

Reducing the Incidence and Prevalence of Pressure Injury in Adult ICU Patients with Support Surface Use: A Systematic Review

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GENERAL PURPOSE: To provide information on the effectiveness of active and reactive support surfaces in reducing the incidence and prevalence of pressure injuries (PIs) in adult ICU patients.

TARGET AUDIENCE: This continuing education activity is intended for physicians, physician assistants, nurse practitioners, and nurses with an interest in skin and wound care.

LEARNING OBJECTIVES/OUTCOMES: After participating in this educational activity, the participant will:

1. Distinguish features of active and reactive support surfaces used in the ICU.
2. Compare the PI incidence in patients using a variety of support surfaces.
3. Synthesize recommendations for the use of support surfaces to reduce the risk of PI in adult ICU patients.

ABSTRACT

OBJECTIVE: To identify and analyze scientific evidence on the effectiveness of active and reactive support surfaces in reducing the incidence and prevalence of pressure injury (PI) in adult ICU patients.

DATA SOURCES: PubMed, ProQuest, ScienceDirect, Wiley Online Library, ClinicalKey for Nursing, Cochrane Library, and secondary searches.

STUDY SELECTION: Studies were included if they related to support surfaces, involved adult ICU patients aged ≥ 18 years, and the primary outcome measured was incidence or prevalence of PI. The initial search resulted in 8,357 articles; after exclusions, 31 complete texts were assessed for feasibility. A total of eight articles were included in this review. A bias risk assessment was performed using the Cochrane Risk of Bias Assessment Tool.

DATA EXTRACTION: Data were extracted by one reviewer and summarized in a table of study results that was examined and verified by two other reviewers.

DATA SYNTHESIS: Reactive (constant low pressure) support surfaces included viscoelastic foam mattresses, static air mattresses, and low-air-loss mattresses, whereas the active support surface consisted of alternating-pressure air mattresses. Alternating pressure mattress and viscoelastic foam mattress use both resulted in significantly lower PI incidence.

CONCLUSION: Support surface use is limited, and no particular type is proven to be superior to others. Clinicians should select support surfaces based on their therapeutic features and how well they meet the patient's particular needs.

KEYWORDS: ICU, incidence, pressure injury, prevalence, prevention, support surface

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INTRODUCTION

In clinical settings, a pressure injury (PI) is more likely to develop after prolonged bed rest, as occurs in the ICU. Studies in three European countries found that PI incidence in critical care rooms was 14% in Italy, 38% in the Netherlands, and 49% in Germany.¹ A study in Turkey reported that the highest PI incidence (35.3%) occurred in ICUs,² and in Indonesia, researchers found that the prevalence of hospital-acquired PI ranged from 7% to 18%.³ A hospital study in the US reported a higher mean PI incidence in ICU patients compared with patients in acute care.⁴ Thus, it can be concluded that ICU patients are at risk of PI.

Several risk factors increase PI incidence in the ICU, including unconsciousness, paralysis, and neurologic disease.⁵ A systematic review confirmed multifactorial risk of PI in the ICU, including medical intervention and medication.⁶ Inherent PI risks in critically ill patients include circulatory impairment resulting from immobility, hemodynamic instability, vasopressor therapy, diminished sensory perception, and organ failure.⁷ However, PI development is often preventable, including in the ICU setting.

The most successful PI prevention protocols address the main pathology of PI (pressure, shear, and friction) by reducing the patient's prolonged exposure to tissue stress and shear.^{4,8} By redistributing the pressure, reducing shear stress, and controlling the microclimate (temperature and/or humidity) of the skin, PI can be prevented.⁹ Thus, preventive methods should include support surfaces to reduce stress, shear, and frictional forces.

