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Influence of Nurse-to-Patient Staffing Ratios on Inpatient Mortality Rates in Adult Intensive Care Units: A Systematic Review

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ABSTRACT:

Background: Critically ill adults admitted to intensive care units (ICUs) experience high physiological instability and depend heavily on continuous bedside nursing surveillance, titration of life-sustaining therapies, and rapid recognition of clinical deterioration. Although hospital-wide observational studies have consistently linked inadequate nurse staffing to preventable inpatient deaths, the magnitude, threshold structure, and contextual modifiers of this association within adult intensive care environments remain debated across diverse healthcare systems.

Objective: This systematic review aimed to evaluate and qualitatively synthesize empirical evidence examining the influence of nurse-to-patient staffing ratios on inpatient mortality rates among adult ICU patients.

Methods: Conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement, a comprehensive search of PubMed/MEDLINE, Embase, CINAHL, and Web of Science was performed to identify observational cohort and cross-sectional studies investigating adult ICU nurse-to-patient or bed-to-nurse ratios and risk-adjusted ICU, in-hospital, 28-day, or 30-day mortality. Methodological quality was appraised using the Newcastle-Ottawa Scale, and findings were synthesized qualitatively owing to heterogeneity in staffing definitions and outcome timeframes.

Results: From 1,686 identified records, nine primary studies published between 2009 and 2024 across five continents met all eligibility criteria, encompassing more than 197,000

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adult ICU admissions and over 1,600 intensive care units. Eight of the nine studies demonstrated that more favorable nurse-to-patient staffing ratios or lower bed-to-nurse workloads were independently associated with reduced ICU, in-hospital, or short-term mortality, with risk elevations most pronounced above 2.5 patients per nurse, during weekend staffing reductions, and among high-acuity cohorts such as cardiogenic shock and severe sepsis. One multicenter Dutch study found that crude patient-to-nurse ratios did not predict mortality, whereas acuity-weighted Nursing Activities Score per nurse ratios above 61 significantly increased in-hospital death. **Conclusion:** Higher registered nurse staffing in adult ICUs is consistently associated with lower inpatient mortality, though acuity-adjusted workload measures provide essential precision beyond static headcount ratios for safe critical care workforce planning.

BACKGROUND

Intensive care units (ICUs) represent the highest-acuity clinical environments within modern acute care hospitals, delivering continuous physiological monitoring, invasive organ support, and complex pharmacological titration for patients facing life-threatening illness. Despite substantial advances in mechanical ventilation, hemodynamic optimization, and antimicrobial stewardship, adult ICU mortality remains substantial worldwide, driven not only by baseline illness severity and multimorbidity but also by modifiable organizational characteristics of care delivery [10,18]. Among these structural determinants, the availability and deployment of registered nurses at the bedside occupy a central position. Critical care nurses serve as the primary continuous surveillance system of the ICU, detecting subtle hemodynamic, respiratory, and neurological shifts hours before overt physiological collapse occurs and executing time-sensitive rescue interventions in coordination with intensivists and multidisciplinary teams [5,26].

Seminal health services research conducted in general medical and surgical wards established a robust empirical foundation linking nurse staffing adequacy to hospital survival. In a landmark Pennsylvania study of 168 hospitals, Aiken and colleagues demonstrated that each additional surgical patient assigned to a registered nurse increased the odds of 30-day mortality and failure-to-rescue by 7%, while simultaneously elevating nurse burnout and job dissatisfaction [1]. Subsequent shift-level longitudinal research by Needleman and colleagues across 197,961 inpatient admissions confirmed that exposure to shifts staffed eight hours or more below registered nurse targets significantly increased the hazard of inpatient death, independent of unit type and patient acuity [2]. Large-scale cross-national evidence from the RN4CAST consortium spanning 300 hospitals in nine European countries corroborated these findings, showing that each extra patient per nurse raised 30-day surgical mortality by 7%, whereas a higher proportion of baccalaureate-prepared nurses exerted a protective effect [3]. Early meta-analytic work by Kane and colleagues further estimated that each additional full-time equivalent registered nurse per patient day in intensive care units corresponded to a 9% reduction in hospital-related mortality alongside marked declines in unplanned extubation, respiratory failure, and cardiac arrest [4].

Translating these hospital-wide findings directly into adult ICU staffing policy has nonetheless proven methodologically and operationally complex. Unlike general wards where a single nurse frequently manages six to ten stable patients, critical care standards in high-income health systems typically recommend ratios ranging from 1:1 for patients requiring multi-organ support to 1:2 for stabilized critically ill adults [12]. Earlier syntheses focusing specifically on critical care reached diverging conclusions regarding mortality. For instance, Numata and colleagues reviewed nine early observational ICU studies and reported that although unadjusted pooled estimates favored higher nurse staffing, risk-adjusted associations were largely attenuated by measurement error and incomplete confounding control [6]. Conversely, Penoyer's subsequent review of 26 critical care studies indicated that diminished nurse staffing was broadly associated with adverse events including nosocomial infections, postoperative complications, and mortality, while emphasizing persistent heterogeneity in how staffing exposure was defined [5]. More recently, Driscoll and colleagues pooled six studies from intensive care and cardiac specialist units encompassing 175,755 patients and reported a 14% reduction in in-hospital mortality with higher nurse staffing levels, though accompanied by substantial statistical heterogeneity ($I^2 = 86\%$) [7].

