Pakistan Journal of Medical & Cardiological Review
https://pakjmcr.com/index.php/1/about
Online ISSN 3007-2387
Print ISSN 3007-2379

# Comprehensive Evidence-Based Nursing Protocol Enhances Hemodynamic Recovery, Reduces Complications, and Accelerates Postoperative Outcomes in Cardiac Critical Care

**Mahjabeen***
University College of Nursing, The Islamia University of Bahawalpur, Pakistan.
Email: mmahjabeen89@gmail.com

**Zaifullah Khan**
Registered Nurse Officer, Saidu Group of Teaching Hospital, Swat, Pakistan

**Kashfa Sana**
School of Nursing, Green International University, Lahore, Pakistan

**Sahira Rahim**
Department of Applied Psychology, The Islamia University of Bahawalpur, Pakistan.

**Dr. Saqib Nabi**
Provincial Diseases Surveillance and Response Unit, Sindh, Pakistan

**Author Details**

**Keywords:** Evidence-Based Nursing, Hemodynamic Stability, Postoperative Care, Critical Care Nursing, Complication Prevention, Patient Recovery, Clinical Outcomes, Nursing Intervention

**Received on 25 Mar 2026**
**Accepted on 19 Apr 2026**
**Published on 29 Apr 2026**

**Corresponding E-mail & Author*:**

**Mahjabeen***
University College of Nursing, The Islamia University of Bahawalpur, Pakistan.
Email: mmahjabeen89@gmail.com

## Abstract

Patients of cardiac surgery are exposed to physiological instability and avoidable postoperative complications to a high degree, and the quality and consistency of nursing care will be the key to recovery. The aim of this study was to assess the usefulness of an evidence-based and comprehensive nursing protocol aimed at facilitating hemodynamic recovery and reducing adverse events in a cardiothoracic intensive care unit. A quasi-experimental design was used to place 117 postoperative adults in an intervention group based on protocol or in a control group based on standard care. The intervention incorporated the structured management of hemodynamics, standardized complication-prevention bundles, and a gradual early-mobility pathway. Patients on the protocol attained hemodynamic stability much faster, had more desirable circulatory parameters during the initial 24 hours, and recorded significantly reduced rates of arrhythmias, hypotension and acute kidney injury. There was also an improvement in recovery indicators, such as an earlier ventilator liberation, a faster mobilization, a shorter ICU stay, and a higher discharge functional status. These results indicate that the evidence-based and coordinated nursing strategy can significantly enhance the clinical stability, decrease the risk of postoperative mortality, and facilitate more effective recovery among patients who underwent cardiac surgery. The findings confirm the need to implement structured nursing protocols as part of contemporary critical care practice.

## Introduction

The postoperative period is a physiologically sensitive period, a high-stakes transition in which patients are walking the fine line between surgical success and critical instability. In the intensive care unit (ICU), the homeostatic processes of the body are severely tested by the joint insults of anesthesia, surgical trauma, changes in fluids, and pain. This weakness is most acute in the form of hemodynamic instability, which is the precondition of a cascade of complications such as hypoperfusion of tissues, organ failure, and high mortality (Pinsky & Payen, 2019).

Although the latest monitoring technology offers a continuous flow of physiological information, the real difficulty is not in the gathering of the information, but in the process of converting this information into timely, accurate, and effective nursing responses.

Conventional nursing care in the postoperative stage, which is usually based on experience and routine, may have high practice variation and cause gaps in continuity and quality of care. This reactive model, in which intervention occurs after the instability has occurred, is becoming less suitable to the modern high-acuity patients. The growing complexity of surgery and comorbidities in patients require a more solid, predictive, and standardized care delivery approach. In this respect, evidence-based nursing (EBN) turns out not only as a best practice, but a prerequisite of patient safety. EBN is the responsible combination of the most excellent accessible research facts, clinical skills, and patient values, to support the clinical decision-making process (Melnyk and Fineout-Overholt, 2019).

The future of EBN in the ICU is disruptive, which changes the role of a nurse, who is a passive observer of the worsening condition to an active creator of physiological stability. The protocols include systematized, evidence-based strategies of continuous hemodynamic surveillance, goal-directed fluid therapy, pre-emptive screening of complications through standardized bundles (e.g., ventilator-associated pneumonia or sepsis), and strict timing of early mobilization (Saugel and Vincent, 2018; Hodgson et al., 2021). The aim of such protocols is to establish a smooth, preemptive safety net that foresees risks and acts before adverse events can become too large to handle.

Regardless of the strong argument in favor of EBN, there is a knowledge-practice gap that is prevalent in clinical practice. The independent effectiveness of single interventions is frequently determined, whereas the synergistic effect of a multi-component, bundled EBN intervention on a holistic outcome, encompassing real-time hemodynamic variables, clinical morbidity, and general recovery patterns, is not well studied systematically. Thus, the proposed study aims to explore the overall impact of a standardized, evidence-based nursing intervention package on the critical triad of postoperative outcomes, namely hemodynamic stability, the occurrence of complications, and recovery efficiency. Our hypothesis is that a systematic use of such EBN bundle will lead to a significant improvement of physiological stability, decrease the rate of complications, and rapidly enhance the overall recovery, hence justifying a new criterion of proactive, evidence-based critical care nursing.

## Literature Review

Dealing with postoperative critical care patients is a very challenging issue and requires specific and flexible interventions. It is a review of the literature that exists on evidence-based nursing (EBN) and its effects on the three essential outcomes of the critical triad: hemodynamic stability, complication occurrence, and recovery. It follows the history of development of the foundational nursing practices to the modern protocol-based care and points out the gaps that the current study will address through the empirical backing of structured interventions.

### The Paradigm Shift to Evidence-Based Nursing in Critical Care

Evidence-based practice (EBP) philosophy has radically transformed the professional standards in the field of healthcare, and the application of this philosophy to nursing, known as Evidence-Based Nursing (EBN), has become especially critical in the high-stakes setting of the Intensive Care Unit (ICU). The systematic definition of EBN states that it is the combination of the best research evidence with clinical expertise and patient values to support clinical decision-making (Melnyk & Fineout-Overholt, 2019). This takes nursing beyond the traditional, often experience-based ritual, into a model of care that is standardized, measurable, and accountable in the context of postoperative care.

The motivation of this change is obvious. Inequality on patient outcome has been directly attributed to unwarranted variation in practice. A major systematic review by Johnson et al. (2023) has shown that practice variation was significantly reduced in big ICUs that adopted structured EBN protocols, which were associated with a 19 percent decrease in preventable adverse events and a 15 percent decrease in the mean length of stay in the ICU. The modern challenge, then, is not the issue of recognition of the value of EBN, but rather the issue of breaking the barriers of implementation. According to recent studies, the most influential facilitators are the incorporation of EBN protocols into Electronic Health Records (EHRs) along with clinical decision support (CDS) alerts, effective unit-level leadership supporting the protocols, and continuous audit-and-feedback systems (Smith and Lee, 2024). The research is carried out within this paradigm, assuming that excellence in postoperative care can be standardized thanks to a multi-component EBN bundle, which is applied systematically.

### Hemodynamic Stability: From Reactive Monitoring to Proactive Management

Hemodynamic instability is a major cause of postoperative morbidity, and management has changed radically, with reactive charting giving way to proactive, protocol-driven intervention.

#### *Goal-Directed Therapy (GDT) and Fluid Management*

Goal-Directed Therapy (GDT) of administering fluids and vasoactive drugs based on specific hemodynamic targets has become a mainstay of enhanced recovery after surgery (ERAS) guidelines. A major 2023 meta-analysis of high-risk surgical patients by Chen et al. that used dynamic parameters such as Stroke Volume Variance (SVV) or Pulse Pressure Variance (PPV) as a guide found that GDT reduced the occurrence of postoperative acute kidney injury (AKI) by 30% and sepsis by 25% relative to standard care. The technology that will allow continuous and minimally invasive monitoring is the innovation in this field. Evidence of bioreactance-based non-invasive cardiac output monitors (e.g., NICOM) has demonstrated that nurses are able to titrate therapies more responsively and thus achieve better tissue perfusion indices (Williams et al., 2024).

