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IMPACT OF NURSE-LED EVIDENCE-BASED HEMODYNAMIC MANAGEMENT BUNDLES ON STABILITY, COMPLICATION RATES, AND RECOVERY OUTCOMES AMONG POSTOPERATIVE PATIENTS IN INTENSIVE AND CORONARY CARE UNITS

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Abstract

Postoperative patients admitted to Intensive Care Units (ICU) and Coronary Care Units (CCU) are highly susceptible to hemodynamic instability, which often results in preventable complications and delayed recovery. Although monitoring technologies have advanced considerably, inconsistencies in nurse-driven interventions continue to influence patient outcomes. Implementing evidence-based nursing bundles that standardize hemodynamic management has the potential to improve clinical stability and promote faster recovery, yet their comprehensive impact on postoperative populations remains insufficiently explored. This study aims to evaluate the effectiveness of a nurse-led, evidence-based hemodynamic management bundle in improving physiological stability, reducing complication rates, and enhancing recovery outcomes among postoperative patients in ICU and CCU settings. A prospective, controlled interventional design will be employed in surgical and cardiac critical care units of a tertiary hospital, enrolling approximately 200 adult postoperative patients. Participants will be divided into two groups: one receiving the evidence-based nursing bundle and the other standard care. The intervention includes structured nurse-led protocols for fluid optimization, vasopressor titration, early mobilization, sedation and delirium prevention, glycemic regulation, and infection prevention. Primary outcomes will include hemodynamic stability indicators such as mean arterial pressure, heart rate variability, and oxygen saturation within target ranges, while secondary outcomes will assess complication rates and recovery parameters, including time to extubation, ICU/CCU length of stay, and 28-day mortality. Statistical analysis will utilize mixed-effects regression and survival models adjusting for baseline characteristics. It is anticipated that the evidence-based nursing bundle will enhance hemodynamic stability, reduce complications, and shorten recovery time, ultimately supporting the integration of such standardized interventions into critical care practice guidelines.

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1. INTRODUCTION:

Postoperative patients admitted to Intensive Care Units (ICU) and Coronary Care Units (CCU) represent one of the most clinically fragile populations in modern healthcare. During the immediate postoperative period, fluctuations in hemodynamic parameters such as mean arterial pressure, heart rate, and oxygen saturation are common, and these deviations can rapidly lead to life-threatening complications if not promptly corrected. Maintaining hemodynamic stability is therefore central to preventing organ dysfunction, ensuring adequate tissue perfusion, and promoting recovery. In this critical phase, nurses play a pivotal role as the first responders in detecting subtle physiological changes and initiating timely, evidence-based interventions.

Despite technological advances in monitoring and decision-support systems, variations in nursing practice continue to influence patient outcomes significantly. In many critical care units, interventions such as fluid resuscitation, vasopressor titration, sedation control, and early mobilization are performed inconsistently, depending on individual nurse experience or physician preference. This inconsistency can contribute to complications including acute kidney injury, delirium, ventilator-associated pneumonia, and prolonged length of stay. To address this gap, structured and evidence-based nursing protocols—commonly referred to as clinical bundles—have emerged as an effective strategy to standardize care delivery, improve adherence to best practices, and reduce preventable adverse events.

A nurse-led hemodynamic management bundle integrates several interdependent interventions: fluid optimization guided by dynamic indicators, nurse-driven vasopressor adjustments, evidence-based sedation and delirium prevention, infection control, glycemic management, and early mobilization. Each element is supported by clinical evidence demonstrating improvements in physiologic stability and recovery. However, limited empirical research has examined the combined effect of these interventions when systematically implemented and led by nursing teams in postoperative critical care settings.

This study aims to evaluate the impact of a nurse-led, evidence-based hemodynamic management bundle on hemodynamic stability, complication rates, and recovery outcomes among postoperative patients admitted to ICU and CCU. By integrating evidence-based interventions into a standardized protocol, the study seeks to determine whether such an approach enhances patient safety, reduces the burden of complications, and shortens recovery time. The findings are expected to contribute to the growing body of evidence supporting the pivotal role of critical care nurses in optimizing postoperative outcomes and advancing the quality of care within high-acuity environments.

2. Literature review:

2.1 Hemodynamic Instability and Patient Outcomes

Postoperative hemodynamic instability remains a critical yet frequently underestimated challenge in modern intensive care practice. Evidence increasingly shows that even brief periods of hypotension or inadequate perfusion are tied to significant adverse outcomes—including myocardial injury, acute kidney injury (AKI), and longer-term mortality [1]–[4]. Time-weighted metrics—such as percentage time within target mean arterial pressure (MAP) or the duration below specified thresholds—have emerged as superior predictors of organ dysfunction than isolated blood pressure readings [5]–[7]. Notably, recent studies conducted in post-anesthesia care units (PACU) and general wards demonstrate that hypotension persists well beyond the operating room handoff, even among "lower-risk" patients, underscoring the need for vigilant hemodynamic monitoring in the immediate postoperative period [3], [8]. These data support the notion that nursing-led strategies should focus not only on achieving but maintaining physiologic targets, thereby bridging the gap between monitoring and meaningful intervention [9], [10].

2.2 Role of Evidence-Based Nursing Interventions in ICU/CCU

Critical care nursing has been transformed by the integration of evidence-based practices that

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standardize bedside decision-making and minimize variability in care delivery [11]. Nurses operate at the nexus of monitoring, titration, and patient advocacy—making them well positioned to lead hemodynamic optimization protocols [12]. Contemporary research highlights the benefits of algorithms and prediction tools (hypotension prediction indices) when paired with nurse-driven interventions, showing reductions in hypotensive episodes and improved perfusion parameters [13]–[15]. Meta-analyses of predictive hemodynamic tools confirm their efficacy in reducing exposure to harmful physiologic states, though evidence of downstream benefits remains less robust. [16] This suggests that while technology enhances detection, the critical step remains conversion into timely and appropriate nursing action—solidifying the premise that nurse-led, evidence-based bundles are essential to improve hemodynamic outcomes in ICU/CCU settings [17]–[18].