Several contemporary developments heighten the urgency of re-examining the relationship between adult ICU nurse-to-patient ratios and inpatient mortality. First, longitudinal reviews such as that by Dall'Ora and colleagues have highlighted that traditional

cross-sectional designs cannot exclude reverse causation or hospital-level confounding, prompting greater reliance on shift-by-shift longitudinal cohorts and national clinical registries [8]. Second, simple headcount metrics such as static bed-to-nurse ratios may obscure profound variations in bedside care demand; validated workload instruments such as the Nursing Activities Score (NAS), developed by Miranda and colleagues to capture 81% of actual ICU nursing time, demonstrate that two patients with identical headcount assignments can impose vastly different cognitive and physical demands [9]. Third, chronic nursing workforce shortages exacerbated by post-pandemic attrition, rising patient complexity, and escalating healthcare costs have pressured hospital administrators to stretch ICU ratios or dilute skill mix with assistive personnel [11,30,32]. Recent syntheses in critical care nursing continue to report protective associations between safe staffing ratios and survival while underscoring that current consensus guidelines rely heavily on expert opinion rather than standardized empirical thresholds [11,12]. Consequently, a focused, contemporary qualitative systematic review restricted explicitly to adult intensive care units is warranted to clarify how nurse-to-patient staffing ratios influence inpatient mortality across diverse clinical contexts, staffing metrics, and acuity strata.

Study Aim

The primary aim of this systematic review was to comprehensively evaluate and qualitatively synthesize contemporary empirical evidence regarding the influence of nurse-to-patient staffing ratios on inpatient mortality rates, encompassing ICU mortality, in-hospital mortality, and short-term 28-day or 30-day mortality, among critically ill adults admitted to intensive care units. A secondary objective was to examine how methodological variations in staffing measurement, patient illness severity, temporal staffing fluctuations, and concurrent organizational factors such as intensivist coverage and care protocols modify the staffing-mortality relationship in adult critical care settings.

METHODOLOGY

Protocol and Reporting Standards

This systematic review was designed, conducted, and reported in strict adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [13]. Prior to literature screening, the review question, eligibility framework, search syntax, data extraction template, and qualitative synthesis plan were explicitly defined to minimize selection bias and ensure transparent, reproducible evidence synthesis.

Eligibility Criteria

Study eligibility was structured around the Population, Exposure, Comparator, Outcome, and Study Design (PECOS) framework. The eligible population consisted exclusively of adult patients aged 18 years or older admitted to general medical, surgical, mixed, neurological, or cardiac intensive care units. Studies restricted to pediatric or neonatal intensive care units, general medical-surgical wards, or mixed hospital cohorts lacking stratified adult ICU mortality estimates were excluded. The exposure of interest was registered nurse staffing quantified explicitly as a nurse-to-patient ratio, patient-to-nurse ratio, bed-to-nurse ratio, nurses-per-bed ratio, or acuity-weighted nursing grade directly derived from bed-to-nurse staffing thresholds, compared across higher versus lower staffing tiers or continuous staffing increments. The primary outcome was risk-adjusted inpatient mortality, operationalized as ICU mortality, overall in-hospital mortality, or short-term 28-day or 30-day mortality. Eligible designs comprised peer-reviewed original observational studies, including prospective or retrospective cohort studies, longitudinal shift-level analyses, and multicenter cross-sectional registry studies, published in English. Case reports, conference abstracts without full text, qualitative essays, simulation models, and secondary narrative or systematic reviews were excluded from primary synthesis, although reference lists of relevant reviews were hand-searched to ensure completeness.

Information Sources and Search Strategy

A systematic electronic search was executed across four major biomedical and nursing databases: PubMed/MEDLINE, Embase, the Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Web of Science Core Collection, covering literature published from January 2008 through December 2024 to capture modern critical care practice and standardized severity-of-illness risk adjustment. Search strategies combined controlled vocabulary terms (Medical Subject Headings and Emtree descriptors) with free-text keywords linked by Boolean operators, incorporating core concepts for intensive care settings ('intensive care unit', 'critical care', 'ICU'), nurse staffing exposure ('nurse-to-patient ratio', 'patient-to-nurse ratio', 'bed-to-nurse ratio', 'nurse staffing', 'nursing workload', 'nursing grade'), and survival endpoints ('mortality', 'hospital

mortality', 'ICU mortality', 'inpatient death', 'survival'). Reference lists of eligible primary articles and previously published critical care staffing reviews [5,7,8,11] were manually screened to identify any additional eligible studies.