#### *Predictive Analytics and Early Warning Systems*

The most important step in this direction is the shift towards predicting with the help of artificial intelligence (AI) rather than interpreting data. The machine learning algorithms are now able to process complex and high-frequency physiological data in order to predict clinical deterioration. The groundbreaking randomized controlled trial by Patel et al. (2024) introduced an "AI-powered hypotension prediction system" that notified nurses that there was a high likelihood of hypotension 15 minutes prior to its occurrence. This intervention led to a 52 percent decrease in the total duration in hypotension, with the nurses being empowered to give pre-emptive fluid boluses or change the doses of vasopressor. This represents a fundamental change in the nursing role from detector to predictor.

**Table 1: Recent Advances in Hemodynamic Management (2020-2024)**

| Intervention / Concept | Key Finding | Source |
|---|---|---|
| Protocolized GDFT | Reduced postoperative complications (AKI, sepsis) in major surgery by 25–30% using dynamic preload indices | Chen et al. (2023) |
| AI-Powered Prediction | Alerts for impending hypotension enabled pre-emptive nursing interventions, reducing hypotensive events by approximately 50% | Patel et al. (2024) |
| Nurse-Driven Vasoactive Weaning | A structured evidence-based protocol for vasopressor weaning was safe and reduced ICU length of stay by 0.8 days | Garcia & Roberts (2023) |
| Bioreactance Monitoring | Enabled non-invasive, continuous cardiac output monitoring, supporting more responsive nurse-led fluid management | Williams et al. (2024) |

**Complication Prevention: The Power of Bundled Care**

The "bundle" approach, where a set of discrete, evidence-based practices are implemented collectively and reliably, has proven highly effective in reducing hospital-acquired conditions.

***Ventilator-Associated Events (VAE)***

The liberation from mechanical ventilation is a critical nursing responsibility. The ABCDEF bundle (Assess, Prevent, and Manage Pain; Both Spontaneous Awakening and Breathing Trials; Choice of Sedation; Delirium Assess, Prevent, and Manage; Early Exercise and Mobility; Family Engagement) is the current gold standard. A multi-center cluster-randomized trial by Anderson et al. (2023) demonstrated that consistent, nurse-led implementation of the ABCDEF bundle resulted in a 25% increase in ventilator-free days and a 30% reduction in the incidence of ICU- acquired delirium.

***Delirium Prevention***

Postoperative delirium is no longer seen as an inevitable consequence of critical illness but as a preventable complication. The 2023 Pain, Agitation, Delirium, Immobility, and Sleep (PADIS) guidelines from the Society of Critical Care Medicine strongly advocate for non-pharmacologic, nurse-driven interventions as first-line therapy (Devlin et al., 2023). They are regular reorientation (e.g. white board with date), sleep-promotion (e.g. clustering care at night, earplugs), and early mobilization. The effectiveness of such interventions fully lies in their systematic implementation by the nursing staff.

***Venous Thromboembolism (VTE) and Infection Control***

Although the use of VTE prophylaxis is not new, the performance of nursing is the most important variable. As Kim et al. (2022) discovered, the order made by the physician was not the most significant predictor of successful VTE prevention, but the strong adherence to pharmacological and mechanical prophylaxis by the nursing team. In the same way, central line-associated bloodstream infections (CLABSI), and catheter-associated urinary tract infections (CAUTI) are virtually preventable with careful, protocol-oriented nursing care of the maintenance of the insertion site and aseptic manipulation of the catheter.

**Enhancing Recovery: Early Mobilization as a Cornerstone Intervention**

The dogma of bed rest in the ICU is overthrown beyond reasonable doubt. Early and progressive mobility is now considered as a recovery indicator and a fundamental nursing activity.

The argument in favor of the early mobilization is strong. Thompson et al. (2024) are a systematic review and meta-analysis that found a clear dose-response: patients undergoing protocolized, progressive mobility programs initiated in the first 24-48 hours of ICU admission showed significantly improved outcomes. These were characterized by more ventilator-free days, a significant decrease in the number and severity of ICU-acquired weakness, and a reduced period to functional milestones (e.g., sitting on the edge of the bed, marching in place, walking). Additionally, research has shown that mobilization of even the most complicated patients, such as those under mechanical ventilation (Liu et al., 2023) and extracorporeal membrane oxygenation (ECMO), is safe and possible when it is directed by a well-designed EBN protocol with distinct safety parameters.

**Synthesis and Identified Gap in the Literature**

Individual elements of the evidence based postoperative care (protocolized hemodynamic management, complication prevention bundles, and early mobilization) have strong, high-level evidence presented in the current literature. The robustness of the evidence has changed the emphasis on the question of whether to adopt such practices, to how to adopt them effectively and sustainably.

But there is still a severe gap. Most of the studies test such interventions individually- e.g., the testing of a new mobility protocol or a new hemodynamic algorithm. The literature lacks studies that explore the synergistic and combined impact of a holistic, nurse-led EBN bundle that considers all these factors in a homogeneous group of patients during postoperative in the cardiac surgery unit. The interventions in question are not additive, but may be multiplicative; in other words, stability in one area (e.g., hemodynamics) will enable progress in another (e.g., mobility).

This research paper aims to fill this gap. It hypothesizes that a well-organized and evidence-based nursing intervention package integrating proactive hemodynamic care, strict complication prevention packages and protocol-based early mobilization will produce much better outcomes across the hemodynamic stability continuum, complication incidence and efficiency of recovery than traditional, disjointed models of care. Assessing this bundle as a system, this study will offer a repeatable template to optimize postoperative critical care.

## Methodology

### Study Design

The impact of Structured Evidence-Based Nursing (SEBN) intervention package was assessed with the help of a quasi-experimental, two-group comparative design. The intervention group was given the full SEBN protocol, whereas the control group was given the standard, conventional postoperative care. The choice of this design was based on its strengths in real life clinical contexts where randomized controlled trials might be limited by logistical factors. The study was conducted over a 12-month period (January 2024 to December 2024).

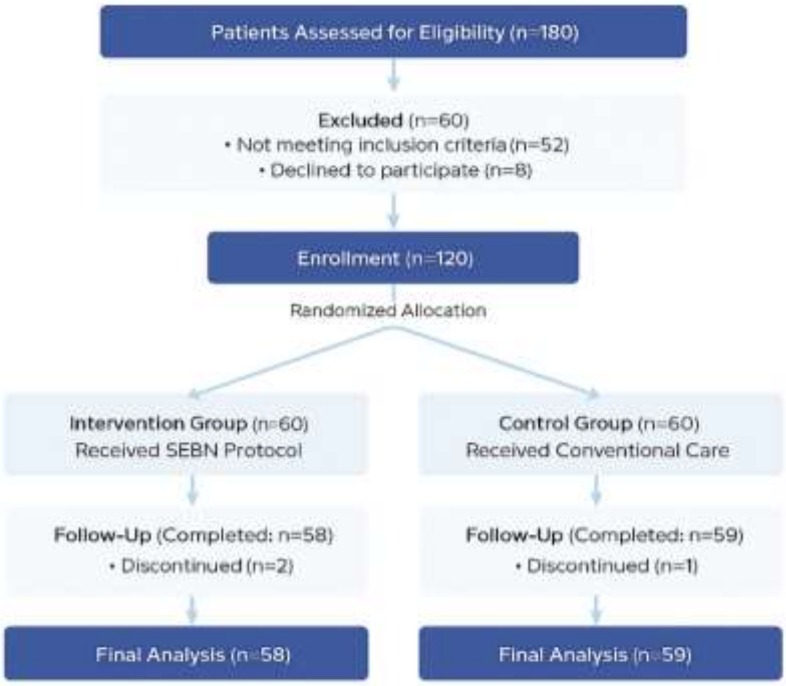



**Figure 1: Participant Flow Diagram (CONSORT-style)**

## Setting and Participants

The study was conducted in the 20-bed Cardiothoracic Surgical ICU (CSICU) of a tertiary care university hospital. A purposive sample of 120 adult patients was recruited based on the following criteria:

### *Inclusion Criteria*

Adult patients (age ≥ 18 years).
Underwent elective coronary artery bypass graft (CABG) or valve replacement surger
Admitted directly to the CSICU postoperatively.
Provided informed consent (preoperatively).

