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ORIGINAL RESEARCH

Effectiveness of an Enhanced Recovery After Surgery (ERAS) Program in Hip Arthroplasty in a Developing Country: A Propensity Score-Matched Study from Vietnam

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Background: Delayed recovery and adverse outcomes frequently follow hip arthroplasty, often due to comorbidities in elderly patients and the invasive nature of the surgery. Although Enhanced Recovery After Surgery (ERAS) programs are widely recommended in developed nations, their effectiveness in developing countries remains under-researched.

Objective: This study aims to evaluate the effectiveness of the ERAS program in improving outcomes for patients undergoing hip arthroplasty.

Patients and Methods: This retrospective observational study was conducted at a single university medical center. Propensity score matching was employed to ensure comparability between the ERAS and routine care groups. The primary outcome measured was the post-operative length of stay. Secondary outcomes focused on rates of complications. Tertiary outcomes included other clinical events and symptoms.

Results: The study initially enrolled 769 participants and retained 548 after matching. In the primary outcome, the ERAS group had a shorter length of stay, with a median of 6.1 compared to 7.0 days (Hodges-Lehmann estimate of 0.9 days, 95% confidence interval of 0.2 to 1.0 days, $p<0.001$). In secondary outcomes, the ERAS group showed lower incidences of composite complications (25.6% vs 33.6%, $p=0.040$) and respiratory complications (6.9% vs 13.1%, $p=0.023$). In tertiary outcomes, the ERAS group had lower rates of constipation (27.0% vs 38.3%, $p=0.006$) and perioperative hyponatremia (21.5% vs 29.6%, $p=0.040$). No statistically significant differences were observed in the remaining outcomes.

Conclusion: The ERAS program improved patient outcomes by reducing length of stay and complications for those undergoing hip arthroplasty in our country. Therefore, this study confirms the effectiveness of ERAS programs and advocates for their broader implementation in similar healthcare settings.

Keywords: length of stays, hip arthroplasty, complications, propensity score matching, healthcare burdens

Introduction

Hip arthroplasty is frequently utilized to manage hip fractures and advanced arthritis, restore mobility and enhance quality of life. The rising rate of hip arthroplasty has encouraged institutions, even in developed nations, to establish

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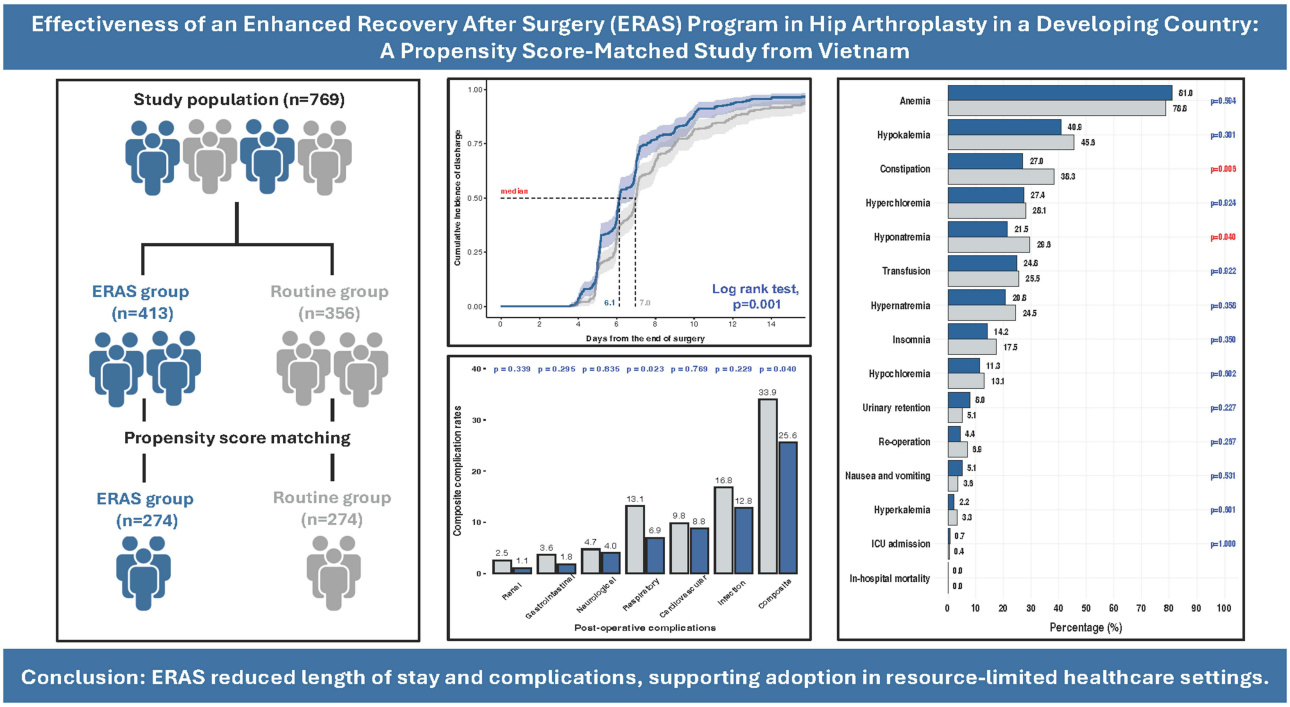
Graphical Abstract