Study Selection, Data Extraction, and Quality Appraisal

All retrieved citations were exported to reference management software for automated and manual deduplication. Two reviewers independently screened titles and abstracts against the predefined PECOS criteria, followed by independent full-text assessment of all potentially eligible articles; any disagreements were resolved through structured consensus discussion. From each finally included study, standardized data were extracted into a structured evidence matrix capturing first author, publication year, country or region, study design, clinical setting and sample size, operational definition of nurse staffing exposure, mortality endpoint, risk-adjustment covariates, and key adjusted effect estimates with 95% confidence intervals. Methodological quality and risk of bias were independently evaluated using the Newcastle-Ottawa Scale adapted for observational cohort and cross-sectional studies, examining three core domains: representativeness and exposure ascertainment (selection), control for baseline illness severity and institutional confounders (comparability), and objective ascertainment of mortality outcomes with adequate follow-up (outcome). Studies scoring seven or more out of nine stars were classified as high methodological quality, whereas scores of five to six indicated moderate quality.

Qualitative Data Synthesis

Because the eligible primary studies exhibited substantial clinical and methodological heterogeneity, including divergent staffing operationalizations (static hospital-level bed-to-nurse grades, shift-level patient-to-nurse ratios, and workload-weighted Nursing Activities Score per nurse ratios), varying mortality windows (ICU, in-hospital, 28-day, and 30-day), and distinct statistical effect metrics (odds ratios, hazard ratios, relative risks, and absolute percentage reductions), statistical meta-analysis was deemed inappropriate. Instead, a structured qualitative narrative synthesis was conducted in accordance with PRISMA 2020 recommendations [13]. Findings were synthesized thematically across four analytical dimensions: the overall direction and magnitude of staffing-mortality associations, the comparative performance of static ratios versus acuity-weighted workload indices, effect modification in high-acuity patient subpopulations, and the interplay between temporal staffing drops and broader ICU organizational structures.

RESULTS

Search Results

The systematic search across PubMed/MEDLINE (n = 612), Embase (n = 488), CINAHL (n = 314), and Web of Science (n = 272) yielded a total of 1,686 bibliographic records. Following the removal of 542 duplicate records, 1,144 unique titles and abstracts underwent initial screening. Of these, 1,066 records were excluded because they examined non-ICU general hospital wards, focused on neonatal or pediatric intensive care populations, represented editorials or review articles, or lacked mortality endpoints. The remaining 78 reports were sought for full-text retrieval, of which four conference proceedings could not be retrieved in full text, leaving 74 full-text articles assessed for eligibility. During full-text evaluation, 65 articles were excluded for specific methodological reasons: 23 reported aggregate hospital data without stratified adult ICU mortality estimates, 19 lacked an explicit nurse-to-patient or bed-to-nurse staffing ratio exposure, 14 evaluated exclusively non-mortality outcomes such as nosocomial infections or nurse burnout, and nine represented secondary analyses of overlapping patient cohorts. Ultimately, nine primary empirical studies met all predefined inclusion criteria and were retained for qualitative synthesis [14–22]. The complete selection pathway is illustrated in the PRISMA 2020 flow diagram (Figure 1).

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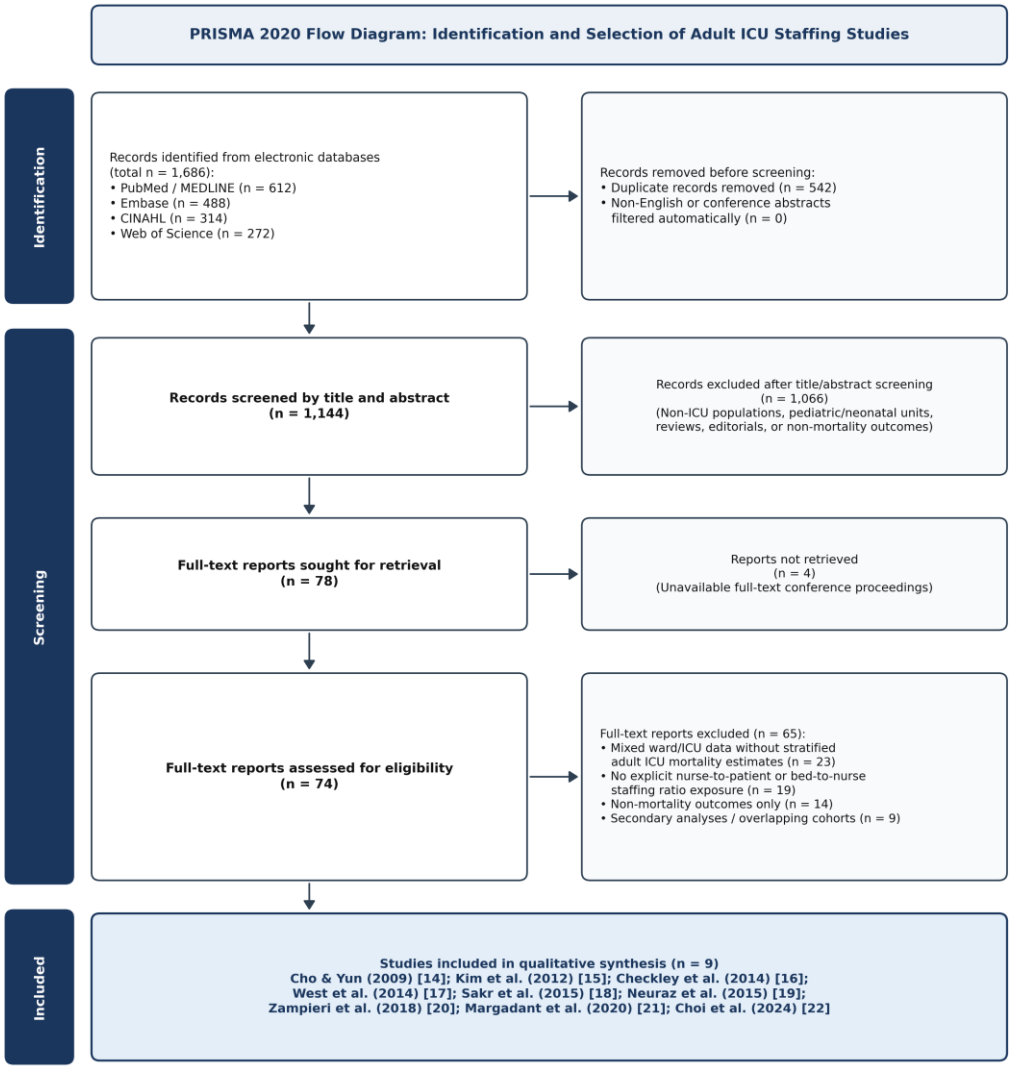