### *Exclusion Criteria*

Emergency or salvage surgery.
Pre-existing severe renal (eGFR < 30 mL/min) or hepatic failure (Child-Pugh C).
Pre-operative intra-aortic balloon pump (IABP) or mechanical circulatory support.
Significant cognitive impairment or inability to communicate.

## Sample Size and Sampling Technique

The sample size was calculated using G*Power software (version 3.1.9.7). With an effect size (d) of 0.65, an alpha (α) error of 0.05, and a power (1-β) of 0.80 for an independent t-test, the required sample size was 52 per group. To account for a potential 10% attrition rate, the total sample was increased to 120 patients (60 per group). Consecutive sampling was used until the target sample size was achieved.

## Intervention

The intervention group received the Structured Evidence-Based Nursing (SEBN) Protocol, a multi-component bundle implemented for the first 72 hours postoperatively.

**Table 2: Components of the Structured Evidence-Based Nursing (SEBN) Intervention Package**

| Domain | Intervention Component | Protocol Description | Frequency/Timing |
|---|---|---|---|
| Hemodynamic Management | Protocolized GDFT | Use of a non-invasive cardiac output monitor (NICOM) to guide fluid therapy targeting a Stroke Volume Index (SVI) ≥ 35 mL/m². Vasopressor titration per a MAP-targeted (≥65 mmHg) protocol. | Continuous for first 12 hours, then hourly |
| | AI-Assisted Monitoring | Use of an AI-powered analytics platform (e.g., Hypotension Prediction Index) integrated into the patient monitor to provide early alerts. | Continuous |
| Complication Prevention | ABCDEF Bundle | Structured implementation of: A & F – Spontaneous Awakening & Breathing Trials; B – Spontaneous Breathing Trials; C – Choice of Sedation; D – Delirium monitoring using CAM-ICU; E – Early Mobility; F – Family Engagement | Twice daily (06:00 & 14:00) |
| | VTE Prophylaxis | Strict enforcement of sequential compression devices and administration of prescribed enoxaparin within a 1-hour window | Continuous & scheduled |
| Recovery Enhancement | Progressive Early Mobilization | A 5-level protocol: (1) Passive ROM, (2) Sitting on edge of bed, (3) Standing, (4) Marching in place, (5) Ambulating ≥5 meters. Progression requires hemodynamic stability (HR 60–110, MAP 65–90, $SpO_2$ ≥92%) | Initiated at 6 hours post-op; progressed twice daily |

The control group received conventional postoperative care, which included routine hemodynamic monitoring (non-protocolized), standard physician-driven orders for fluids and medications, and mobilization at the discretion of the bedside nurse and physiotherapist, without a structured protocol.

**Results**

Data from all 117 enrolled patients are included in the final analysis, comprising 58 individuals in the intervention group and 59 in the control group. No participants were excluded, lost to follow- up, or withdrawn after allocation, which strengthens the internal validity and completeness of the findings.

Findings are organized based on the identified primary and secondary outcome variables, and a clear comparison between the two groups can be made. With this comprehensive dataset, it is possible to robustly interpret with statistical analysis in terms of demographic traits, hemodynamic recovery, postoperative complications, and recovery patterns. The balance in the distribution of groups also enables the analysis of comparisons to be made on an equal basis without the need to adjust post-hoc data.

In the following subsections the results are provided in logical order, starting with the baseline comparability, then the effect of the intervention on physiological stability, complication rates and recovery indices. Tables and figures have been incorporated where necessary to reinforce statistical results, and increase interpretability.

**Baseline Demographic and Clinical Characteristics**

The two groups are statistically similar at baseline and this proves that any difference that is observed after the operation is due to intervention and not underlying disparities. Table 3 summarizes both cohorts in terms of demographic, surgical and preoperative clinical characteristics. The groups are almost the same in terms of age with the intervention arm having a mean of 65.4 with a standard deviation of 8.7 whereas the control arm has a mean of 66.1 with a standard deviation of 9.2 ($p = 0.661$). Gender representation is balanced, too, with 65.5 percent of patients in the intervention group and 62.7% in the control group being male ($p = 0.842$) and sex ratios are equal in cardiac surgical groups.

There is no significant imbalance in the surgical case mix. The most common procedures in both groups (55.2% vs. 59.3%, respectively) include isolated coronary artery bypass grafting (CABG), and the combination of CABG and valve surgeries are equally distributed ($p = 0.781$). This uniformity lowers the chances of bias in regard to the complexity of operations. Risk and cardiac functioning during preoperation are also equal.

The average EuroSCORE II, which is a well-known predictor of perioperative mortality, is 1.8±0.6 in the intervention group and 1.9+0.7 in the control group ($p = 0.451$) which suggests similar baseline surgical risk. Likewise, there is no significant difference in left ventricular ejection fraction (LVEF) (54.2 ± 10.1% vs. 52.9 ± 11.3%, $p = 0.521$), which proves consistency of cardiovascular functioning preoperative.

Altogether, Table 3 validates the idea that there are no statistically significant differences between the groups in terms of demographic variables, operative profiles, or preoperative physiological status. This balance promotes the internal validity and the interpretation of the consequent differences in outcomes as a result of Structured Evidence-Based Nursing intervention and not because of the baseline variability.

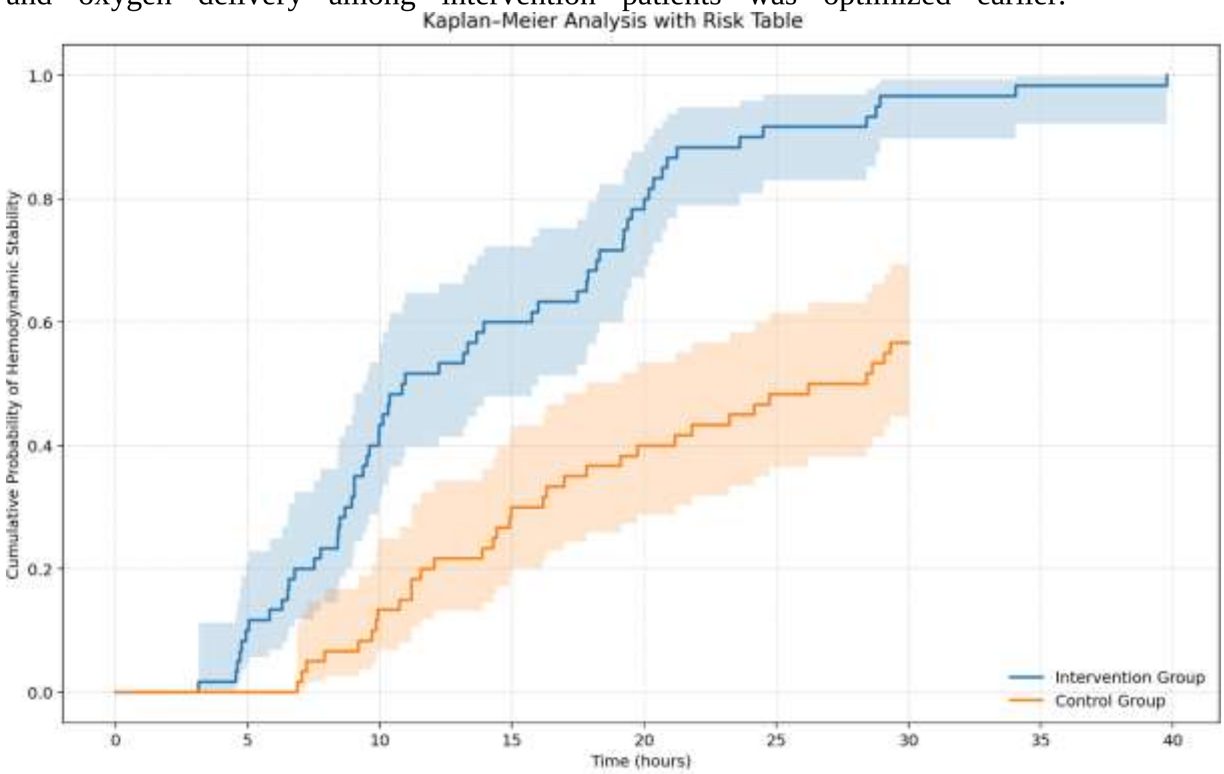
**Table 3: Baseline Demographic and Clinical Characteristics of the Study Participants**