Support surfaces are devices designed for pressure management, microclimate control, and/or other therapeutic functions⁸ and are the focus of international recommendations and national guidelines.^{10,11} Specifically, they are designed to increase the bodily surface area that is in contact with the support surface (to reduce interface pressure) or sequentially change the part of the body that is bearing the load, thereby reducing the loading duration at specific anatomic locations.⁴ Support surfaces can be divided into two types: active support surfaces (alternating pressure) and reactive support surfaces (constant low/continuous pressure).¹² Active support surfaces include alternating-pressure mattresses/overlays.¹³ Reactive support surfaces include standard foam, air- or gel-filled, low-air-loss, and air-fluidized mattresses.¹³

The effectiveness of both active and reactive support surfaces is still widely debated. Viscoelastic foam (VEF),¹⁴⁻¹⁶ low-air-loss beds,¹⁷ and alternating-pressure mattresses¹⁸ have been demonstrated to be effective in reducing the incidence and prevalence of PI in adult ICU patients. However, other studies have found that static air mattresses¹⁹ and alternating-pressure mattresses²⁰ were not effective in reducing PI incidence. Another study reported that alternating pressure was effective in reducing PI

incidence after a length of stay of more than 14 days in the ICU.²¹

Clinicians should conduct a comprehensive clinical assessment before deciding which support surface to use based on the patient's specific needs.¹³ When it is unclear what type of support surface should be used, the patient may experience pain, depression, and anxiety;²² suffering;²³ interference with the healing process; and increases in the length of hospital stay and burden of care.²⁴ To date, several systematic reviews have analyzed support surfaces in terms of PI prevention.²⁵ However, despite the importance of choosing a support surface that is compatible with the care setting,^{4,12,26} the effectiveness of support surfaces in the ICU remains unclear. Accordingly, the current systematic review aimed to identify and analyze scientific evidence regarding the extent to which active and reactive support surfaces reduce the incidence and prevalence of PI in adult ICU patients.

METHODS

Protocol Registration

This systematic review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO no. CRD42020204919).²⁷

Search Strategy

The databases and publisher websites searched included PubMed, ProQuest, ScienceDirect, Wiley Online Library, ClinicalKey for Nursing, and Cochrane Library. To complete a secondary search, the authors searched the reference lists of the included studies. The same keywords were used for all searches, and similar subject titles were used in the other six databases.

Inclusion and Exclusion Criteria

The inclusion criteria were studies that evaluated the effect of support surfaces on PI incidence or prevalence as primary or secondary outcomes and involved adult participants 18 years or older. All studies compared two or more groups, were written in English, and were published in the past 10 years. The authors included randomized controlled trials, quasi-experiments, and prospective cohort studies.

Study Selection

A search that matched the keywords was conducted using the PICO(T) formula.²⁸ The keywords were Population (ICU OR Intensive Care OR Intensive Care Unit OR Critical Care OR Intensive Therapy), Intervention (Support Surface OR Mattress), Control (Control OR No Intervention OR Placebo), and Outcome (Incidence OR Prevalence AND Pressure Injury OR Ulcers Pressure OR Bed Sore OR Pressure Ulcer OR Decubitus OR Pressure Damage OR Pressure Sore), respectively. One

author screened the titles and abstracts to include studies that matched the research questions and inclusion criteria. If one author disagreed with a study's inclusion, it was discussed with the other authors until consensus was reached. Further screening identified duplicate and non-full-text articles. Final screening was conducted to identify nonrelevant outcome with the research question. Inclusion articles were determined and evaluated by two authors.

Extraction and Data Synthesis

One author extracted data using an adapted data collection form developed by The Cochrane Collaboration.²⁹ The forms completed for each study included the following: author, year, country, design, intervention, control, monitoring duration, and primary outcome. Data analysis was carried out by all authors.

Quality Assessment

The authors used the Cochrane Risk of Bias Assessment Tool to assess the risk of bias from each article.³⁰ The quality of the clinical studies was assessed using the Oxford Centre for Evidence-Based Medicine guidelines.³¹

RESULTS

The authors retrieved a total of 8,357 articles from PubMed (73 articles), ProQuest (1,523 articles), ScienceDirect (4,755 articles), Wiley Online Library (1,902 articles), ClinicalKey for Nursing (24 articles), Cochrane Library (78 articles), and secondary searches (2 articles). After screening for publication date, language, subject, title/abstract, non-full texts, duplicate articles, research question relevance, and nonrelevant outcomes, eight articles were included in the review (Figure).