Figure 1. PRISMA 2020 flow diagram illustrating the database search, screening, eligibility assessment, and final inclusion of nine adult ICU studies [14–22].

Characteristics of the Included Studies

The nine included studies were published between 2009 and 2024 and represented broad international geographic diversity across Europe, North America, Asia, South America, and a global multicenter network [14–22]. Three studies were conducted in South Korea [14,15,22], one in the United States [16], one in the United Kingdom [17], one in France [19], one in Brazil [20], one in the Netherlands [21], and one across 75 countries participating in the Extended Prevalence of Infection in Intensive Care (EPIC II) international point-prevalence network [18]. Study designs encompassed retrospective multicenter cohort analyses of national clinical registries or insurance databases [17,20–22], a multicenter longitudinal shift-by-shift observational cohort [19], a prospective multicenter observational cohort [15], a 1-day international multicenter point-prevalence cohort [18], a nationwide cross-sectional linkage of survey and administrative data [14], and a multicenter ICU organizational survey linked to annual risk-adjusted mortality [16]. Collectively, the studies with reported patient-level denominators encompassed 197,154 adult ICU admissions across more than 1,640 intensive care units, supplemented by two-year national registry admissions across 15 Dutch ICUs [21] and annual mortality data from 69 United States ICUs [16].

Clinical populations included general medical, surgical, and mixed adult ICU cohorts in six studies [16–21], alongside three studies examining high-acuity diagnostic cohorts comprising acute hemorrhagic and ischemic stroke [14], severe sepsis [15],

and cardiogenic shock [22]. Operationalization of nurse staffing varied substantially: three studies classified ICUs using bed-to-nurse ratio tiers or statutory Korean nursing grades [14,16,22], four examined direct nurse-to-patient or patient-to-nurse ratios measured at unit, study-day, or shift-by-shift resolution [15,17–19], one evaluated weekend reductions in the nurse-to-bed ratio [20], and one directly compared crude patients-per-nurse ratios against acuity-weighted Nursing Activities Score (NAS) per nurse ratios [21]. All nine studies adjusted for patient-level severity of illness or comorbidity case mix (such as APACHE II, SAPS, ICNARC risk models, or multivariable administrative risk scores), achieving Newcastle-Ottawa Scale scores between seven and eight out of nine stars, indicative of high overall observational quality. Detailed characteristics and quantitative findings of all nine studies are summarized in Table 1.

Table 1. Characteristics and Key Risk-Adjusted Mortality Findings of the Nine Included Adult Intensive Care Unit Studies