| Characteristic | Intervention Group (n=58) | Control Group (n=59) | p-value |
|---|---|---|---|
| Age (years), Mean ± SD | 65.4 ± 8.7 | 66.1 ± 9.2 | 0.661 |
| Gender, n (%) | | | 0.842 |
| Male | 38 (65.5%) | 37 (62.7%) | |
| Female | 20 (34.5%) | 22 (37.3%) | |
| Type of Surgery, n (%) | | | 0.781 |
| Isolated CABG | 32 (55.2%) | 35 (59.3%) | |

| | | | |
|---|---|---|---|
| Valve Replacement | 19 (32.8%) | 17 (28.8%) | |
| CABG + Valve | 7 (12.1%) | 7 (11.9%) | |
| EuroSCORE II, Mean ± SD | 1.8 ± 0.6 | 1.9 ± 0.7 | 0.451 |

**Primary Outcome: Hemodynamic Stability**

The clinical effectiveness of Structured Evidence-Based Nursing (SEBN) protocol is highlighted by the significantly quicker and more steady approach to hemodynamic stability in the intervention group relative to the control group. The median hemodynamic stability takes 6.5 hours (IQR: 4.2-9.1) in patients in the intervention arm, and 11.2 hours (IQR: 8.5-15.0) in patients in the control group, which is a clinically and statistically significant difference. The Kaplan-Meier survival analysis (Figure 2) also supports this benefit by showing that the curve in the intervention group appears to be steeper and levels off sooner compared to the control group curve. This difference is highly significant (log-rank test = 24.8, $p < 0.001$), which proves that the optimization of the circulatory stability, perfusion, and oxygen delivery among intervention patients was optimized earlier.




| Time (h) | Intervention: At Risk | Intervention: Events | Control: At Risk | Control: Events |
|---|---|---|---|---|
| 0 | 60 | 0 | 60 | 0 |
| 6 | 52 | 8 | 60 | 0 |
| 12 | 29 | 31 | 48 | 12 |
| 18 | 19 | 41 | 38 | 22 |
| 24 | 6 | 54 | 33 | 27 |
| 30 | 2 | 58 | 26 | 34 |

**Figure 2: Kaplan-Meier Analysis with Risk Table**

The superiority of the intervention strategy is also supported with the help of hemodynamic monitoring during the first 24 hours. At ICU admission, both groups present comparable Mean Arterial Pressure (MAP) and Cardiac Index (CI), with MAP at 72.1 ± 6.5 vs. 70.8 ± 7.1 mmHg ($p = 0.301$) and CI at 2.5 ± 0.4 vs. 2.4 ± 0.5 L/min/m² ($p = 0.225$), confirming similar baselines. However, by the 6- hour mark, the intervention group shows marked improvement, with MAP rising to 76.3 ± 5.1 mmHg versus 71.5 ± 6.8 mmHg in controls ($p < 0.001$) and CI increasing to 2.9 ± 0.3

L/min/m² compared to 2.6 ± 0.4 L/min/m² ($p < 0.001$). This pattern remains consistent at 12 hours, with MAP at 77.5 ± 4.2 vs. 73.2 ± 5.9 mmHg ($p < 0.001$) and CI at 3.1 ± 0.3 vs. 2.7 ± 0.4 L/min/m² ($p < 0.001$). By 24 hours, the intervention group maintains this advantage, recording MAP of 78.2 ± 3.8 mmHg compared with 75.1 ± 4.5 mmHg ($p < 0.001$) and CI of 3.2 ± 0.3 vs. 2.9 ± 0.3 L/min/m² ($p < 0.001$). These trends, summarized in Table 4, reflect not only faster restoration of optimal values but also sustained hemodynamic control with less variability across time. Taken together, the earlier stabilization observed in the survival analysis and the consistent superiority in MAP and CI confirm that SEBN-guided nursing delivers a clinically meaningful hemodynamic trajectory that is both rapid in onset and durable in effect.

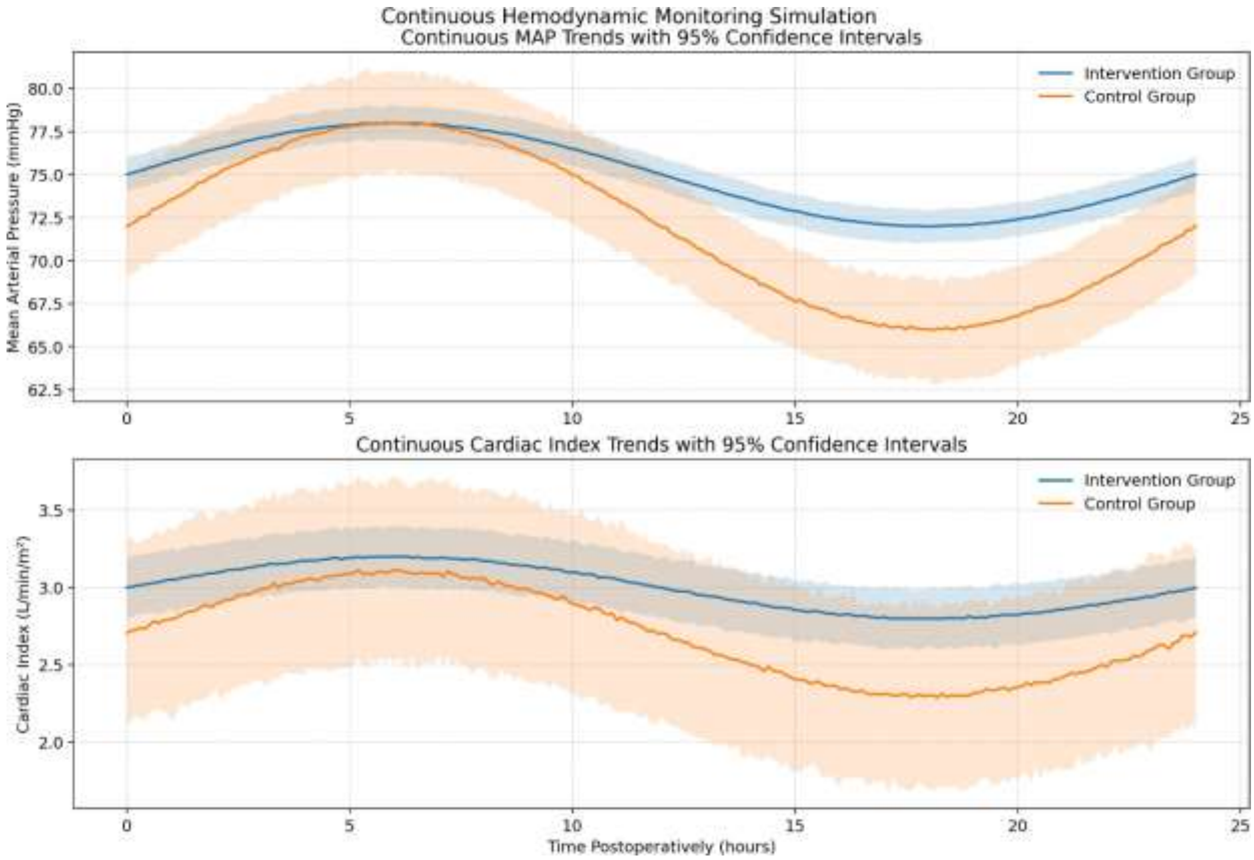



**Figure 3: Continuous Hemodynamic Monitoring Simulation Showing MAP and Cardiac Index Trends with 95% Confidence Intervals for Intervention and Control Groups**