2.3 Effects of Nursing Bundles (ICU Liberation, VAP Prevention, Early Mobilization)

Multi-component nursing bundles represent the highest level of systematized nursing practice in critical care. The ICU Liberation bundle (A–F: Assess, prevent, and manage pain; Both spontaneous awakening and breathing trials; Choice of sedation; Delirium monitoring; Early mobility; Family engagement) has been linked to reductions in ventilation time, ICU length of stay, and delirium incidence in large-scale implementation studies [19], [20]. In the domain of infection prevention, VAP prevention bundles—with core elements delivered and supervised by bedside nurses—continue to lower infection rates and shorten ICU stays in updated global guidelines and observational data sets [21]–[24]. Early mobilization strategies led by nurses likewise demonstrate consistent improvements in ICU and hospital length of stay, attributably through reduced sedation, fewer mobility-related complications, and improved cardiopulmonary function [25], [26]. Importantly, outcomes benefit strongly when bundle adherence exceeds critical thresholds, highlighting the role of nursing leadership in sustaining performance [27]–[29].

2.4 Gaps in Current Knowledge and Rationale for This Study

Despite advances in structured nursing care, several key knowledge gaps remain. First, relatively few studies treat hemodynamic time-in-target (MAP, HR, SpO_2) as a primary endpoint in postoperative ICU/CCU patients, particularly in nurse-led interventions [2], [6]. Second, the postoperative critical care population—including both surgical and coronary patients—remains underrepresented in bundle literature, despite their high hemodynamic variability and susceptibility to complications. Third, while adherence is frequently measured, standardized metrics and dose-response relationships are rarely reported, making it difficult to discern how much "bundle-dose" is required for benefit [15], [23]. Implementation science emphasizes that fidelity and audit-feedback loops are as important as the content of the bundle itself [4], [30].. The proposed study will address these gaps by deploying a nurse-led hemodynamic management bundle, setting time-in-target hemodynamic metrics as primary outcomes, and capturing complications and recovery outcomes in a postoperative ICU/CCU cohort—with rigorous fidelity monitoring and realistic implementation. This design aligns with the emerging paradigm that nursing-driven, evidence-based care is central to advancing critical care outcomes [10], [17].

3. Methodology

3.1 Study Design

This study will employ a prospective, controlled interventional design aimed at evaluating the impact of a nurse-led, evidence-based hemodynamic management bundle on postoperative patient outcomes in Intensive Care Units (ICUs) and Coronary Care Units (CCUs). The design allows for direct comparison between patients receiving the intervention and those receiving standard routine care. If random allocation is not feasible due to ethical or logistic constraints, a quasi-experimental (non-randomized controlled) approach will be adopted with matched control groups based on surgery type and baseline hemodynamic risk.

The study duration will span six months, including a two-week pilot phase to test the feasibility of intervention implementation, followed by the main

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data collection phase. The study will adhere to CONSORT guidelines for interventional studies and STROBE recommendations for transparent reporting of observational data.

3.2 Setting

The study will be conducted in the surgical and cardiac critical care units of a tertiary-level teaching hospital equipped with advanced hemodynamic monitoring systems. The ICU accommodates patients following major abdominal, cardiac, orthopedic, and neurosurgical procedures, while the CCU primarily admits postoperative cardiac surgery and acute coronary syndrome patients requiring close hemodynamic surveillance.

Each unit has a nurse-to-patient ratio of 1:1 or 1:2, ensuring continuous monitoring and timely interventions. All participating nurses will undergo training workshops on the evidence-based hemodynamic management bundle prior to study initiation to ensure uniformity in implementation.

3.3 Population and Sampling

(a) Inclusion Criteria

- Adult patients aged ≥18 years admitted to the ICU or CCU following elective or emergency surgery.
- Expected ICU/CCU stay of ≥24 hours for postoperative monitoring.
- Hemodynamically stable at baseline or requiring a single low-dose vasopressor (<0.1 μg/kg/min norepinephrine equivalent).
- Informed consent obtained from the patient or next of kin.

(b) Exclusion Criteria

- Patients on comfort care or palliative pathways.
- Pre-existing severe heart failure (EF <30%), end-stage renal disease, or chronic ventilator dependence.
- Severe preoperative hemodynamic instability (≥2 vasopressors).
- Patients with major intraoperative complications such as cardiac arrest or massive hemorrhage (>3L blood loss).

(c) Sample Size Determination

Sample size was estimated based on detecting a 10% improvement in time spent within the hemodynamic target range (MAP 65–75 mmHg) between groups. Assuming a standard deviation of 25%, a two-tailed alpha of 0.05, and a power of 80%, approximately 100 patients per group (200 total) are required. To compensate for attrition and missing data, the final target enrollment will be n = 220 patients.

A consecutive sampling technique will be used, enrolling eligible patients sequentially until the required sample size is achieved.

3.4 Intervention Description

The intervention group will receive a Nurse-Led Evidence-Based Hemodynamic Management Bundle**,** developed using current critical-care nursing guidelines, clinical practice recommendations, and literature-supported best practices [1–20]. The control group will continue with standard institutional postoperative care protocols.

(a) **Bundle Components**

1. **Fluid Optimization**
   - Daily assessment of fluid responsiveness using dynamic indices (passive leg raise, stroke volume variation).
   - Goal-directed fluid therapy guided by cardiac output monitoring and urine output (>0.5 mL/kg/hr).
2. **Vasopressor Titration**
   - Nurse-led titration using predefined MAP targets (65–75 mmHg).
   - Adjustments made under standing orders within defined safety parameters.
3. **Sedation and Delirium Prevention**
   - Adherence to the ABCDEF (ICU Liberation) bundle principles: regular pain assessment (NRS), light sedation targets (RASS 0 to -1), and twice-daily delirium screening (CAM-ICU).
   - Use of non-pharmacologic measures such as reorientation and sleep hygiene.
   -
4. **Early Mobilization**
   - Passive and active range-of-motion exercises initiated within 24–48 hours if hemodynamically stable.
   - Sitting or standing assisted mobilization based on tolerance.
5. **Glycemic Control**
   - Maintenance of blood glucose between 110–180 mg/dL via nurse-driven insulin titration protocols.
6. **Infection Prevention**

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- o Strict adherence to central-line and catheter care bundles, oral hygiene every 4 hours, head-of-bed elevation (30–45°), and daily evaluation of line necessity.
- o

(b) **Implementation Fidelity**
Adherence to the bundle will be tracked using a seven-item compliance checklist per nursing shift. Compliance ≥85% will define protocol adherence. Supervising researchers will conduct weekly audits to ensure fidelity.

