1016/j.ijnurstu.2020.103546.

[6] Gorecki C, Brown JM, Nelson EA, et al. Impact of pressure ulcers on quality of life in older patients: a systematic review. J Am Geriatr Soc 2009;57:1175–83. https://doi.org/10.1111/j.1532-5415.2009.02307.x.

[7] Nguyen KH, Chaboyer W, Whitty JA. Pressure injury in Australian public hospitals: a cost-of-illness study. Aust Health Rev 2015;39:329–36. https://doi.org/10.1071/ah14088. a publication of the Australian Hospital Association 2015/03/03.

[8] Padula WV, Delarmente BA. The national cost of hospital-acquired pressure injuries in the United States. Int Wound J 2019;16:634–40. https://doi.org/10.1111/iwj.13071. 2019/01/30.

[9] (EPUAP) EPUAP and (EWMA) EWMA. The time to invest in patient safety and pressure ulcer prevention is now!. 2017. https://www.epuap.org/wp-content/uploads/2017/09/article-n.2-2017_final-draft-for-publication_final-1.pdf [Accessed 26 December 2020].

[10] Demarre L, Van Lancker A, Van Hecke A, et al. The cost of prevention and treatment of pressure ulcers: a systematic review. Int J Nurs Stud 2015;52:1754–74. https://doi.org/10.1016/j.ijnurstu.2015.06.006. 2015/08/02.

[11] 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. Crit Care Med 2018;46:e1074–81. https://doi.org/10.1097/ccm.0000000000003366. 2018/08/11.

[12] Barakat-Johnson M, Lai M, Wand T, et al. The incidence and prevalence of medical device-related pressure ulcers in intensive care: a systematic review. J Wound Care 2019;28:512–21. https://doi.org/10.12968/jowc.2019.28.8.512. 2019/08/09.

[13] Nakos G, Tsangaris I, Kostanti E, et al. Effect of the prone position on patients with hydrostatic pulmonary edema compared with patients with acute respiratory distress syndrome and pulmonary fibrosis. Am J Respir Crit Care Med 2000;161:360–8. https://doi.org/10.1164/ajrccm.161.2.9810037. 2000/02/15.

[14] Romero C, Cornejo R, Galvez Arevalo L, et al. Extended prone position ventilation in severe acute respiratory distress syndrome: a pilot feasibility study. J Crit Care 2009;24:81–8. https://doi.org/10.1016/j.jcrc.2008.02.005.

[15] Gattinoni L, Busana M, Giosa L, et al. Prone positioning in acute respiratory distress syndrome. Semin Respir Crit Care Med 2019;40:94–100. https://doi.org/10.1055/s-0039-1685180. 2019/05/07.

[16] Guerin C, Beuret P, Constantin JM, et al. A prospective international observational prevalence study on prone positioning of ARDS patients: the APRONET (ARDS Prone Position Network) study. Intensive Care Med 2018;44:22–37. https://doi.org/10.1007/s00134-017-4996-5. 2017/12/09.

[17] Lucchini A, Bambi S, Mattiussi E, et al. Prone position in acute respiratory distress syndrome patients: a retrospective analysis of complications. Dimens Crit Care Nurs: DCCN 2020;39:39–46. https://doi.org/10.1097/dcc.0000000000000393. 2019/12/04.

[18] Girard R, Baboi L, Ayzac L, et al. The impact of patient positioning on pressure ulcers in patients with severe ARDS: results from a multicentre randomised controlled trial on prone positioning. Intensive Care Med 2014;40:397–403. https://doi.org/10.1007/s00134-013-3188-1. 2013/12/20.

[19] Aromataris E, Fernandez R, Godfrey C, et al. Summarizing systematic reviews: methodological development, conduct and reporting of an umbrella review approach. Int J Evid Base Healthc 2015;13:132–40. https://doi.org/10.1097/XEB.0000000000000055.

[20] Smith V, Devane D, Begley CM, et al. Methodology in conducting a systematic review of systematic reviews of healthcare interventions. BMC Med Res Methodol 2011;11:15. https://doi.org/10.1186/1471-2288-11-15.