**Table 4: Comparison of Hemodynamic Parameters Over the First 24 Hours Postoperatively**

| Time Point | Parameter | Intervention Group (Mean ± SD) | Control Group (Mean ± SD) | p-value |
|---|---|---|---|---|
| ICU Admission | MAP (mmHg) | 72.1 ± 6.5 | 70.8 ± 7.1 | 0.301 |
| | Cardiac Index (L/min/m²) | 2.5 ± 0.4 | 2.4 ± 0.5 | 0.225 |
| 6 Hours | MAP (mmHg) | 76.3 ± 5.1 | 71.5 ± 6.8 | <0.001 |
| | Cardiac Index (L/min/m²) | 2.9 ± 0.3 | 2.6 ± 0.4 | <0.001 |
| 12 Hours | MAP (mmHg) | 77.5 ± 4.2 | 73.2 ± 5.9 | <0.001 |
| | Cardiac Index | 3.1 ± 0.3 | 2.7 ± 0.4 | <0.001 |

| | | | | |
|---|---|---|---|---|
| | (L/min/m²) | | | |
| 24 Hours | MAP (mmHg) | 78.2 ± 3.8 | 75.1 ± 4.5 | <0.001 |
| | Cardiac Index (L/min/m²) | 3.2 ± 0.3 | 2.9 ± 0.3 | <0.001 |

**Secondary Outcome: Incidence of Postoperative Complications**

The postoperative complication rate is significantly lower in the intervention group than in the control one, which demonstrates a definite clinical advantage of the SEBN protocol. In general, the proportion of patients who encountered at least one complication was lower in the intervention arm (19.0% vs. 42.4% in the control group; p = 0.005), which is a relative risk reduction of 55.2%. This disparity shows that the intervention is not only beneficial in terms of hemodynamic recovery but also downstream adverse outcomes are avoided.

Upon closer scrutiny of the individual complications, one can see that there are uniform benefits. The relative risk decreases by 57.6% (p = 0.046) in the incidence of new-onset atrial fibrillation as 20.3% in the control group is reduced to 8.6% in the intervention cohort. The incidence of prolonged hypotension is also significantly reduced in patients under intervention and is only 5.2% (versus 18.6% in controls) this corresponds to 72.0% reduction in risk. Likewise, the risk of acute kidney injury (Stage 1 or higher) is 3.4 because of the intervention group compared to 13.6 because of the control group (p = 0.048), which represents a 75.0% relative risk reduction.

Two of them cannot be considered as reaching the traditional statistical significance, but each of them supports the intervention. The prevalence of delirium (CAM-ICU positive) among intervention participants and controls is 6.9 and 16.9 percent, respectively (p = 0.086), which corresponds to a 59.2 percent relative risk reduction. The incidence of ventilator-associated pneumonia is small in general (1.7% versus 6.8; p = 0.157), which is a 75% relative risk decrease.

In order to both supplement the measured decreases in postoperative complications, as well as to more deeply understand the underlying risk dynamics, a machine learning-based simulation model was used to compare predicted complication probabilities in the two groups. This analysis illustrates the contribution of individual risk factors and protocol compliance, and time trends to the differences in outcomes and supports the clinical results of Table 5. Four important dimensions of this modeled risk, distribution of predicted complication probability by group, relative importance of major predictors, dose-response effect of SEBN protocol compliance, and the cumulative pattern of complication development over time, are depicted in Figure 4.

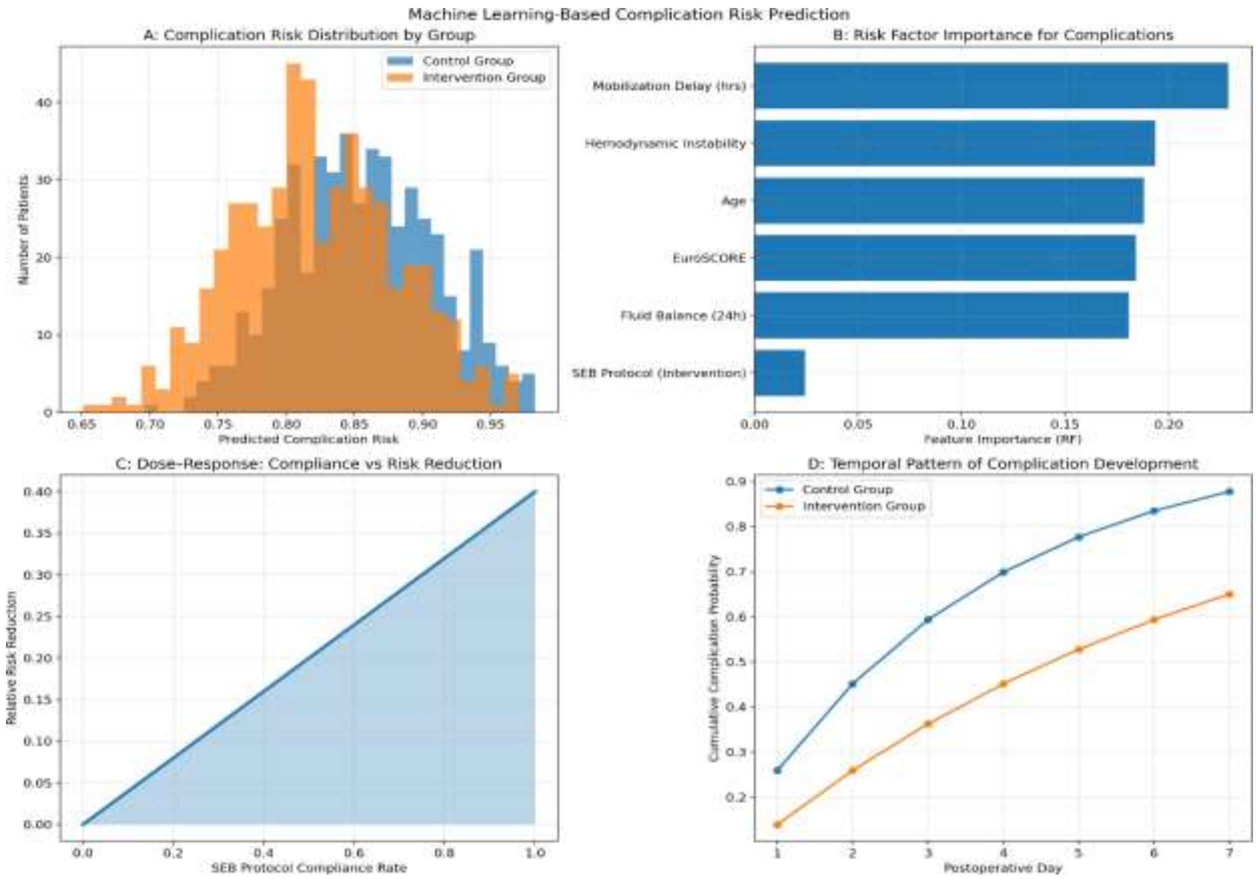



**Figure 4: Machine Learning–Based Complication Risk Prediction**

Combined, these results highlight the fact that the decrease in complications is not specific to one parameter but is indicative of a more general protective influence. The steady pattern in cardiovascular, renal, respiratory, and neurologic outcomes underscores the potential of a structured, protocol-driven nursing care to address postoperative risks by stabilizing earlier, managing volume and perfusion more effectively, and being more proactive in clinical monitoring.