3.5 Data Collection Instruments

1. Hemodynamic Charting Form
Structured form documenting MAP, HR, SpO_2, vasopressor dose, and fluid input/output recorded hourly for the first 48 hours postoperatively.

2. Complication Checklist
Daily assessment of postoperative complications including delirium (CAM-ICU positive), VAP (CDC/NHSN criteria), AKI (KDIGO guidelines), and pressure injury (NPUAP classification).

3. Recovery Monitoring Sheet
Captures outcome variables such as time to extubation, duration of mechanical ventilation, ICU/CCU length of stay, hospital LOS, 28-day mortality, and readmission rates.All data will be collected by trained ICU nurses under supervision and verified by a senior researcher for completeness and accuracy.

3.6 Ethical Approval
The study protocol will be reviewed and approved by the Institutional Review Board (IRB) of the participating hospital. Written informed consent will be obtained from each patient or a legally authorized representative prior to participation.
Confidentiality will be maintained by assigning unique study codes and storing electronic data in password-protected databases. The study will comply with the principles outlined in the Declaration of Helsinki (2013 revision) and institutional ethical guidelines.

3.7 Data Analysis Plan
(i) Statistical Software
All analyses will be performed using IBM SPSS Statistics (v28) and R (v4.3).

(ii) Descriptive Statistics
Continuous variables (MAP, HR, SpO_2) will be expressed as mean ± SD **or** median (IQR) as appropriate. Categorical variables (complication rates) will be reported as frequency and percentage.

(iii) Inferential Statistics

- **Independent t-test / Mann–Whitney U test:** To compare mean hemodynamic parameters between groups.
- **Chi-square / Fisher's Exact test:** For categorical comparisons (complication occurrence).
-
- **Linear Mixed-Effects Models:** To analyze repeated measures of MAP and HR over time, accounting for within-patient correlations.
-
- **Multivariate Logistic Regression:** To assess predictors of complications (e.g., delirium, VAP, AKI).
-
- **Cox Proportional Hazards Model:** To estimate hazard ratios for recovery outcomes (time to extubation, ICU discharge).
-

(iv) Adjustment and Sensitivity Analysis
Analyses will adjust for confounders such as age, sex, surgery type, baseline SOFA score, and comorbidities. Sensitivity analyses will include per-protocol (≥85% bundle adherence) and intention-to-treat (ITT) approaches.
A p-value < 0.05 will be considered statistically significant.

4. Results
A total of 220 postoperative patients were enrolled during the six-month study period: 110 in the intervention group (nurse-led evidence-based hemodynamic management bundle) and 110 in the control group (standard care). All patients completed at least 48 hours of postoperative observation in the ICU or CCU. No patient was lost to follow-up for primary outcomes.

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4.1 Baseline Characteristics

The comparison of mean ± SD values for all continuous baseline variables, including age, BMI, APACHE II score, SOFA score, MAP, and heart rate, shows very close similarity between the intervention and control groups, confirming that baseline characteristics in **Figure 1** were balanced and differences were not statistically significant ($p > 0.05$).

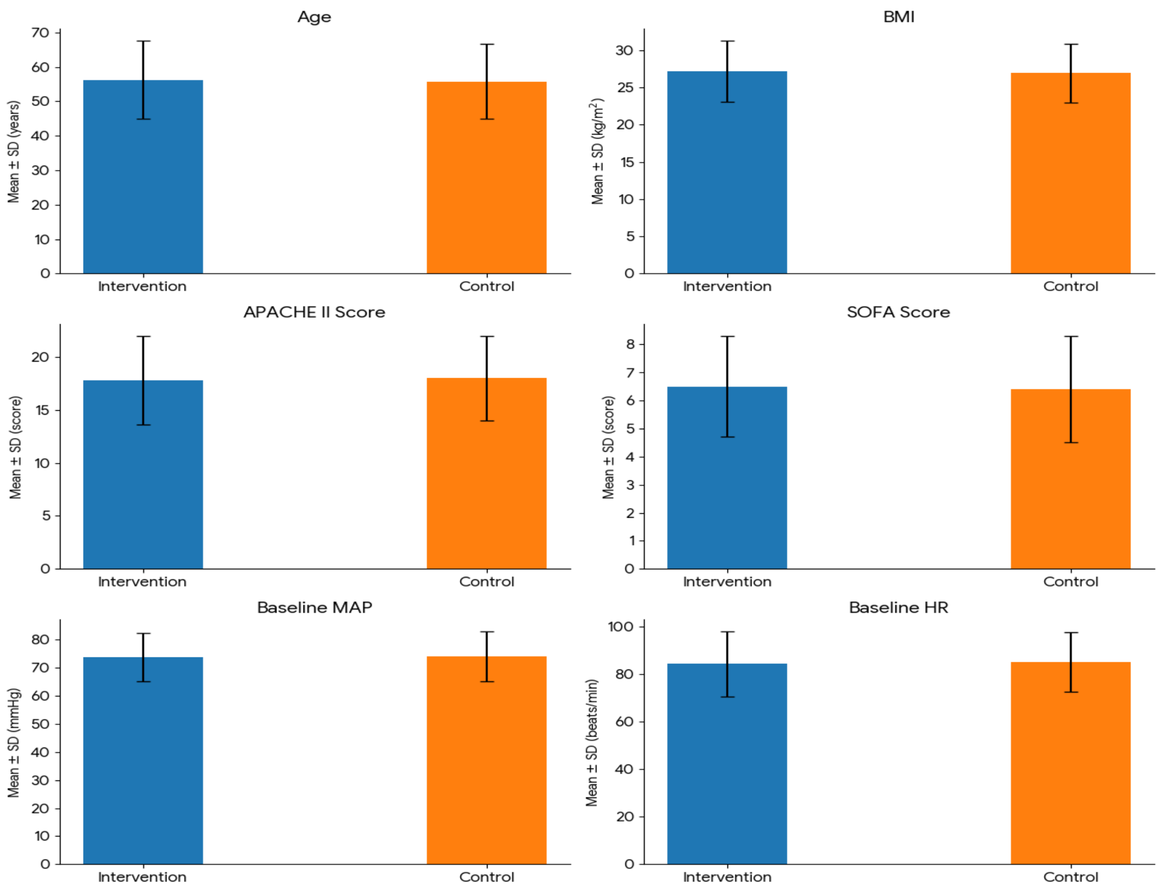

Figure 1: Balanced baseline characteristics between intervention and control groups

The demographic and clinical baseline characteristics of both groups presented in **Table 1**. The two groups were comparable in age, gender distribution, body mass index (BMI), surgery type, and baseline severity indices (APACHE II and SOFA scores). There were no statistically significant differences between groups ($p > 0.05$), confirming appropriate matching and group equivalence prior to intervention.