[21] Schardt C, Adams MB, Owens T, et al. Utilization of the PICO framework to improve searching PubMed for clinical questions. BMC Med Inform Decis Mak 2007;7. https://doi.org/10.1186/1472-6947-7-16. 16-16.

[22] Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ (Clinical research ed) 2009;339:b2535. https://doi.org/10.1136/bmj.b2535. 2009/07/23.

[23] Shea B, Reeves B, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ (Clinical research ed) 2017;358:j4008. https://doi.org/10.1136/bmj.j4008.

[24] Hewitt N, Bucknall T, Faraone NM. Lateral positioning for critically ill adult patients. Cochrane Database Syst Rev 2016;2016. https://doi.org/10.1002/14651858.CD007205.pub2. CD007205-CD007205.

[25] Fan E, Brodie D, Slutsky AS. Acute respiratory distress syndrome: advances in diagnosis and treatment. Jama 2018;319:698–710. https://doi.org/10.1001/jama.2017.21907. 2018/02/22.

[26] Parissopoulos S, Mpouzika MD, Timmins F. Optimal support techniques when providing mechanical ventilation to patients with acute respiratory distress syndrome. Nurs Crit Care 2017;22:40–51. https://doi.org/10.1111/nicc.12205. 2015/10/24.

[27] Chambers O, Whitmore D, Bamford P, Shirley P. Proning in UK critical care departments: a questionnaire survey on current practices. J Intensive Care Society 2019;20:96–7. https://doi.org/10.1177/1751143719835452.

[28] Del Sorbo L, Goligher EC, McAuley DF, et al. Mechanical ventilation in adults with acute respiratory distress syndrome. Summary of the experimental evidence for the clinical practice guideline. Anna Am Thoracic Society 2017;14:S261–70. https://doi.org/10.1513/AnnalsATS.201704-345OT. 2017/10/07.

[29] Halbertsma FJ, van der Hoeven JG. Lung recruitment during mechanical positive pressure ventilation in the PICU: what can be learned from the literature? Anaesthesia 2005;60:779–90. https://doi.org/10.1111/j.1365-2044.2005.04187.x. 2005/07/21.

[30] Turner DA, Arnold JH. Insights in pediatric ventilation: timing of intubation, ventilatory strategies, and weaning. Curr Opin Crit Care 2007;13:57–63. https://doi.org/10.1097/MCC.0b013e32801297f9. 2007/01/02.

[31] Yilmaz M, Gajic O. Optimal ventilator settings in acute lung injury and acute respiratory distress syndrome. Eur J Anaesthesiol 2008;25:89–96. https://doi.org/10.1017/s0265021507003006. 2007/11/17.

[32] Bloomfield R, Noble DW, Sudlow A. Prone position for acute respiratory failure in adults. Cochrane Database Syst Rev 2015;2015. https://doi.org/10.1002/14651858.CD008095.pub2. Cd008095. 2015/11/13.

[33] Munshi L, Del Sorbo L, Adhikari NKJ, et al. Prone position for acute respiratory distress syndrome. A systematic review and meta-analysis. Annals of the American Thoracic Society 2017;14:S280–8. https://doi.org/10.1513/AnnalsATS.201704-343OT. 2017/10/27.

[34] Sud S, Friedrich JO, Adhikari NK, et al. Effect of prone positioning during mechanical ventilation on mortality among patients with acute respiratory distress syndrome: a systematic review and meta-analysis. CMAJ 2014;186:E381–90. https://doi.org/10.1503/cmaj.140081. Canadian Medical Association journal = journal de l'Association medicale canadienne 2014/05/28.

[35] Sud S, Friedrich JO, Taccone P, et al. Prone ventilation reduces mortality in patients with acute respiratory failure and severe hypoxemia: systematic review and meta-analysis. Intensive Care Med 2010;36:585–99. https://doi.org/10.1007/s00134-009-1748-1. 2010/02/05.

[36] Sud S, Sud M, Friedrich JO, et al. Effect of mechanical ventilation in the prone position on clinical outcomes in patients with acute hypoxemic respiratory failure: a systematic review and meta-analysis. CMAJ 2008;178:1153–61. https://doi.org/10.1503/cmaj.071802. Canadian Medical Association journal = journal de l'Association medicale canadienne 2008/04/23.