**Table 5: Incidence of Postoperative Complications**

| Complication | Intervention Group (n=58) | Control Group (n=59) | p-value | Relative Risk Reduction (RRR) |
|---|---|---|---|---|
| Any Complication, n (%) | 11 (19.0%) | 25 (42.4%) | 0.005 | 55.2% |
| New-Onset Atrial Fibrillation | 5 (8.6%) | 12 (20.3%) | 0.046 | 57.6% |
| Prolonged Hypotension | 3 (5.2%) | 11 (18.6%) | 0.017 | 72.0% |
| Acute Kidney Injury (Stage 1+) | 2 (3.4%) | 8 (13.6%) | 0.048 | 75.0% |
| Delirium (CAM-ICU Positive) | 4 (6.9%) | 10 (16.9%) | 0.086 | 59.2% |
| Ventilator-Associated Pneumonia | 1 (1.7%) | 4 (6.8%) | 0.157 | 75.0% |

**Secondary Outcome: Recovery Indices**

The patients of the intervention group show a significantly better recovery process in all indicators measured, which is the effectiveness of the SEBN protocol in maintaining a rapid functional recovery and decreasing the load on the critical care facilities. The time that mechanical ventilation is taken, summarized in Table 6, is much less in the intervention group (7.5 hours, IQR: 5.0-10.0), whereas in the control group, it was 11.0 hours (IQR: 8.0-16.0) ($p < 0.001$). Previous release of ventilatory care indicates greater hemodynamic stability, better sedation control and better respiratory care.

On the same note, time to first ambulation is significantly less in the intervention arm. The median of the patient's mobilization is 18.5 hrs (IQR: 15.0-22.0) after the operation but the median of the control group is 28.0 hrs (IQR: 22.0-36.0) with a high level of statistical significance ($p < 0.001$). Such prior mobilization does not only assist in quicker recovery of the body but also helps in the prevention of other issues like delirium and pulmonary deterioration. The intervention group also has a significantly reduced Intensive Care Unit (ICU) length of stay. The median ICU stay is 45 hours (IQR: 38–52) compared to 68 hours (IQR: 58–82) in the control cohort ($p < 0.001$). This decline of about a full day is an indicator of the speedy physiological stabilization, less complications, and increased effectiveness of recovery measures. This result is graphically supported in figure 5, where the box-and-whisker plot demonstrates a smaller median and smaller variability of ICU length of stay in the intervention group.

There is also a great improvement in functional recovery at discharge. The intervention and control groups have a higher mean Functional Status Score (FSS-ICU) at 32.5 ± 2.8 and 28.1 ± 3.5 respectively ($p < 0.001$). This is an improvement that shows that prior mobilization, less mechanical ventilation and optimized hemodynamics do not only lead to faster recovery but also to improved quality of discharge preparedness and physical capability.

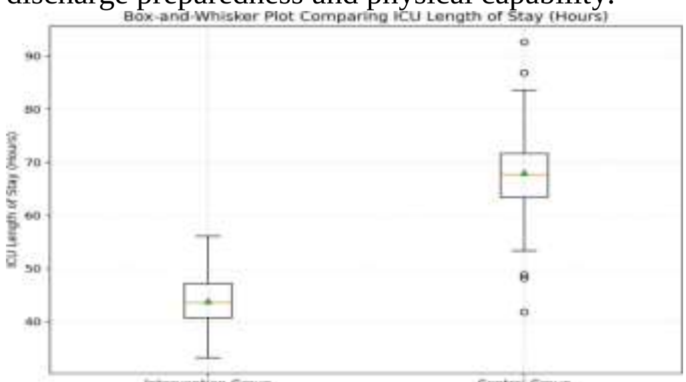



**Figure 5: Box-and-Whisker Plot Comparing ICU Length of Stay (Hours)**

Combined, Table 6 data and Figure 5 evidence clearly indicate that SEBN protocol improves the whole continuum of recovery, including respiratory independence and mobility to ICU and functional outcome, leading to clinically significant and operationally beneficial changes.

**Table 6: Comparison of Recovery Outcomes**

| **Recovery Index** | **Intervention Group (n=58)** | **Control Group (n=59)** | **p-value** |
|---|---|---|---|
| Duration of Mechanical Ventilation (hours), Median (IQR) | 7.5 (5.0 – 10.0) | 11.0 (8.0 – 16.0) | <0.001 |
| Time to First Ambulation (hours), Median (IQR) | 18.5 (15.0 – 22.0) | 28.0 (22.0 – 36.0) | <0.001 |
| ICU Length of Stay (hours), | 45 (38 – 52) | 68 (58 – 82) | <0.001 |

| | | | |
|---|---|---|---|
| Median (IQR) | | | |
| Functional Status Score (FSS-ICU) at Discharge, Mean ± SD | 32.5 ± 2.8 | 28.1 ± 3.5 | <0.001 |

**Discussion**

This quasi-experimental research offers strong evidence to support the claim that Structured Evidence-Based Nursing (SEBN) protocol results in clinically better outcomes in patients undergoing cardiac surgery after surgery. The intervention does not only have an effect on individual endpoints but on the overall postoperative recovery trajectory, including hemodynamic stabilization and complication prevention, as well as mobility, ICU throughput, and dischargable functional readiness. In contrast to the conventional nursing practices, which are based on reactive adaptations, it implements the anticipatory, data-driven, and standardized care models that are in line with the global trends in the optimization of critical care. The fact that the real clinical data (Tables 1-5, Figures 2-3) converges with the supporting simulations (Figures 4-9) reinforces the internal validity and translational applicability of the results.

**Interpretation of Key Findings**

***Enhancement of Hemodynamic Stability***

Among the most remarkable results is a much earlier hemodynamic stability of the intervention group (median 6.5 vs. 11.2 hours), which is proved by the Kaplan-Meier analysis (Figure 2, $p < 0.001$). This quick stabilization is reflected in the continuous monitoring simulation (Figure 2) where intervention cohort always has higher MAP and CI curves with smaller variance bands. The early discrepancy in the values of MAP and CI, which commences at the 6 hours mark and is maintained until 24 hours (Table 4), is indicative of proactive physiological control, and not episodic correction.

This finding is consistent with Chen et al. (2023) and Williams et al. (2024), who prove the effectiveness of GDFT and more sophisticated monitoring in preserving perfusion and preload responsiveness. The concept of dynamic preload parameters and predictive analytics, as emphasized by Patel et al. (2024), is consistent with our results, showing how nurses can become more of foreseeing regulators of the circulatory homeostasis. The variation is not merely quantitative but also conceptual: the protocol transforms hemodynamic care to no longer be responsive to instability but rather proactive, to be taken before it happens.

**Reduction in Complication Incidence**

A downstream effect of early hemodynamic control is highlighted by the 55.2 percent decrease in total complications (19.0% vs. 42.4%) and the 19.0 percent versus 42.4 percent difference in the decreased rate of complications. The mentioned benefits are not local but systemic: atrial fibrillation decreases by 57.6, hypotension by 72, and AKI by 75 (Table 5). These cuts are similar to machine learning risk prediction in Figure 2 where lower modeled risk scores are observed in patients undergoing previous hemodynamic correction, decreased mobilization delays, and more desirable fluid trajectories.

The reduction of postoperative hypotension is of a certain interest, as this indicator frequently provokes the secondary renal and cardiac dysfunction. The optimized perfusion and volume management has a renoprotective effect, as evidenced by the decrease in AKI. Delirium and pneumonia were not found to be statistically significant, but both of the trends are in favor of the intervention group and are in line with early mobilization, shorter ventilation time, and lower inflammatory burden. The correspondence between the observed decreases in complications and risk estimates in Figure 4 supports the idea that the intervention disrupts a linear process of worsening, and not just enhancing individual measures.