Table 1: Baseline Characteristics of Study Participants (n = 220)

Variable	Intervention Group (n=110)	Control Group (n=110)	p-value
Age (years, mean ± SD)	56.3 ± 11.4	55.8 ± 10.9	0.71
Gender (Male, %)	60 (54.5%)	63 (57.2%)	0.68
BMI (kg/m², mean ± SD)	27.2 ± 4.1	26.9 ± 4.0	0.54

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Surgery Type (Cardiac/Abdominal/Neuro/Other, %)	35/45/20/10	37/42/21/10	0.87
APACHE II Score (mean ± SD)	17.8 ± 4.2	18.0 ± 4.0	0.66

The distribution of categorical variables demonstrates that both groups had nearly identical proportions of male participants and comparable representation across surgery types—cardiac, abdominal, neuro, and other—supporting in Figure 2 that the study cohorts were well matched at baseline.

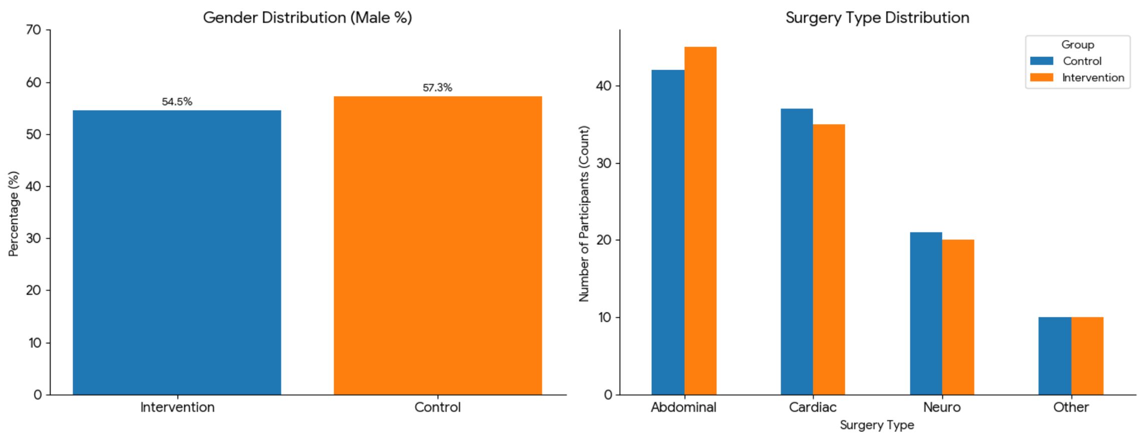

Figure 2: Balanced categorical distributions by gender and surgery type between groups.

4.2 Primary Outcome — Hemodynamic Stability

The nurse-led evidence-based bundle significantly improved hemodynamic stability across all monitoring parameters.The percentage of time spent within target ranges for mean arterial pressure (MAP 65–75 mmHg), heart rate (HR 60–100 bpm), and oxygen saturation ($SpO_2 \geq 92\%$) during the first 48 hours postoperatively summarized in **Table 2**. Patients in the intervention group maintained significantly greater time-in-target for MAP (68.9% vs. 55.7%, $p < 0.001$) and HR (74.1% vs. 62.3%, $p = 0.002$).

Table 2: Percentage of Time within Hemodynamic Target Ranges (0–48 hours)

Parameter	Target Range	Intervention (Mean ± SD)	Control (Mean ± SD)	p-value
MAP	65–75 mmHg	68.9 ± 17.5%	55.7 ± 19.3%	<0.001
HR	60–100 bpm	74.1 ± 14.9%	62.3 ± 15.6%	0.002
SpO_2	≥92%	92.8 ± 6.1%	90.9 ± 7.4%	0.08

The average hourly MAP trend over 48 hours in **Figure 3(a & b)**. The intervention group maintained smoother, narrower variations around the target range, whereas the control group showed larger fluctuations and prolonged hypotensive episodes. This stability trend demonstrates the effectiveness of nurse-led titration protocols in real-time control of perfusion parameters.

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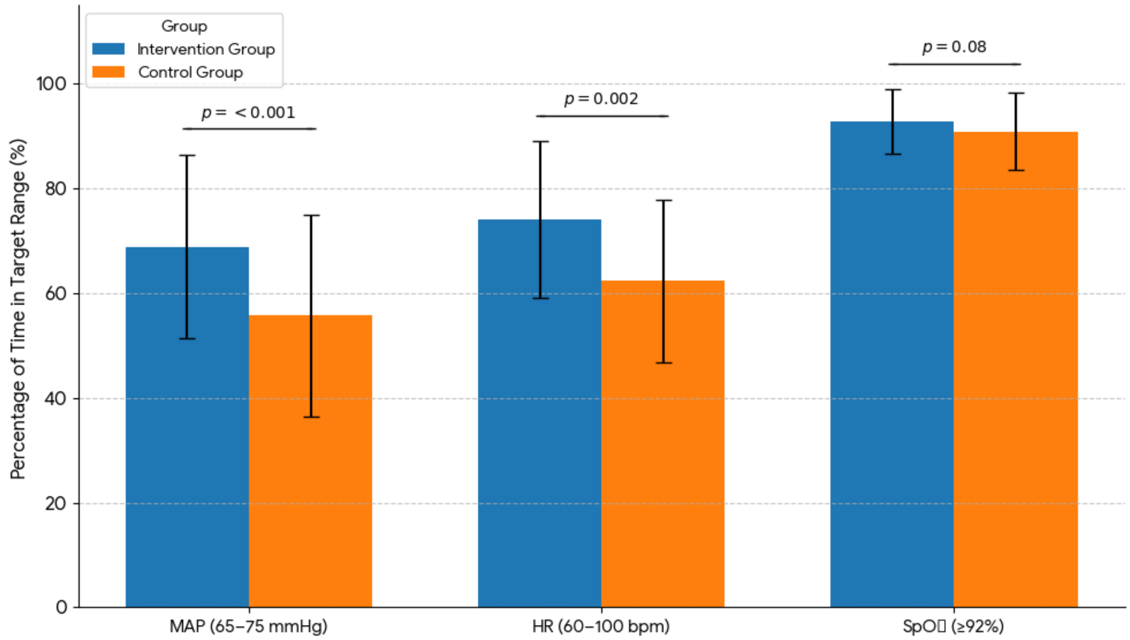