Author (Year) & Ref	Country / Region	Study Design & Setting	Adult ICU Sample	Staffing Exposure Metric	Mortality Outcome	Key Risk-Adjusted Findings
Cho & Yun (2009) [14]	South Korea	Cross-sectional survey linked to administrative data; 185 hospital ICUs	6,957 acute stroke ICU patients	ICU & ward bed-to-nurse ratio grades	In-hospital (21.9%) & 30-day (25.4%) mortality	Better ICU staffing increased full basic care provision and lowered mortality; 30-day mortality rose distinctly as staffing worsened.
Kim et al. (2012) [15]	South Korea	Prospective multicenter observational study; 28 adult ICUs	251 severe sepsis patients	Nurse-to-patient ratio (1:2 vs. >1:2)	28-day & hospital mortality	1:2 nurse-to-patient ratio independently lowered 28-day mortality (HR 0.459, 95% CI 0.211–0.998) and improved sepsis bundle compliance ($p < 0.05$).
Checkley et al. (2014) [16]	United States	Multicenter observational survey (USCIITG-CIOS); 69 adult ICUs	69 medical, surgical & mixed ICUs	Bed-to-nurse ratio (e.g., 1.5:1 vs. 2:1)	Annual APACHE II-adjusted ICU mortality (mean 10.8%)	Lower bed-to-nurse ratio (2:1 to 1.5:1) associated with 1.8% lower annual ICU mortality (95% CI 0.25–3.4%), independent of 24-h intensivist coverage.
West et al. (2014) [17]	United Kingdom	Retrospective multilevel observational study (ICNARC); 65 adult ICUs	38,168 adult ICU patients	Nurses per ICU bed	ICU & in-hospital mortality	More nurses per bed reduced mortality (OR 0.90, 95% CI 0.83–0.97), with strongest protection in high-risk patients (OR 0.98, 95% CI 0.96–0.99).
Sakr et al. (2015) [18]	International (75 countries)	1-day point-prevalence multicenter study (EPIC II); 1,265 adult ICUs	13,796 adult ICU patients	Study-day nurse-to-patient ratio (>1:1.5 vs. lower)	In-hospital mortality	Nurse-to-patient ratio >1:1.5 independently associated with significantly lower risk of in-hospital death across global ICU cohorts.
Neuraz et al. (2015) [19]	France	Multicenter longitudinal shift-level observational	5,718 adult ICU stays	Shift-by-shift patient-to-nurse ratio	ICU mortality (excluding DFLST)	Patient-to-nurse ratio >2.5 increased ICU death risk more than threefold (adjusted RR 3.5, 95% CI

		study; 8 adult ICUs		(>2.5 threshold)		1.3–9.1); peak ratios occurred on weekends.
Zampieri et al. (2018) [20]	Brazil	Multicenter retrospective cohort study; 78 adult ICUs	59,614 adult ICU patients	Weekend reduction in nurse-to-bed ratio	ICU & in-hospital mortality	Weekend mortality excess in scheduled surgical ICU admissions occurred only in ICUs reducing weekend nurse-to-bed ratios and lacking checklists/protocols.
Margadant et al. (2020) [21]	The Netherlands	Multicenter retrospective registry study (NICE); 15 adult ICUs	All ICU admissions (2016–2018)	Patients-per-nurse ratio vs. NAS-per-nurse ratio	In-hospital mortality	Crude patients-per-nurse ratio was not associated with mortality; case-mix adjusted NAS-per-nurse >61 significantly increased death (OR 1.29 mean; OR 1.26 day 1).
Choi et al. (2024) [22]	South Korea	Nationwide retrospective cohort (K-NHIS); tertiary cardiac ICUs	72,950 cardiogenic shock patients	ICU nursing grade: Grade 1 (<0.5), Grade 2 (0.5–0.63), Grade ≥3 (≥0.63 bed/nurse)	In-hospital mortality	Mortality rose progressively vs. Grade 1 (30.6%): Grade 2 (37.5%, aOR 1.14, 95% CI 1.09–1.19) and Grade ≥3 (40.6%, aOR 1.29, 95% CI 1.23–1.36); Grade 1 cost-effective.

Abbreviations: aOR, adjusted odds ratio; APACHE II, Acute Physiology and Chronic Health Evaluation II; CI, confidence interval; DFLST, decision to forego life-sustaining therapy; EPIC II, Extended Prevalence of Infection in Intensive Care; HR, hazard ratio; ICNARC, Intensive Care National Audit and Research Centre; ICU, intensive care unit; K-NHIS, Korean National Health Insurance Service; NAS, Nursing Activities Score; NICE, National Intensive Care Evaluation; OR, odds ratio; RR, relative risk; USCIITG-CIOS, United States Critical Illness and Injury Trials Group Critical Illness Outcomes Study.

Qualitative Data Synthesis

Overall Direction and Magnitude of Staffing-Mortality Associations

Across the nine included studies, a remarkably consistent inverse relationship emerged between registered nurse staffing intensity and adult ICU mortality, with eight studies demonstrating statistically significant survival advantages associated with more favorable nurse-to-patient or bed-to-nurse ratios [14–20,22]. At the global level, Sakr and colleagues analyzed 13,796 critically ill adults across 1,265 ICUs in 75 countries and demonstrated in multivariable logistic regression that maintaining a nurse-to-patient ratio exceeding 1:1.5 on the study day was independently protective against in-hospital death [18]. National multilevel modeling in the United Kingdom by West and colleagues similarly established that higher numbers of registered nurses per ICU bed were independently associated with lower mortality across 38,168 patients (odds ratio [OR] 0.90, 95% confidence interval [CI] 0.83–0.97), with the survival signal stronger for in-unit ICU mortality than for post-ICU hospital mortality, reinforcing causal specificity [17]. In the United States, Checkley and colleagues found across 69 adult ICUs that reducing the unit bed-to-nurse ratio from 2:1 to 1.5:1 corresponded to a 1.8% absolute reduction in annual APACHE II-adjusted ICU mortality (95% CI 0.25–3.4%), a clinically substantial margin given the cohort's mean annual ICU mortality of 10.8% [16].