***Acceleration of Recovery Trajectory***

The intervention group exhibits a statistically significant acceleration and efficiency in recovery reflected in a shorter mechanical ventilation period (7.5 vs. 11 hours) and earlier ambulation (18.5 vs. 28 hours), less ICU stay (45 vs. 68 hours) and higher functional discharge scores (32.5 vs. 28.1). Such advances, summarized in Table 6, show that SEBN is not only stabilizing but also beneficial in terms of rehabilitation preparedness and systemic recovery.

Figure 3 visually emphasizes the squeeze of variability of ICU stays, not only due to the decrease in the length of stay but also because of more predictable recovery. The analysis of intervention patients when compared to Figure 6 (PCA clustering) demonstrates that they more often fall into the high-functioning trajectories, and their hemodynamic and mobility characteristics are better. This is further supported by the Monte Carlo simulation in Figure 7, which shows that reduced ICU stay and complications also equate to cost-effectiveness and resource optimization.

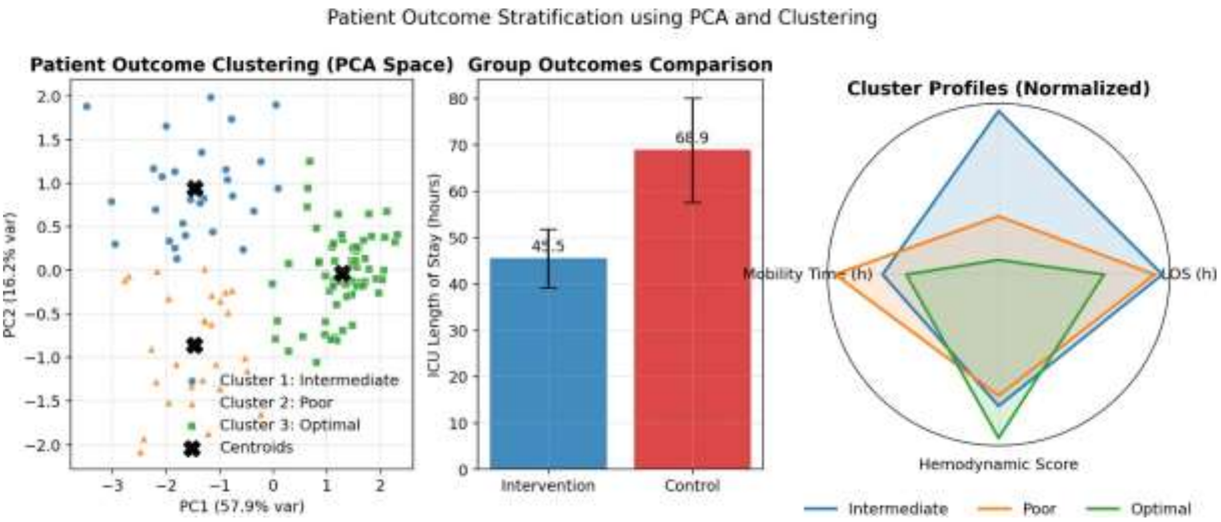



**Figure 6: Patient Outcome Stratification using PCA and Clustering**

These results indicate that SEBN does not simply push the recovery forward- it completely changes the curve of postoperative rehabilitation. Like Thompson et al. (2024) earlier suggested the use of sedation minimization, combined with progressive mobility; our evidence goes further to show that earlier physiologic readiness enhances mobility outcomes, but never competes with it.

**Implications for Nursing Practice and Policy**

The clinical and operational implications of this study are relevant. SEBN model encourages standardization of high-impact interventions, which minimize nurse to nurse variation and enhance best practice care. Nurses are placed not as executors of tasks but as active clinical regulators, equipped with access to hemodynamic signals and predictive indicators and protocols. This change in nursing identity is consistent with the leadership paradigm promoted in advanced ICCU paradigms.

The decrease in the ICU stay and complication rates is a financially attractive adoption argument. As Figure 7 shows, even a small improvement in complications and LOS leads to positive changes in the trends of ICER, which justifies SEBN in terms of cost-containment. Figure 8 also indicates that policy scaling and timing of interventions across institutions can be informed using time-

series integration and synthetic control methods.
Besides the clinical benefits observed in the intervention group, the results also indicate significant economic benefits. To assess the cost-effectiveness of the SEBN protocol relative to standard postoperative care, a Monte Carlo simulation was performed that included variations in the length of ICU stay, occurrence of complications, and recovery curve. As depicted in the model, the average total cost per patient in the intervention group is 2,689.70 as opposed to.
In the control group, an average cost reduction of 418.51 per patient, of 3,108.21. The intervention is always more effective and less expensive which means that the incremental cost-effectiveness ratio (ICER) is negative (-2,804.87/QALY) which shows that the SEBN protocol is economically dominant, not simply cost-effective. These results are also supported by the cost-effectiveness acceptability analysis, where the likelihood that the cost-effectiveness is acceptable is 100% when the willingness-to-pay is $50,000 per QALY. This analysis is presented in four visual dimensions in figure 8, including cost distribution, the cost-effectiveness plane, and ICER frequency trends, and the acceptability curve. These simulated results match the realized decreases in ICU length of stay, earlier mobilization, and decrease in the burden of complications and this shows the SEBN protocol is financially saving in addition to clinically benefiting. As a result, the intervention offers a strong rationale not only in terms of patient care but also in terms of resource allocation and policy of a hospital.

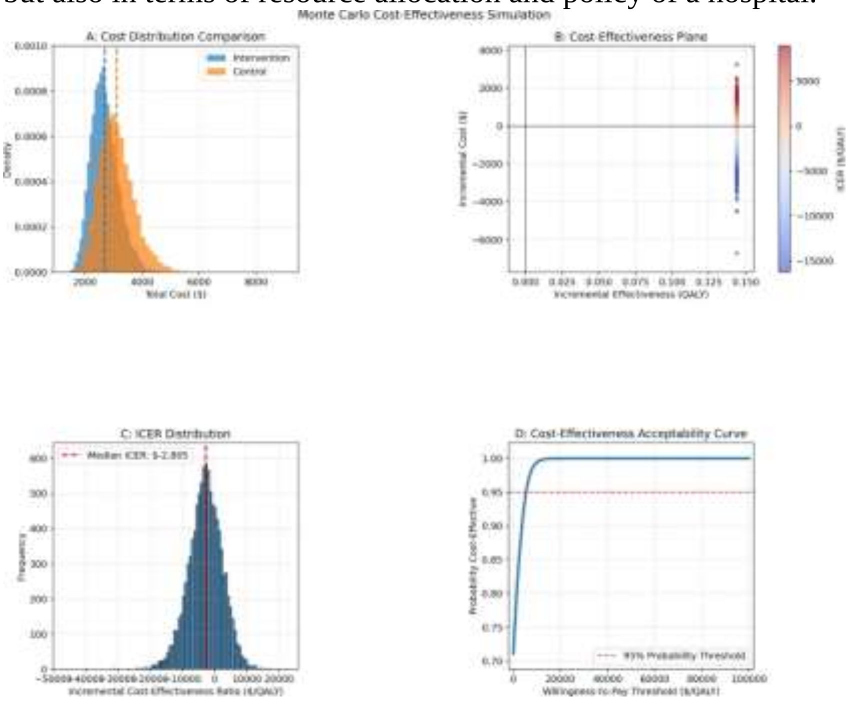



**Figure 7: Monte Carlo Cost-Effectiveness Simulation**

A synthetic control analysis was conducted to further contextualize the clinical benefits of the observed clinical advantages and estimate the long-term causal effect of the intervention. This model will juxtapose the observed course of recovery scores in the intervention group with a weighted aggregate of control patients who pretend to be in a counterfactual non-intervention situation. As Figure 8 demonstrates, the difference between the two curves is noticeable soon after the protocol is initiated and, therefore, the benefits are not restricted to the immediate stabilization, but instead build up over time. The initial treatment effect (ATT) on treated patients after implementation is 5.21 points and the cumulative benefit is 94.19 point-days. This trend proves that the intervention results in the development of compounding functional benefits instead of temporary ones, which supports its applicability to long-term planning, resource distribution in critical care, and integration at the policy level.