protocols that ensure safe and cost-effective care aligned with value-based healthcare trends.[1] However, the reality is that post-operative recovery for patients undergoing hip arthroplasty can be extended due to multiple factors such as advanced age, multiple comorbidities, the invasive nature of the surgery, significant pain, and urinary retention.[2,3] These multifactorial disadvantages collectively lead to a prolonged post-operative length of stay (LOS). Additionally, these patients are at high risk of post-operative multiorgan complications, with rates reaching nearly 30% even in the United States.[4] Such adverse outcomes place a significant burden on patients and national healthcare systems, particularly in developing countries with resource-limited settings, inadequate infection control, and insufficient multidisciplinary coordination.[4,5]

Enhanced recovery after surgery (ERAS) programs have been developed and implemented widely to reduce recovery time and improve surgical outcomes through multidisciplinary management. In 2019, the ERAS Society released specific hip and knee arthroplasty guidelines, providing evidence-based strategies to optimize perioperative care.[6] Studies in developed countries have consistently demonstrated that ERAS programs reduce LOS and complications.[7–9] In recent decades, there has been a considerable amount of progress in reducing the LOS and improvements in short-term complications for patients undergoing hip arthroplasty.[10]

In developing countries, patients undergoing hip arthroplasty often experience prolonged hospital stays and higher rates of postoperative complications. While ERAS protocols offer a promising solution, their impact in low-resource settings remains underexplored. Currently, evidence indicates that LOS in developed countries typically falls below five days, whereas LOS in developing countries is significantly longer.[10–16] Furthermore, socioeconomic disparities contribute to this variation, with lower-income patients consistently demonstrating extended hospitalizations.[17] Prolonged LOS in these settings is primarily attributed to limited access to rehabilitation services, workforce shortages, patient informed consent, and inadequate perioperative infrastructure.[18,19] The lack of standardized protocols and institutional consistency impedes early mobilization and discharge.[20] This paradox highlights the research gap in the evidence supporting ERAS implementation in resource-constrained environments.

This study aims to assess the impact of ERAS protocols on post-operative outcomes in patients undergoing hip arthroplasty to provide evidence supporting the broader adoption of these protocols in developing countries. We hypothesize that ERAS protocols would improve outcomes, notably by reducing post-operative LOS and complications, thus providing a viable approach to enhance care in these healthcare settings.

Materials And Methods

Study Settings and Participants

This retrospective observational study was conducted at the University Medical Center Ho Chi Minh City (UMC HCMC), involving patients who underwent hip arthroplasty. This study compared the outcomes between two groups, with and without implementing ERAS, from January 2022 to December 2024. We present this article following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) reporting checklist.[21] The study was conducted concerning the principles of the Declaration of Helsinki for research on human subjects. This study contributes to a broader project to assess outcomes for patients undergoing hip arthroplasty. Related works on this project have explored various outcomes utilizing the same data set.