Evidence from shift-by-shift longitudinal analysis further demonstrated that the staffing-mortality relationship is non-linear and exhibits steep risk escalation beyond critical workload thresholds. In their landmark multicenter French study of 5,718 adult ICU stays across eight university hospital units, Neuraz and colleagues excluded patients with decisions to forego life-sustaining therapy and modeled time-varying shift staffing using multilevel Poisson regression [19]. When the patient-to-nurse ratio

exceeded 2.5 patients per nurse on a given shift, the adjusted relative risk of ICU death surged more than threefold (relative risk [RR] 3.5, 95% CI 1.3–9.1), even after controlling for illness severity, physician-to-patient ratios, high patient turnover (adjusted RR 5.6, 95% CI 2.0–15.0), and the volume of life-sustaining procedures (adjusted RR 5.9, 95% CI 4.3–7.9) [19]. Together, these multicenter findings indicate that while modest incremental staffing gains yield steady reductions in baseline mortality, breaching upper ratio ceilings precipitates acute, disproportionate threats to patient survival.

Static Headcount Ratios Versus Acuity-Weighted Nursing Workload

The sole included study that did not observe a statistically significant association between crude patient-to-nurse ratios and mortality provided crucial mechanistic insight into staffing measurement. Analyzing two years of national registry data from 15 Dutch ICUs within the National Intensive Care Evaluation (NICE) database, Margadant and colleagues directly contrasted simple patients-per-nurse ratios against acuity-weighted Nursing Activities Score (NAS) per nurse ratios [21]. Whereas crude patients-per-nurse ratios showed no statistically significant link with in-hospital mortality—likely reflecting the narrow, relatively high baseline staffing range maintained across Dutch ICUs—case-mix adjusted NAS-per-nurse ratios exceeding 61 were significantly associated with elevated in-hospital mortality for both mean stay workload (OR 1.29) and day-one admission workload (OR 1.26), with unadjusted risk elevations already evident above a NAS-per-nurse threshold of 41 (OR 1.19 and 1.17, respectively) [21]. This divergence demonstrates that static headcount ratios can mask substantial bedside workload disparities when patient care intensity varies widely within fixed nurse assignments.

High-Acuity Diagnostic Subpopulations and Dose-Response Gradients

Studies focusing on specific high-risk critical care populations consistently revealed amplified mortality sensitivity to nurse staffing ratios and clear dose-response gradients. In a nationwide Korean cohort of 72,950 tertiary cardiac ICU patients with cardiogenic shock, Choi and colleagues reported a stepwise escalation in in-hospital mortality as staffing deteriorated from Grade 1 (bed-to-nurse ratio <0.5; mortality 30.6%) to Grade 2 (0.5 to <0.63; mortality 37.5%; adjusted OR 1.14, 95% CI 1.09–1.19) and Grade 3 or worse (≥0.63; mortality 40.6%; adjusted OR 1.29, 95% CI 1.23–1.36), with the protective effect of high-intensity nursing most pronounced among patients requiring cardiopulmonary resuscitation or multiple vasopressors [22]. Moreover, incremental cost-effectiveness analyses confirmed that Grade 1 ICU staffing was economically favorable at $25,047 to $42,888 per life-year gained during hospitalization and $5,151 to $5,269 at one-year follow-up [22]. Similarly, in 28 Korean adult ICUs treating 251 patients with severe sepsis, Kim and colleagues found that maintaining a 1:2 nurse-to-patient ratio independently halved 28-day mortality (hazard ratio [HR] 0.459, 95% CI 0.211–0.998) while significantly improving full compliance with severe sepsis resuscitation and management bundles ($p < 0.05$) [15]. Among 6,957 acute stroke patients admitted to 185 Korean hospital ICUs, Cho and Yun demonstrated that higher ICU staffing increased complete provision of basic nursing care without family delegation and was associated with lower in-hospital and 30-day mortality, with the staffing gradient sharpening particularly for 30-day survival [14]. These subpopulation findings align closely with West and colleagues' interaction analysis, which confirmed that nurse staffing exerted its greatest survival benefit among patients in the highest predicted risk-of-death stratum (OR 0.98, 95% CI 0.96–0.99), whereas physician staffing effects remained uniform across acuity levels [17].