Study Characteristics

The eight included articles comprised four randomized controlled trials, two cohort studies, and two quasi-experimental studies. Research was carried out in China, Turkey, the US, Spain, Brazil, Greece, and Belgium and sample sizes ranged from 52 to 1,654 participants. Five studies examined reactive support surfaces, including VEF,^{14–16} static air,¹⁹ and low air loss.¹⁷ Meanwhile, three studies examined an active support surface (an alternating low-pressure air mattress; Table 1).^{18,20,21}

Effectiveness of Support Surfaces for PI Prevention

Four studies confirmed the efficacy of active and reactive support surfaces in reducing PI incidence,^{14,15,17,18} and one study demonstrated the efficacy of an active support surface after 14 days.²¹ Three studies did not find evidence that active and reactive support surface use reduced PI incidence (Table 2).^{16,19,20}

Active Support Surface: Alternating Pressure Mattresses. After 3 days of monitoring, Marvaki et al¹⁸ noted a lower PI incidence in the intervention group (alternating-pressure mattresses, 18.8%) compared with the control group (foam mattress, 48.8%; $P = .011$). In addition, following more than 14 days of monitoring, Manzano et al²¹ reported lower PI incidence in the intervention group (alternating-pressure air mattresses; 21.2%) compared with the control group (alternating-pressure air overlay, 50%; $P = .03$; 0.80 [95% confidence interval, 0.42–1.83]). However, Demarre et al²⁰ found no significant reduction in PI incidence in the intervention group (alternating-pressure mattresses with multistage inflation [5.7%] compared with single inflation [5.8%]) after 15 days of monitoring.

Reactive Support Surface: Viscoelastic Foam. Jiang et al¹⁴ found lower PI incidence in the intervention group after 7 days (VEF, 0.3%) compared with the control group (air-pressure mattress, 1.8%; $P = .022$; 1.5 [95% confidence interval, 0.2–2.6]). Camargo et al¹⁵ also confirmed lower PI incidence in the intervention group with a median time of 7 days (VEF, 32.2%) compared with the control group (pyramidal mattress, 80.6%; $P = .001$). Ozyurek and Yavuz¹⁶ found no difference in PI incidence in the intervention group after 7 days (VEF II, 42.8%) compared with the control group (VEF I, 40.3%; $P = .44$).

Reactive Support Surface: Air Mattress. After 5 days of monitoring, Black et al¹⁷ determined that PI incidence was lower in the intervention group (low air loss, 0%) compared with the control group (air-pressure mattress, 18%; $P = .046$). Jiang et al¹⁹ found no difference in PI incidence between the intervention group (static air mattress, 2.56%) and the control group (dynamic air mattress, 1.32%; $P = .576$) following 5 days of monitoring.

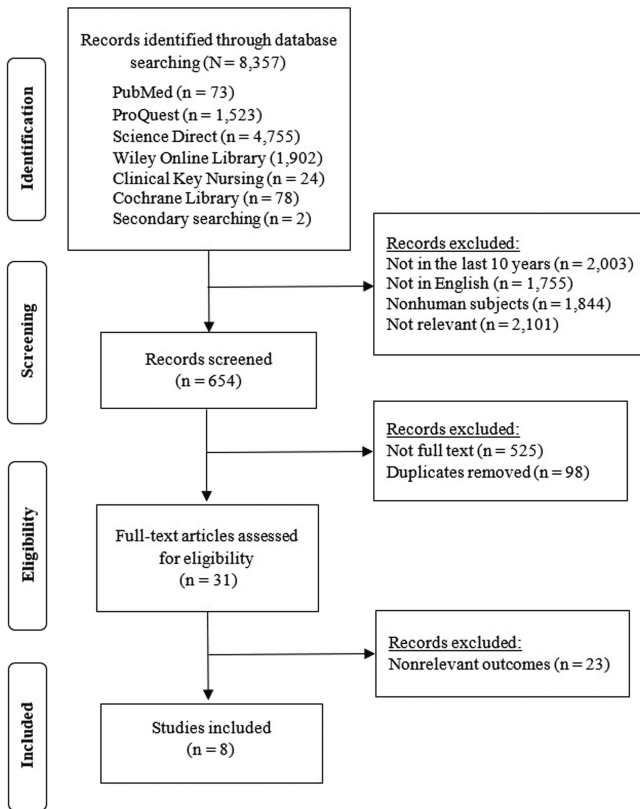
Treatment Modalities

Surprisingly, the treatment modalities provided during support surface use differed across studies. Two studies did not explain in detail the treatment modality used.^{15,20} One study used VEF mattresses in combination with repositioning every 4 hours.¹⁴ Another study used alternating-pressure mattresses with the patient's position changed every 4 hours (semi-Fowler's position, 30°; right lateral position, 30°; and left side lateral position, 30°).²¹ One study used static- and alternating-pressure mattresses in combination with repositioning every 2 hours.¹⁹ One study used VEF I and II mattresses with repositioning, cushioning, and skin care,¹⁶ and one study used low-air-loss mattresses with skin care.¹⁷