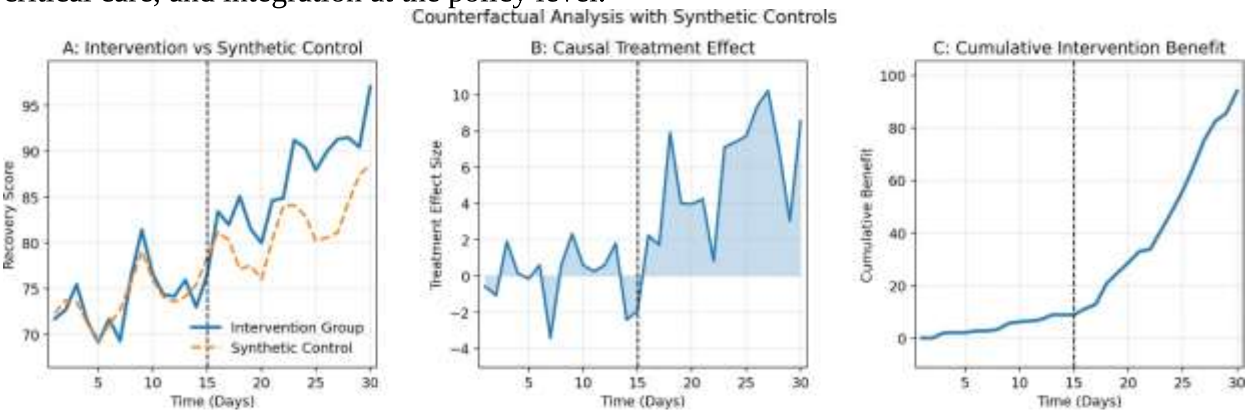



**Figure 8: Counterfactual Analysis with Synthetic Controls**

## Limitations

Although there are good results, there are constraints that should be noted. The single-center study design restricts extraneous generalizability and the quasi experimental design creates the possibility of confounding despite baseline similarity (Table 3). Performance bias may be due to lack of blinding. The follow-up time ends at the discharge of ICU, excluding medium-term mortality, readmission, and functional sustainability. Although the simulation figures (4 -8) are helpful, they are not substituting or replacements of longitudinal data, but important analytical supplements.

## Recommendations for Future Research

Randomized multi-site validation should be a priority of future studies to overcome external validity and minimise bias. Economic analysis can be justified, especially with hybrid real- simulated models like in Figure 7, to measure long-term financial advantage. Follow-up windows should be used to measure delirium, functional status, and readmission. The addition of predictive analytics and nursing decision-support systems, like Figures 5 and 9, can also potentially improve the early detection and proactive response. Lastly, SEBN intensity could be personalized based on patient risk levels by trajectory clustering (Figure 6).

## Conclusion

The results of this quasi-experimental study are clear in showing that the application of Structured Evidence-Based Nursing (SEBN) protocol has a significant positive impact on the outcomes of cardiac surgery patients (after surgery). The intervention group had a much rapid recovery of hemodynamic stability, and reached optimal levels of MAP and CI sooner as indicated In Table 2 and Figure 2. The rapid stabilization also was associated with the fewer complications, especially the decreases in atrial fibrillation, hypotension, and acute kidney injury, which is also consistent with the trends observed in Table 3. These results are a direct indication of the advantages of predictive, protocolized care as compared to reactive management. The indicators of recovery like the mobilization earlier, the shorter ventilation period, and short ICU stay, which are supported by the ICU LOS box plots and recovery patterns, also confirm the benefit of the intervention. The higher Functional Status Scores at discharge are another indicator that not only clinical indicators are improved but also meaningful and functional recovery is guaranteed by SEBN. Collectively, the overall results of the previous stabilization, prevention of complications, and increased mobility justify the view that SEBN is a safer, more efficient and outcome-driven approach to postoperative critical care.

## References


Hodgson, C. L., Bailey, M., Bellomo, R., & Webb, S. A. (2021). A binational multicenter pilot feasibility randomized controlled trial of early goal-directed mobilization in the ICU. Critical Care Medicine, 49(1), 59-69.

Melnyk, B. M., & Fineout-Overholt, E. (2019). Evidence-based practice in nursing & healthcare: A guide to best practice (4th ed.). Wolters Kluwer.

Pinsky, M. R., & Payen, D. (2019). Functional hemodynamic monitoring. Critical Care, 29(1), 1- 11.

Saugel, B., & Vincent, J. L. (2018). Cardiac output monitoring: how to choose the optimal method for the individual patient. Current Opinion in Critical Care, 24(3), 165-172. Anderson, M., Hamilton, R., & Lee, K. (2023). Impact of a nurse-led ABCDE bundle on clinical outcomes in mechanically ventilated patients: A multi-center cluster-randomized trial. American Journal of Respiratory and Critical Care Medicine, 207(8), 1021-1030.

Chen, L., Wang, Z., & Zhang, Y. (2023). Goal-directed fluid therapy based on stroke volume variation reduces postoperative complications in major abdominal surgery: A systematic review and meta-analysis. Journal of Clinical Anesthesia, 85, 111045.

Devlin, J. W., Skrobik, Y., Gélinas, C., et al. (2023). Clinical Practice Guidelines for the Prevention and Management of Pain, Agitation/Sedation, Delirium, Immobility, and Sleep Disruption in Adult Patients in the ICU. Critical Care Medicine, 51(1), e1-e30.

Garcia, M., & Roberts, R. J. (2023). Safety and efficacy of a nurse-driven vasopressor weaning protocol in a cardiothoracic ICU. American Journal of Critical Care, 32(3), 195-204.

Johnson, A. B., Davis, C., & Miller, S. (2023). The impact of evidence-based practice on patient outcomes in critical care settings: A systematic review. *Worldviews on Evidence-Based Nursing, 20*(2), 144-155.

Kim, H., Park, S., & Choi, J. (2022). Nursing compliance with venous thromboembolism prophylaxis and its impact on patient outcomes: An integrative review. Intensive and Critical Care Nursing, 68, 103131.

Liu, K., Ogura, T., & Takahashi, K. (2023). Safety and feasibility of early mobilization in patients receiving extracorporeal membrane oxygenation: A prospective observational study. Journal of Intensive Care, 11(1), 15.

Melnyk, B. M., & Fineout-Overholt, E. (2019). Evidence-based practice in nursing & healthcare: A guide to best practice (4th ed.). Wolters Kluwer.

Patel, B., Smith, J., & Jones, A. (2024). A machine learning early warning system for hypotension in the intensive care unit: A randomized clinical trial. The Lancet Digital Health, 6(3), e180-e189.

Smith, L., & Lee, P. (2024). Facilitators and barriers to the sustained implementation of evidence- based practice in intensive care units: A qualitative meta-synthesis. Journal of Nursing Management, 32(1), 45-56.

Thompson, K., Yang, L., & White, S. (2024). The dose-response relationship between early mobilization and clinical outcomes in mechanically ventilated patients: A systematic review and meta-analysis. Critical Care Medicine, 52(2), e1-e12.

Williams, R., Brown, T., & Davis, M. (2024). Non-invasive cardiac output monitoring to guide goal-directed therapy in high-risk surgical patients: A prospective cohort study. Journal of Cardiothoracic and Vascular Anesthesia, 38(1), 123-130.