This study's inclusion criteria were patients undergoing hip arthroplasty surgery from 2021 to 2024. The exclusion criteria were comprehensive to ensure the integrity of the study results. Patients were excluded if they were under 18 years of age, had an American Society of Anesthesiologists (ASA) physical status classification of IV or greater, required emergency surgery, or had multiple traumas or surgeries concurrent with the hip arthroplasty. Additional exclusions were made for patients undergoing bilateral hip arthroplasty, those with severe deformity or instability of the hip, patients classified within Crowe group IV, those with previous spine surgery, and any cases where essential data was missing.

ERAS Program

The ERAS protocol at our medical center is crafted based on the 2019 ERAS Society recommendations, specifically their consensus statement for perioperative care in total hip and knee replacement surgeries.[6] Its design involved a comprehensive evaluation of the pre-admission phase, when patients were assessed in the outpatient clinic prior to admission, and of the perioperative period, including preoperative, intraoperative, and postoperative care. A dedicated multidisciplinary ERAS Task Force, composed of department heads and unit leaders, was established to oversee implementation, coordinate cross-departmental activities, and conduct continuous audits and quality improvement initiatives.

Full implementation of the ERAS protocol commenced in 2022, supported by extensive staff training and structured checklist systems to monitor adherence. Despite limited regional data supporting ERAS efficacy at the time, we proactively expanded its adoption across our institution. The key ERAS components and responsible healthcare professionals are depicted in Figure 1, and a detailed description of protocol activities is provided in Supplement 1. A total of seven clinical specialties are actively involved in the multidisciplinary implementation and operation of the ERAS program. Adherence to individual ERAS elements was prospectively recorded using structured checklists (Supplement 2), with regular perioperative audits conducted to ensure compliance. Patient allocation to the ERAS or routine care groups was based on the documented application of ERAS measures recorded through standardized reporting and monitoring systems.

Nutritional status was assessed and optimized perioperatively through collaboration among nutritionists, surgeons, and anesthesiologists. Blood transfusions were administered when hemoglobin levels fell below target thresholds, adjusted for patient age and cardiovascular comorbidities. Therapeutic antibiotics were initiated promptly upon confirmation or suspicion of infection. The CAPRINI score guided thromboprophylaxis. Patients were discharged once predefined clinical criteria were met. Intraoperative hemodynamic stability was maintained using a combination of vasopressors, antihypertensive agents, and targeted fluid management. Neuromuscular blocking agents were reversed when indicated.

For pain management during hip arthroplasty, a multimodal approach is employed, incorporating 1–3 non-opioid analgesics. These typically include intravenous acetaminophen, NSAID, and nefopam, which are administered toward the