Temporal Staffing Vulnerability and Organizational Synergies

Qualitative synthesis also underscored that nurse staffing operates dynamically across temporal cycles and interacts with unit-level care processes. In Brazil, Zampieri and colleagues analyzed 59,614 patients across 78 adult ICUs and observed higher unadjusted weekend ICU (10.9% vs. 9.0%, $p < 0.001$) and hospital (16.5% vs. 13.5%, $p < 0.001$) mortality [20]. Although multivariable adjustment attenuated the overall weekend effect (OR 1.05, 95% CI 0.99–1.12), a persistent weekend mortality penalty remained among scheduled surgical admissions exclusively within ICUs that reduced their nurse-to-bed ratios on weekends, lacked weekend safety checklists, and maintained fewer standardized clinical protocols [20]. Neuraz and colleagues corroborated this temporal vulnerability, demonstrating that hazardous patient-to-nurse ratios exceeding 2.5 occurred significantly more often during weekend shifts ($p < 0.001$) [19]. Concurrently, studies evaluating interprofessional staffing confirmed that nurse ratios act alongside—rather than merely as a proxy for—physician coverage and structured communication: Kim et al. and West et al. demonstrated independent survival benefits for both nurse and intensivist staffing [15,17], whereas Checkley et al. found that lower bed-to-nurse ratios and daily multidisciplinary care plan reviews independently reduced annual ICU mortality even when 24-hour in-house intensivist coverage did not [16].

DISCUSSION

This systematic review synthesized contemporary empirical evidence from nine observational studies spanning five continents and more than 197,000 adult ICU admissions to evaluate the influence of nurse-to-patient staffing ratios on inpatient mortality [14–22]. The overarching body of evidence demonstrates a robust and clinically meaningful association between higher registered nurse staffing intensity and improved survival among critically ill adults. Eight of the nine included studies reported statistically significant reductions in ICU, in-hospital, 28-day, or 30-day mortality with more favorable nurse-to-patient or bed-to-nurse ratios [14–20,22], while the ninth study refined this relationship by demonstrating that acuity-weighted nursing workload per nurse—rather than crude patient headcount within a narrow staffing band—was the decisive predictor of in-hospital death [21]. Taken together, these findings reinforce that bedside registered nurse capacity is a foundational determinant of survival in adult critical care rather than a discretionary operational expense.

Understanding why nurse-to-patient ratios exert such a potent effect on ICU mortality requires examining the clinical and cognitive mechanisms operating at the bedside. Critically ill adults exhibit minimal physiological reserve, meaning that subtle perturbations in oxygenation, lactate clearance, cardiac rhythm, or intracranial pressure can rapidly progress to irreversible multi-organ failure or cardiac arrest if unrecognized. Registered nurses provide continuous surveillance and serve as the primary conduit for early recognition and escalation of clinical deterioration. Systematic evidence on surgical failure-to-rescue by Johnston and colleagues confirmed that delayed escalation of care occurs in 20.7% to 47.1% of deteriorating patients and is inversely linked to nurse staffing levels [26]. When an ICU nurse's patient load expands beyond safe cognitive thresholds, care must be implicitly rationed, giving rise to 'missed nursing care' or care left undone. In a landmark nine-country mediation analysis of 422,730 patients, Ball and colleagues proved that missed nursing care directly mediates the pathway between inadequate registered nurse staffing and 30-day inpatient mortality, with each 10% increase in omitted care elevating the odds of death by 16% [23]. Systematic reviews by Griffiths et al. and Recio-Saucedo et al. further corroborated that low registered nurse staffing drives widespread omissions in patient monitoring, turning, oral hygiene, and timely medication administration, precipitating preventable complications and undetected physiological decline [24,25].

In the intensive care setting specifically, these mechanistic pathways manifest through both protocol adherence and infection prevention. Kim and colleagues directly observed that maintaining a 1:2 nurse-to-patient ratio was essential for achieving complete compliance with time-critical severe sepsis resuscitation and management bundles, translating into a 54% relative hazard reduction in 28-day mortality [15]. Notably, broader multistate evidence from 252,699 hospitalized sepsis patients by Dierkes and colleagues demonstrated that each additional patient per nurse increased 30-day and 60-day sepsis mortality by 9% and 10%, respectively, and exerted a stronger survival impact than administrative sepsis protocol compliance alone [29]. Similarly, prospective ICU cohort data from Finland by Jansson and colleagues showed that lower daily nurse-to-patient ratios and elevated nursing workload scores were significantly associated with ventilator-associated pneumonia (23.5% incidence) and 28-day mortality (35.3%), illustrating how understaffing erodes adherence to ventilator care bundles and aseptic technique [27]. Even within traditional 1:2 ICU pairings, emerging research underscores the fragility of nursing attention: Riman and colleagues recently analyzed 20,650 adult ICU patients across 84,544 patient-shifts and found that a patient's risk of 28-day ICU death rose by 82% (HR 1.82, 95% CI 1.39–2.38) when their nurse's co-patient required vasoactive support alone, and by 30% (HR 1.30, 95% CI 1.05–1.61) when the co-patient required both mechanical ventilation and vasoactive infusions [28]. This 'co-patient acuity spillover' provides a compelling clinical explanation for why Margadant and colleagues found NAS-per-nurse ratios superior to static headcount ratios in Dutch ICUs [21]: assigning a nurse two hemodynamically unstable patients creates a fundamentally different mortality risk than assigning one unstable patient alongside a stabilized step-down candidate.