Quality Assessment

One article had a high risk of random sequence generation bias.²¹ Two articles had a high risk of bias because allocation concealment was not described in detail.^{17,21} Two articles had a high risk of performance bias as

Figure. STUDY FLOWCHART



both the patients and nurses were not blinded to the intervention group.^{19,20} In addition, six articles had a high risk of other bias because the treatment modalities were different in each study, which could have affected the treatment results.^{14,16–19,21} Further, three articles had an unclear risk of attrition bias in outcome reporting because the outcome data incompletely addressed the purpose of the study.^{14,18,20} Six articles had an unclear risk of reporting bias because the findings were presented only in narrative form rather than as quantitative data.^{14–18,20,21} Two articles had an unclear risk of other bias because they did not explicitly describe the modality during the treatment^{18,20} (Table 3).

The authors assessed the quality of the clinical studies using guidelines from the Oxford Centre for Evidence-Based Medicine.³¹ Two articles were determined to have evidence level 1b and recommendation level A,^{15,20} two articles had evidence level 1c and recommendation level B,^{16,19} and four articles had evidence level 3b and recommendation level B.^{14,17,18,21}

DISCUSSION

Active support surfaces are powered surfaces that can change their load distribution properties, with or without applied load.³² These surfaces achieve pressure redistribution by frequently changing the point of contact

between the surface and the body, reducing the duration of pressure being applied to specific anatomical sites.²⁶ Thus, the use of active support surfaces generally involves programmed alternating pressure.

Reactive support surfaces can be powered or nonpowered; these surfaces change their load distribution properties only in response to applied load.³² They are considered reactive because the pressure redistribution effect is determined by the surface area of the body in contact with the mattress; the larger the area of the body the mattress supports, the lower the pressure at that particular point of contact.³³ For example, VEF is a porous polymer material that conforms in proportion to the applied weight. The material exhibits dampened elastic properties when load is applied.³² Its use is associated with a reduction in interface pressure by 20% to 30% compared with that of a standard hospital mattress.³⁴ Therefore, the use of reactive support surfaces reduces the pressure during loading (lying or sitting).

Effectiveness of Support Surfaces in Preventing PI

Alternating-Pressure Mattresses. The use of alternating-pressure mattresses prevents pressure ulceration by redistributing the pressure under the body, increasing blood flow to the tissues, and eliminating skin and tissue distortion.³⁵ In their cohort study, Marvaki et al¹⁸ confirmed that alternating-pressure air mattresses are effective in reducing PI incidence in critically ill patients compared with foam mattresses. These findings are in agreement with other research showing that patients managed with an air flow mattress had a significantly lower PI incidence compared with those managed with a standard hospital mattress.^{36,37}

In addition, the use of alternating-pressure mattresses after a length of stay of more than 14 days was effective in reducing PI incidence; this finding can serve as a foundation for future studies.²¹ In the study by Manzano et al,²¹ an alternating-pressure air mattress was used for a patient with a mechanical ventilator. In critical care, patients often cannot be adequately repositioned because of the placement of monitors, lines, and devices or because of hemodynamic instability.³⁸ Thus, it is important to initiate the proper administration of preventive interventions using special support surfaces to prevent the development of severe PI.³⁹ The use of an alternating-pressure mattresses is recommended in patients who are immobile, are difficult to reposition due to mechanical ventilation, or who are under sedation, to reduce their risk of PI.