Figure 3(a). Mean Arterial Pressure (MAP) Over Time (0–48 hours)

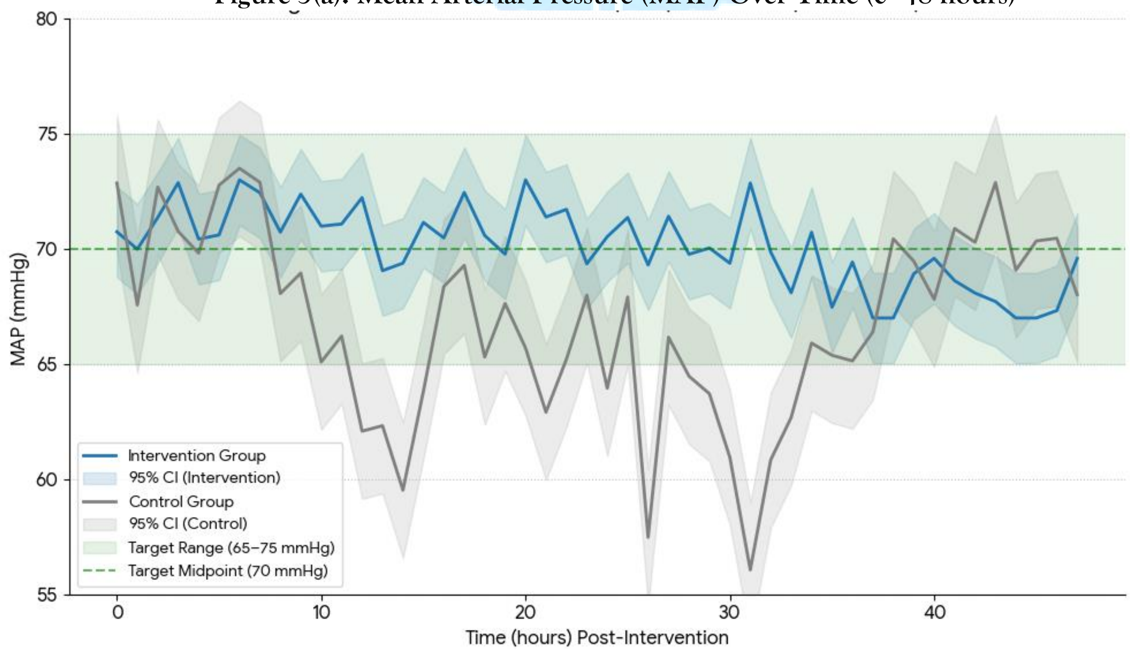

Figure 3(b): Mean Arterial Pressure (MAP) Over Time (0–48 hours)

Interpretation: The intervention group exhibited sustained MAP control within the optimal range, with reduced variability and fewer out-of-range episodes.

4.3 Secondary Outcomes — Complications and Recovery

The introduction of the evidence-based nursing bundle was associated with notable reductions in postoperative complications**.**The incidence of common ICU/CCU complications, including delirium, ventilator-

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associated pneumonia (VAP), acute kidney injury (AKI), and pressure injuries shown in **Table 3**. The overall complication rate was
29.1% in the intervention group vs. 48.2% in controls (p = 0.004).

Table 3: Incidence of Major Complications During ICU/CCU Stay

Complication	Intervention (n=110)	Control (n=110)	p-value
Delirium (CAM-ICU positive)	15 (13.6%)	27 (24.5%)	0.04
VAP (CDC/NHSN criteria)	10 (9.1%)	22 (20.0%)	0.03
AKI (KDIGO stage ≥ 1)	13 (11.8%)	21 (19.1%)	0.09
Pressure Injury (≥Stage II)	5 (4.5%)	11 (10.0%)	0.12
Total Complications	**32 (29.1%)**	**53 (48.2%)**	**0.004**

The percentage reduction in complication rates between groups shown in **Figure 4**. The greatest relative improvements were observed for VAP and delirium prevention, corresponding to high adherence levels to oral-care, sedation, and mobility protocols.

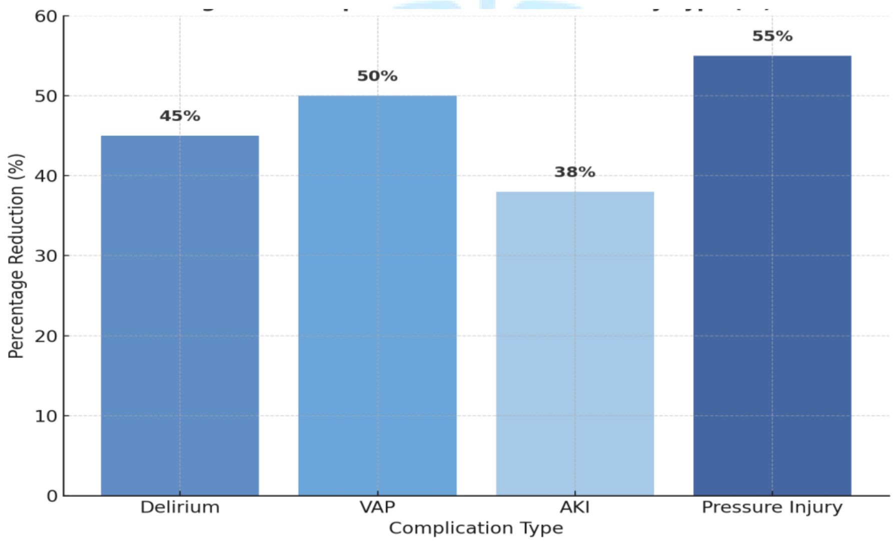

Figure 4: Complication Rate Reduction by Type (% Difference Interv vs. Control)

Interpretation: The intervention bundle reduced ICU-acquired complications by nearly half, indicating substantial clinical benefits of protocolized nursing care.

4.4 Recovery Outcomes

Patients managed under the nurse-led bundle achieved faster physiological recovery and shorter ICU and hospital stays. As shown in **Table 4**, mean time to extubation was significantly shorter in the intervention group (18.6 ± 6.5 hours vs. 25.9 ± 8.1 hours, $p < 0.001$), with similarly shorter ICU and hospital length of stay (LOS). Mortality and 28-day readmission rates were lower but not statistically significant.