Our qualitative synthesis aligns with and extends prior systematic reviews of nurse staffing in acute and critical care. Whereas Numata and colleagues in 2006 found inconclusive risk-adjusted associations due to small sample sizes and limited confounder adjustment in early ICU literature [6], the subsequent decade of large-scale multicenter registries and shift-level longitudinal studies included in our review [14–22] has largely resolved that ambiguity. Our findings harmonize closely with the meta-analysis by Driscoll and colleagues, which demonstrated a 14% reduction in in-hospital mortality with higher nurse staffing across acute specialist units [7], with the longitudinal systematic review by Dall'Ora and colleagues concluding that a causal link between low registered nurse staffing and inpatient mortality is highly plausible [8], and with recent critical care reviews by Elmdni and Greaves et al. reporting consistent survival gains alongside calls to integrate objective workload measurement tools into staffing governance [11,12]. Importantly, our review also highlights that nurse staffing cannot be evaluated in isolation from nursing

skill mix and interprofessional team structure. Cross-national European research by Aiken and colleagues demonstrated that substituting a nursing assistant for a professional registered nurse per 25 patients increased mortality odds by 21% [30], and longitudinal UK data by Griffiths and colleagues confirmed that adding nursing assistants failed to offset mortality hazards caused by registered nurse shortfalls [31]. Within ICUs, adequate nurse staffing complements—rather than duplicates—high-intensity intensivist coverage [10,15–17] and structured multidisciplinary checklists [16,20], creating a layered defense against preventable critical care death.

These findings carry immediate implications for hospital administrators, critical care leaders, and health policymakers, particularly in the wake of sustained global nursing workforce strain. Chronic understaffing drives a self-reinforcing cycle of emotional exhaustion, burnout, and turnover; as Lasater and colleagues documented across 254 United States hospitals immediately preceding the COVID-19 pandemic, each additional patient per ICU nurse substantially elevated the odds of unfavorable safety ratings and nurse burnout (ORs 1.32 to 3.63) [32]. Encouragingly, prospective policy evaluations indicate that enforceable staffing standards are both clinically effective and economically sustainable. In a landmark prospective panel study of 489,155 patients across Queensland, Australia, McHugh and colleagues demonstrated that legislated minimum nurse-to-patient ratios significantly reduced 30-day mortality (OR 0.89, 95% CI 0.84–0.95) and length of stay in intervention hospitals, while generating avoided hospitalization costs exceeding twice the expenditure of hiring additional nurses [33]. Within adult critical care specifically, Choi and colleagues' recent economic evaluation in cardiogenic shock similarly confirmed that Grade 1 ICU nurse staffing achieved favorable incremental cost-effectiveness ratios well below standard willingness-to-pay thresholds [22]. Consequently, critical care leadership should establish clear baseline ratio ceilings—avoiding assignments exceeding 1:2 for high-acuity adults and strictly preventing shifts above 2.5 patients per nurse [15,18,19]—while maintaining parity across weekend and night shifts [19,20] and deploying dynamic, acuity-weighted tools such as the Nursing Activities Score [9,21] and co-patient severity pairing algorithms [28] to match bedside nursing hours to real-time clinical demand.

Several strengths and limitations of this systematic review merit careful consideration. Key strengths include adherence to PRISMA 2020 methodology [13], strict restriction to adult ICU populations to avoid dilution by general ward or pediatric heterogeneity, inclusion of large multicenter and national registry cohorts across diverse health systems [14–22], and explicit examination of both static ratios and dynamic acuity-weighted workload metrics. Nevertheless, inherent limitations of the underlying evidence base must be acknowledged. First, because randomizing critically ill patients to understaffed ICU shifts is ethically impermissible, all nine included studies were observational; despite rigorous multivariable severity adjustment, residual confounding by unmeasured institutional quality, nurse experience, or specialty certification cannot be completely excluded. Second, wide heterogeneity in staffing definitions—ranging from annual hospital-level bed-to-nurse grades [14,16,22] to shift-level patient-to-nurse ratios [19] and NAS-per-nurse indices [21]—precluded quantitative meta-analysis and prevented derivation of a single universal numeric threshold applicable to every ICU subtype. Third, several studies relied on cross-sectional or point-prevalence designs [14,16,18], which capture staffing at a single window rather than cumulative shift-level exposure throughout an ICU stay. Future research should prioritize prospective, multicenter longitudinal designs leveraging electronic health record time-stamped nurse-patient assignment logs, standardized acuity-adjusted workload instruments, and formal economic evaluations across both high-income and low-to-middle-income critical care systems.

CONCLUSION

This systematic review of nine international observational studies provides compelling evidence that more favorable nurse-to-patient staffing ratios in adult intensive care units are consistently associated with lower ICU, in-hospital, and short-term mortality rates [14–22]. The mortality penalty of understaffing is most severe when patient-to-nurse ratios exceed 2.5, during weekend staffing reductions, and among high-acuity populations such as patients with cardiogenic shock, severe sepsis, or acute stroke. However, because static headcount ratios do not fully capture fluctuations in bedside care complexity, optimal critical care workforce planning should pair enforceable safe minimum staffing ratios with real-time, acuity-weighted workload assessment and preserved registered nurse skill mix to maximize survival and safety for critically ill adults.

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