Viscoelastic Foam. Two studies included in this review found that VEF was effective in reducing PI incidence.^{14,15} Jiang et al¹⁴ provided a VEF mattress for patients who were not mechanically ventilated or sedated. Camargo et al¹⁵ reported that VEF was effective in reducing PI

**Table 1. SEARCH STRATEGY OF ELECTRONIC DATABASES**

Database	Keywords	Result	Search Screening	Screening Result	Included Studies
PubMed	ICU OR Intensive Care OR Intensive Care Unit OR Critical Care OR Intensive Therapy AND Support Surface OR Mattress AND Incidence OR Prevalence OR Pressure Injury OR Ulcers Pressure OR Bed Sore OR Pressure Ulcer OR Decubitus OR Pressure Damage OR Pressure Sore	2,307	Last 10 y: 1,292 Full text: 1,235 Clinical trial and randomized controlled trial: 76 English: 73 Humans: 73	73	2
ProQuest	Intensive Care OR Critical Care AND Support Surface OR Mattress AND Incidence OR Prevalence AND Pressure Injury	290,671	Full text: 278,064 Last 10 y: 223,403 English: 221,449 Article: 203,284 Publication title critical care: 1,523	1,523	1
ScienceDirect	“Intensive Care” AND Support Surface OR Mattress AND Incidence OR Prevalence AND Pressure Injury OR Pressure Ulcer	206,538	Last 10 y: 95,992 Research articles: 42,618 Subject areas nursing and health professions: 4,755 Publication title International Journal of Nursing Studies: 200	200	1
Wiley Online Library	Intensive Care OR Intensive Care Unit OR Critical Care OR Intensive Therapy AND Support Surface OR Mattress AND Incidence OR Prevalence AND Pressure Injury OR Ulcers Pressure OR Bed Sore OR Pressure Ulcer	7,075	Last 10 y: 2,607 Journals: 1,902	1,902	1
ClinicalKey for Nursing	Intensive Care OR Critical Care AND Support Surface OR Mattress AND Incidence OR Prevalence AND Pressure Injury	26	Full text only: 24	24	0
Cochrane Library	ICU OR Intensive Care OR Intensive Care Unit OR Critical Care OR Intensive Therapy AND Support Surface OR Mattress AND Incidence OR Prevalence AND Pressure Injury OR Ulcers Pressure OR Bed Sore OR Pressure Ulcer OR Decubitus OR Pressure Damage OR Pressure Sore	97	Trials: 92 Last 10 y: 78	78	1

incidence. Ozyurek and Yavuz¹⁶ compared the use of VEF I (two layers) and VEF II (three layers) and found no difference in PI incidence.¹⁶ The National Institute for Health and Clinical Excellence recommends a high-specification foam mattress as the standard for vulnerable patients.⁴⁰ Viscoelastic foam support surfaces can redistribute pressure points and, consequently, reduce the intensity of pressure on the body. This type of support surface can improve body adaptability, enable a larger contact surface, and more effectively reduce pressure compared with other nonpowered surfaces.¹⁶ Thus, the use of a VEF mattress is recommended for patients at risk of PI development.

Low Air Loss. Black et al¹⁷ reported that the use of low-air-loss mattresses was effective in reducing PI incidence in mechanically ventilated patients. The skin of critically ill patients may be exposed to moisture from perspiration or exposure to bodily fluids. Microclimate control aims to reduce moisture accumulation and heat buildup by moving the air under the patient’s skin, keeping the skin cool, which can reduce tissue metabolic requirements.⁴¹ Low-air-loss mattresses provide airflow

to better manage heat and moisture from the skin surface.^{42,43} Therefore, a low-air-loss mattress is recommended for patients who are exposed to bodily fluids and difficult to reposition due to mechanical ventilation.

Treatment Modality

Active and reactive support surfaces use different treatment modalities. The findings included in this review reveal possible interactions between positioning, turning, and use of a support surface strategy.⁴⁴ Developing a complete picture of effective skin care requires managing the moisture, hygiene, and dehydration of the skin, and maintaining the natural skin pH.⁴⁵ Thus, it is difficult to ascertain the independent effect of using a support surface or a combination of treatment modalities.