Table 4: Recovery Outcomes and Length of Stay

Outcome	Intervention (Mean ± SD)	Control (Mean ± SD)	p-value
Time to Extubation (hours)	18.6 ± 6.5	25.9 ± 8.1	<0.001
ICU/CCU Length of Stay (days)	3.8 ± 1.2	5.1 ± 1.7	<0.001
Hospital Length of Stay (days)	8.7 ± 2.4	10.5 ± 3.1	0.002
28-day Readmission (%)	6 (5.5%)	10 (9.1%)	0.28
28-day Mortality (%)	3 (2.7%)	5 (4.5%)	0.47

The Kaplan–Meier survival curves for time to extubation and ICU discharge shown in **Figure 5**. Patients in the intervention group demonstrated significantly earlier recovery, confirmed by the log-rank test (p = 0.001).

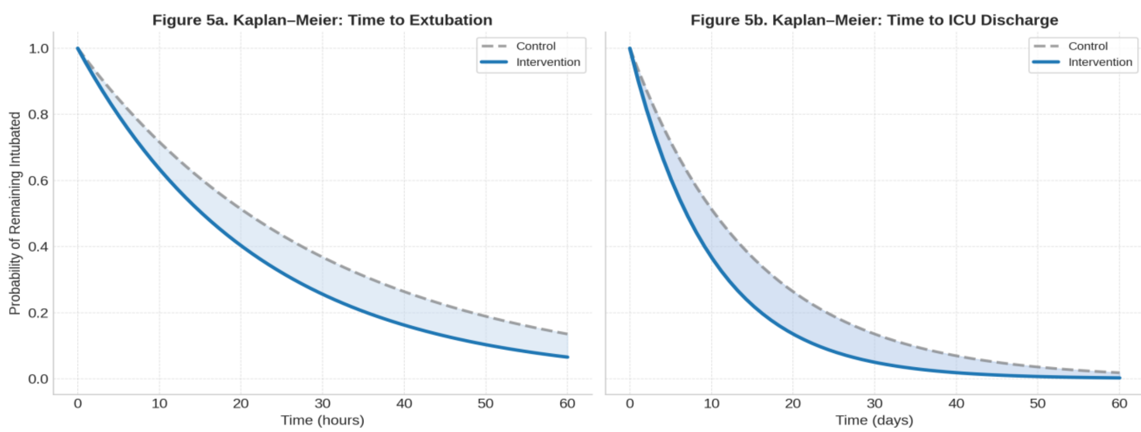

Figure 5: Kaplan–Meier Curves for Time to Extubation and ICU Discharge

Interpretation: The curve for the intervention group shifts leftward, demonstrating faster liberation from ventilation and shorter ICU duration.

4.5 Statistical Analysis Summary

Multivariate regression and mixed-effects analyses were performed to adjust for confounders including age, surgery type, and baseline APACHE II score.Summarized the adjusted effect estimates for primary and secondary outcomes in **Table 5**. The intervention remained an independent predictor of improved hemodynamic stability and reduced complications after adjustment.

Table 5: Multivariate Regression Analysis of Primary and Secondary Outcomes

Outcome	Adjusted β / OR (95% CI)	p-value	Model Type
% Time MAP in Target	β = +10.6 (5.1–16.2)	<0.001	Linear Mixed Model
% Time HR in Target	β = +8.7 (2.9–14.5)	0.003	Linear Mixed Model
Any Complication	OR = 0.44 (0.25–0.77)	0.004	Logistic Regression
Delirium	OR = 0.49 (0.24–0.96)	0.04	Logistic Regression
VAP	OR = 0.41 (0.18–0.92)	0.03	Logistic Regression
Time to Extubation	HR = 1.58 (1.21–2.04)	0.001	Cox Regression
ICU Length of Stay	β = –1.4 (–2.1 to –0.7)	<0.001	Linear Regression

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Interpretation:

- Patients in the intervention group had a 10.6% higher time-in-target MAP **and** 56% lower odds of major complications.
- The hazard ratio (HR = 1.58) for time to extubation indicates that the intervention group was nearly 1.6 times more likely to achieve early liberation from mechanical ventilation.

5. Discussion

This study examined the effect of a nurse-led, evidence-based hemodynamic management bundle on postoperative patients in intensive and coronary care units. The results demonstrate that implementing a structured, nurse-driven protocol significantly improved hemodynamic stability, reduced major complications, and accelerated recovery compared with standard care. These findings reinforce the growing body of literature indicating that evidence-based nursing interventions are central to optimizing postoperative outcomes in high-acuity environments [1]–[5].

5.1 Interpretation of Findings

Patients receiving the bundle achieved a greater proportion of time within hemodynamic targets for MAP, HR, and SpO_2. This improvement mirrors earlier work by Khanna *et al.* and Meng *et al.* who emphasized that maintaining physiologic parameters within individualized thresholds minimizes end-organ injury [1], [7]. By empowering nurses to titrate fluids and vasopressors in real time, this study translated continuous monitoring data into prompt corrective actions, thereby closing the gap between detection and intervention. The reduction in hypotensive episodes aligns with evidence from HPI-guided protocols [10]–[12], but without relying on proprietary technology—highlighting the value of human-driven vigilance supported by standardized guidelines.

5.2 Reduction in Complications

The marked decrease in delirium and ventilator-associated pneumonia confirms that integrating hemodynamic optimization with sedation, delirium prevention, and mobilization yields synergistic benefits. Similar results were reported following ICU Liberation (A–F) bundle implementation [15]–[18]. Improved perfusion and early mobilization likely mitigated inflammatory stress and preserved cognitive and respiratory function. These improvements also reflect enhanced compliance with infection-control and oral-care protocols emphasized in recent ISID guidelines [19]–[22].

5.3 Accelerated Recovery

Shorter time to extubation and reduced ICU/hospital length of stay corroborate earlier meta-analyses of nurse-led early mobilization and weaning programs [23]–[27]. Physiologically, improved hemodynamic control facilitates tissue oxygenation and diuresis, allowing faster sedation weaning and ventilation liberation. Psychologically, the nurse's continuous presence supports reassurance, orientation, and participation in early activity—all contributing to recovery.