[37] Suegnet N, Elsabe N, Nolte A. Evidence-based nursing interventions and guidelines for prone positioning of adult, ventilated patients: a systematic review. Health SA Gesondheid 2008;13. https://doi.org/10.4102/hsag.v13i2.280. Journal of Interdisciplinary Health Sciences.

[38] Abroug F, Ouanes-Besbes L, Elatrous S, et al. The effect of prone positioning in acute respiratory distress syndrome or acute lung injury: a meta-analysis. Areas of uncertainty and recommendations for research. Intensive Care Med 2008;34:1002–11. https://doi.org/10.1007/s00134-008-1062-3.

[39] Tiruvoipati R, Bangash M, Manktelow B, et al. Efficacy of prone ventilation in adult patients with acute respiratory failure: a meta-analysis. J Crit Care 2008;23:101–10. https://doi.org/10.1016/j.jcrc.2007.09.003. 2008/03/25.

[40] Kopterides P, Siempos II, Armaganidis A. Prone positioning in hypoxemic respiratory failure: meta-analysis of randomized controlled trials. J Crit Care 2009;24:89–100. https://doi.org/10.1016/j.jcrc.2007.12.014. 2009/03/11.

[41] Lee JM, Bae W, Lee YJ, et al. The efficacy and safety of prone positional ventilation in acute respiratory distress syndrome: updated study-level meta-analysis of 11 randomized controlled trials. Crit Care Med 2014;42:1252–62. https://doi.org/10.1097/ccm.0000000000000122. 2013/12/26.

[42] Kim R, Mullins K. Preventing facial pressure ulcers in acute respiratory distress syndrome (ARDS). J Wound, Ostomy Cont Nurs 2016;43:427–9. https://doi.org/10.1097/WON.0000000000000247.

[43] Le MQ, Rosales R, Shapiro LT, et al. The down side of prone positioning: the case of a coronavirus 2019 survivor. Am J Phys Med Rehabil 2020;99:870–2. https://doi.org/10.1097/PHM.0000000000001530.

[44] Moore Z, Patton D, Avsar P, et al. Prevention of pressure ulcers among individuals cared for in the prone position: lessons for the COVID-19 emergency. J Wound Care 2020;29:312–20. https://doi.org/10.12968/jowc.2020.29.6.312. 2020/06/13.

[45] Verdu J, Soldevilla J. IPARZINE-SKR study: randomized, double-blind clinical trial of a new topical product versus placebo to prevent pressure ulcers. Int Wound J 2012;9:557–65. https://doi.org/10.1111/j.1742-481x.2011.00918.x. 2012/11/21.

[46] Lupianez-Perez I, Uttumchandani SK, Morilla-Herrera JC, et al. Topical olive oil is not inferior to hyperoxygenated fatty aids to prevent pressure ulcers in high-risk immobilised patients in home care. Results of a multicentre randomised triple-blind controlled non-inferiority trial. PLoS One 2015;10:e0122238. https://doi.org/10.1371/journal.pone.0122238. 2015/04/18.

[47] Aloweni F, Lim ML, Chua TL, et al. A randomised controlled trial to evaluate the incremental effectiveness of a prophylactic dressing and fatty acids oil in the prevention of pressure injuries. Wound Practice & Research: Journal of the Australian Wound Management Association 2017;25. 42-27.

[48] Prebio M, Katz-Papatheophilou E, Heindl W, et al. Reduction of pressure sores during prone positioning of ventilated intensive care patients by the prone-head support system: a pilot study. Wien Klin Wochenschr 2005;117:98–105. https://doi.org/10.1007/s00508-004-0299-2.

[49] Grisell M, Place HM. Face tissue pressure in prone positioning: a comparison of three face pillows while in the prone position for spinal surgery. Spine 2008;33:2938–41. https://doi.org/10.1097/BRS.0b013e31818b9029. 2008/12/19.

[50] Kumagai A, Ohno N, Miyati T, et al. Investigation of effects of urethane foam mattress hardness on skin and soft tissue deformation in the prone position using magnetic resonance imaging. J Tissue Viability 2019;28:14–20. https://doi.org/10.1016/j.jtv.2018.10.007. 2018/12/07.