Quality Assessment Review

Based on the Cochrane Bias Risk Assessment Tool guidelines,³¹ two studies did not blind patients or nurses to the intervention group and thus had a high risk of performance bias.^{19,20} Blinding in research is highly desirable to prevent bias in the study results.⁴⁶ Double or single blinding

Table 2. SUMMARY OF THE STUDY RESULTS

Author (Year) Country	Design	Intervention	Control	Monitoring Duration (d)	PI Incidence: Intervention Group (%)	PI Incidence: Control Group (%)	P	Relative Risk (95% Confidence Interval)
Jiang et al (2020), ¹⁴ China	Quasi-experiment	Viscoelastic foam mattress	Air pressure mattress	7	0.3	1.8	.022	1.5 (0.2–2.6)
Ozyurek and Yavuz (2015), ¹⁶ Turkey	Randomized controlled trial	Viscoelastic foam II	Viscoelastic foam I	15	42.8	40.3	.44	—
Black et al (2012), ¹⁷ US	Cohort	Low air loss mattress	Air pressure mattress	5	0	18.0	.046	—
Jiang et al (2014), ¹⁹ China	Randomized controlled trial	Static air mattress	Dynamic air mattress	5	2.56	1.32	.576	—
Manzano et al (2013), ²¹ Spain	Quasi-experiment	Alternating-pressure air mattress	Alternating-pressure air overlays	>14	21.2	50.0	.03	0.89 (0.42–1.83)
Camargo et al (2018), ¹⁵ Brazil	Randomized controlled trial	Viscoelastic foam mattress	Pyramidal mattress	30	32.2	80.6	.001	—
Marvaki et al (2020), ¹⁸ Greece	Cohort	Alternating-pressure air mattress	Foam mattress	21	18.8	48.5	.011	—
Demarre et al (2012), ²⁰ Belgium	Randomized controlled trial	Alternating low-pressure air mattress (multistage inflation)	Alternating low-pressure air mattress (single-stage inflation)	15	5.7	5.8	.97	—

Abbreviation: PI, pressure injury.

can affect the attitudes and objectivity of patients and nurses in their assessments and interventions.⁴⁷

Limitations

In terms of article screening, the search was confined to six databases and included only articles in English; potential articles published in other languages were not included. In addition, the included studies did not control the treatment modalities during the application of support surfaces, which might have influenced the study outcomes. In addition, none of the included articles investigated prevalence data. Therefore, further evaluation is needed

based on the type of support surface, as well as subgroup analysis according to various treatment modalities to identify which are most effective in reducing PI incidence in adult ICU patients.

CONCLUSIONS

Clinicians should select support surfaces based on their therapeutic features and how well they meet the patient’s particular needs: no one type or brand of support surface has been proven superior. Active support surfaces, which offer alternating pressure, are particularly useful for immobilized patients and those who are difficult to

Table 3. BIAS RISK ASSESSMENT

Author (Year)	Random Sequence Generation (Selection Bias)	Allocation Concealment (Selection Bias)	Blinding of Participants and Personnel (Performance Bias)	Blinding of Outcome Assessment (Detection Bias)	Incomplete Outcome Data (Attrition Bias)	Selective Reporting (Reporting Bias)	Other Sources of Bias (Other Bias)
Jiang et al (2020) ¹⁴	+	+	+	?	?	?	–
Ozyurek and Yavuz (2015) ¹⁶	+	+	+	+	+	?	–
Black et al (2012) ¹⁷	+	–	+	+	+	?	–
Jiang et al (2014) ¹⁹	+	+	–	+	+	+	–
Manzano et al (2013) ²¹	–	–	+	?	+	+	–
Camargo et al (2018) ¹⁵	+	+	+	+	+	?	?
Marvaki et al (2020) ¹⁸	+	+	+	–	?	?	–
Demarre et al (2012) ²⁰	+	+	–	–	?	?	?

+ indicates a low risk of bias; – indicates a high risk of bias; ? indicates an unclear risk of bias.



reposition because of mechanical ventilation or sedation. Reactive support surfaces with VEF are the standard for vulnerable patients, whereas low air loss mattresses should be used for patients who are exposed to bodily fluids and difficult to reposition. ●

PRACTICE PEARLS

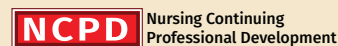
- Pressure injuries are more likely to develop in ICU patients with multifactorial risk.
- One essential PI prevention strategy is the use of support surfaces to redistribute pressure, reduce shear, and control the microclimate.
- Clinicians should consider the therapeutic features of support surfaces and individual patients' needs to select the most appropriate support surface.
- Further research is needed to investigate the effectiveness of support surfaces in combination with various modalities.

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