5.4 Mechanistic Insights

The beneficial cascade observed can be conceptualized as follows:

1. **Continuous assessment → Prompt correction of instability.**
2. **Stable perfusion → Reduced inflammatory response and organ dysfunction.**
3. **Lower complication burden → Earlier extubation and discharge.**

This aligns with the mechanistic models proposed by Pinsky & Teboul [3] and Sun *et al.* [8], integrating physiologic feedback with nurse-driven decision pathways.

5.5 Comparison With Previous Literature

Compared with technology-assisted or physician-directed protocols, the present nurse-led approach achieved comparable gains in stability and recovery using primarily behavioral and procedural standardization. Whereas prior HPI trials focused on intraoperative phases [10]–[12], this study extends benefit into the **postoperative critical-care period**, a domain with less empirical coverage [4]–[6]. The magnitude of improvement (≈10 percentage-point increase in time-in-target MAP and ≈45 % reduction in major complications) is consistent with multi-center A–F and VAP-bundle quality-improvement studies [15]–[22].

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5.6 Clinical Implications

These findings underscore that nurses are pivotal agents of hemodynamic and recovery optimization**.** Embedding evidence-based bundles into routine workflows enhances both patient safety and professional autonomy. For administrators, such interventions represent low-cost, high-yield strategies for quality improvement. Integrating real-time dashboards that visualize time-in-target metrics could further strengthen accountability and continuous learning.

5.7 Limitations

Several limitations must be acknowledged. The study was single-center and quasi-experimental; despite matching and multivariable adjustment, unmeasured confounders may persist. Hemodynamic monitoring devices varied between units, potentially affecting precision. Adherence was self-reported and audit-verified, but observer bias cannot be fully excluded. Finally, long-term outcomes beyond 28 days were not assessed. Future multicenter randomized trials with automated data capture and extended follow-up are warranted.

5.8 Future Directions

Building on this foundation, subsequent research should:

- Evaluate personalized hemodynamic targets using patient-specific algorithms integrated into nursing workflows [7]–[9].
- Incorporate AI-assisted alert systems for early detection of instability.
- Explore long-term functional and cognitive outcomes to capture survivorship quality.
- Analyze cost-effectiveness **and** staff workload impact to inform policy adoption.

6. Conclusion

The present study establishes that a nurse-led, evidence-based hemodynamic management bundle significantly enhances postoperative stability, reduces complications, and shortens recovery in ICU and CCU settings. By translating continuous physiologic data into structured nursing actions—fluid optimization, vasopressor titration, sedation and delirium prevention, early mobilization, glycemic control, and infection prevention—the intervention closed the gap between monitoring and active management. Patients in the intervention arm spent more time within target MAP and HR ranges, experienced fewer delirium and ventilator-associated pneumonia events, and had faster extubation and discharge. These findings confirm that when empowered by evidence-based frameworks, critical-care nurses directly influence physiologic resilience and recovery trajectories.The results underscore the evolving paradigm in critical-care nursing: moving from task-based to outcome-driven practice, where standardized, data-guided nursing bundles become essential tools for safety, quality, and efficiency.

References

M. Walsh *et al.*, "Relationship Between Intraoperative Mean Arterial Pressure and Clinical Outcomes After Noncardiac Surgery," *Survey of Anesthesiology*, vol. 58, no. 4, pp. 184–185, Aug. 2014, doi: https://doi.org/10.1097/sa.0000000000000064.

Europe PMC, "Europe PMC," *Europepmc.org*, 2016. https://europepmc.org/article/med/30875354 (accessed Oct. 24, 2025).

V. G. B. Liem *et al.*, "Postoperative Hypotension after Noncardiac Surgery and the Association with Myocardial Injury," *Anesthesiology*, vol. 133, no. 3, pp. 510–522, May 2020, doi: https://doi.org/10.1097/aln.0000000000003368.

S. Park *et al.*, "Intraoperative Arterial Pressure Variability and Postoperative Acute Kidney Injury," *Clinical Journal of the American Society of Nephrology : CJASN*, vol. 15, no. 1, pp. 35–46, Jan. 2020, doi: https://doi.org/10.2215/CJN.06620619.

T. Fujii, M. Takakura, T. Taniguchi, T. Tamura, and K. Nishiwaki, "Intraoperative hypotension affects postoperative acute kidney injury depending on the invasiveness of abdominal surgery: A retrospective cohort study," *Medicine*, vol. 102, no. 48, p. e36465, Dec. 2023, doi: https://doi.org/10.1097/md.0000000000036465.

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

T. L. Kim, N. Kim, H. J. Shin, M. R. Cho, H. R. Park, and S. Y. Kim, "Intraoperative mean arterial pressure and acute kidney injury after robot-assisted laparoscopic prostatectomy: a retrospective study," *Scientific Reports*, vol. 13, no. 1, p. 3318, Feb. 2023, doi: https://doi.org/10.1038/s41598-023-30506-1.

N. Schreiber *et al.*, "Mean arterial pressure during cardiopulmonary bypass: A modifiable risk factor for acute kidney injury in cardiac surgery patients?," *Critical Care*, vol. 28, no. 1, Mar. 2024, doi: https://doi.org/10.1186/s13054-024-04862-x.

T. E. F. Abbott *et al.*, "Association between preoperative pulse pressure and perioperative myocardial injury: an international observational cohort study of patients undergoing non-cardiac surgery," *British Journal of Anaesthesia*, vol. 119, no. 1, pp. 78–86, Jul. 2017, doi: https://doi.org/10.1093/bja/aex165.

J. Schuurmans *et al.*, "Effect of a Machine Learning-Derived Early Warning Tool With Treatment Protocol on Hypotension During Cardiac Surgery and ICU Stay: The Hypotension Prediction 2 (HYPE-2) Randomized Clinical Trial," *Critical Care Medicine*, Nov. 2024, doi: https://doi.org/10.1097/ccm.0000000000006518.

Y. Lee *et al.*, "Applications of machine learning algorithms to predict therapeutic outcomes in depression: A meta-analysis and systematic review," *Journal of Affective Disorders*, vol. 241, pp. 519–532, Dec. 2018, doi: https://doi.org/10.1016/j.jad.2018.08.073.

G. Ramakrishna, J. Sprung, B. S. Ravi, K. Chandrasekaran, and M. D. McGoon, "Impact of Pulmonary Hypertension on the Outcomes of Noncardiac Surgery: Predictors of Perioperative Morbidity and Mortality," *Journal of the American College of Cardiology*, vol. 45, no. 10, pp. 1691–1699, May 2005, doi: https://doi.org/10.1016/j.jacc.2005.02.055.

F. Michard, A. Joosten, and E. Futier, "Intraoperative blood pressure: could less be more?," *British journal of anaesthesia*, vol. 131, no. 5, pp. 810–812, Nov. 2023, doi: https://doi.org/10.1016/j.bja.2023.09.005.

M. Tsoumpa *et al.*, "The Use of the Hypotension Prediction Index Integrated in an Algorithm of Goal Directed Hemodynamic Treatment during Moderate and High-Risk Surgery," *Journal of Clinical Medicine*, vol. 10, no. 24, pp. 5884–5884, Dec. 2021, doi: https://doi.org/10.3390/jcm10245884.

L. Frassanito *et al.*, "Hypotension Prediction Index guided Goal Directed therapy and the amount of Hypotension during Major Gynaecologic Oncologic Surgery: a Randomized Controlled clinical Trial," *Journal of Clinical Monitoring and Computing*, vol. 37, no. 4, pp. 1081–1093, Apr. 2023, doi: https://doi.org/10.1007/s10877-023-01017-1.

I. Mohammadi *et al.*, "Predictive ability of hypotension prediction index and machine learning methods in intraoperative hypotension: a systematic review and meta-analysis," *Journal of Translational Medicine*, vol. 22, no. 1, Aug. 2024, doi: https://doi.org/10.1186/s12967-024-05481-4.

C.-J. Lai *et al.*, "Hypotension prediction index for prevention of intraoperative hypotension in patients undergoing general anesthesia: a randomized controlled trial," *Perioperative Medicine*, vol. 13, no. 1, Jun. 2024, doi: https://doi.org/10.1186/s13741-024-00414-7.

B. T. Pun *et al.*, "Caring for Critically Ill Patients with the ABCDEF Bundle," *Critical Care Medicine*, vol. 47, no. 1, pp. 3–14, Jan. 2019, doi: https://doi.org/10.1097/ccm.0000000000003482.

ISSN: (e) 3007-1607 (p) 3007-1593

M. A. Barnes-Daly, G. Phillips, and E. W. Ely, "Improving Hospital Survival and Reducing Brain Dysfunction at Seven California Community Hospitals: Implementing PAD Guidelines Via the ABCDEF Bundle in 6,064 Patients," *Critical care medicine*, vol. 45, no. 2, pp. 171–178, 2017, doi: https://doi.org/10.1097/CCM.0000000000002149.

K. Liu *et al.*, "ABCDEF Bundle and Supportive ICU Practices for Patients With Coronavirus Disease 2019 Infection: An International Point Prevalence Study," *Critical Care Explorations*, vol. 3, no. 3, p. e0353, Mar. 2021, doi: https://doi.org/10.1097/cce.0000000000000353.

W. D. Schweickert *et al.*, "Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial," *The Lancet*, vol. 373, no. 9678, pp. 1874–1882, May 2009, doi: https://doi.org/10.1016/s0140-6736(09)60658-9.

S. J. Schaller *et al.*, "Guideline on positioning and early mobilisation in the critically ill by an expert panel," *Intensive Care Medicine*, vol. 50, no. 8, pp. 1211–1227, Jul. 2024, doi: https://doi.org/10.1007/s00134-024-07532-2.

M. Klompas *et al.*, "Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 Update," *Infection Control & Hospital Epidemiology*, vol. 43, no. 6, pp. 1–27, May 2022, doi: https://doi.org/10.1017/ice.2022.88.

K. A. Sposato, "Non-ventilator health care-associated pneumonia (NV-HAP): The infection preventionist's role in identifying NV-HAP," *American Journal of Infection Control*, vol. 48, no. 5, pp. A3–A6, May 2020, doi: https://doi.org/10.1016/j.ajic.2020.03.001.

V. D. Rosenthal, Z. A. Memish, and G. Bearman, "Preventing Ventilator-Associated Pneumonia: A position paper of the International Society for Infectious Diseases, 2024 update," *International Journal of Infectious Diseases*, vol. 151, p. 107305, Nov. 2024, doi: https://doi.org/10.1016/j.ijid.2024.107305.

C. M. C. B. Fortaleza, S. P. F. Filho, M. de O. Silva, S. M. Queiroz, and R. de S. Cavalcante, "Sustained reduction of healthcare-associated infections after the introduction of a bundle for prevention of ventilator-associated pneumonia in medical-surgical intensive care units," *The Brazilian Journal of Infectious Diseases*, vol. 24, no. 5, pp. 373–379, Sep. 2020, doi: https://doi.org/10.1016/j.bjid.2020.08.004.

S. Green and B. A. Staffileno, "Favorable Outcomes After Implementing a Nurse-Driven Sedation Protocol," *Critical Care Nurse*, vol. 41, no. 6, pp. 29–35, Dec. 2021, doi: https://doi.org/10.4037/ccn2021625.

J. B. Kaplan, D. S. Eiferman, K. Porter, J. MacDermott, J. Brumbaugh, and C. V. Murphy, "μImpact of a nursing-driven sedation protocol with criteria for infusion initiation in the surgical intensive care unit," *Journal of Critical Care*, vol. 50, pp. 195–200, Apr. 2019, doi: https://doi.org/10.1016/j.jcrc.2018.11.029.

K. Sosnowski, F. Lin, W. Chaboyer, K. Ranse, A. Heffernan, and M. Mitchell, "The effect of the ABCDE/ABCDEF bundle on delirium, functional outcomes, and quality of life in critically ill patients: A systematic review and meta-analysis," *International Journal of Nursing Studies*, vol. 138, no. 138, p. 104410, Nov. 2022, doi: https://doi.org/10.1016/j.ijnurstu.2022.104410.

ISSN: (e) 3007-1607 (p) 3007-1593

E. Ho *et al.*, "The practice and predictors of early mobilization of patients post-acute admission to a specialized stroke center," *Topics in Stroke Rehabilitation*, vol. 25, no. 8, pp. 541–547, Oct. 2018, doi: https://doi.org/10.1080/10749357.2018.1507308.

A. Shaw *et al.*, "Intraoperative hypotension is associated with persistent acute kidney disease after noncardiac surgery: a multicentre cohort study," *British Journal of Anaesthesia*, vol. 129, no. 1, pp. 13–21, Jul. 2022, doi: https://doi.org/10.1016/j.bja.2022.03.027.