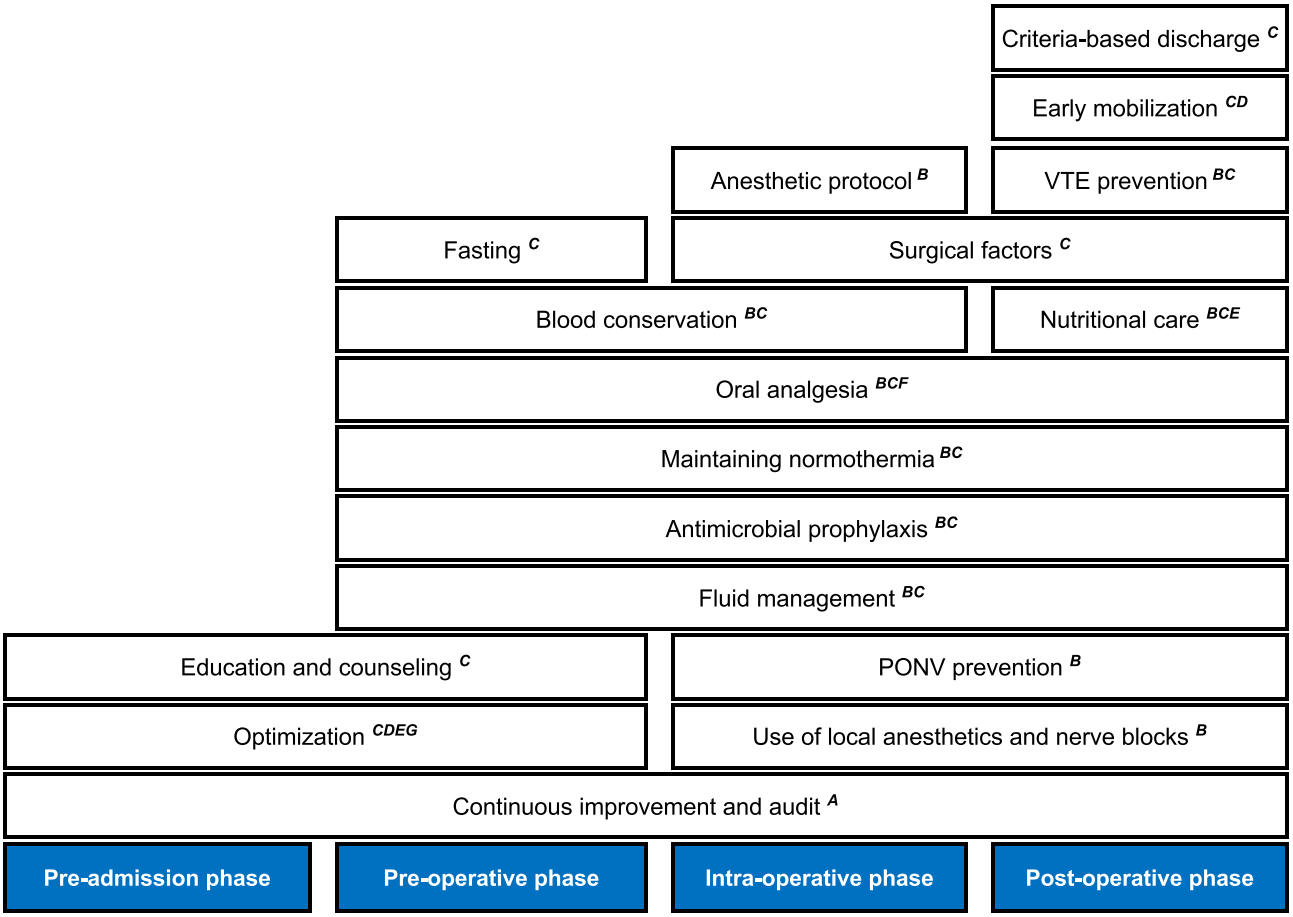


Figure 1 Core components in consensus statement for perioperative care in total Hip replacement and total knee replacement surgery by ERAS Society.
Abbreviations: ERAS, Enhanced Recovery After Surgery; PONV, Post-operative Nausea and Vomiting; VTE, venous thromboembolism.

end of the surgical procedure. Advanced analgesic techniques may be utilized, including lumbar epidural analgesia (LEA), femoral nerve block (FNB), ilioinguinal nerve block (INB), quadratus lumborum block (QL), and pericapsular nerve group block (PENG). Intravenous opioids, such as tramadol or morphine, are reserved for proactive or rescue analgesia. Postoperatively, oral non-opioids like paracetamol, non-steroidal anti-inflammatory drug (NSAIDs), and pregabalin are introduced as soon as it is feasible to manage pain further and enhance recovery.

Extubation was performed in the operating room once standard criteria were satisfied for patients undergoing general anesthesia. These criteria included complete reversal of neuromuscular blockade, adequate spontaneous ventilation (tidal volume ≥5 mL/kg, respiratory rate 12–20 breaths/min), hemodynamic stability, normothermia, and an appropriate level of consciousness. Following extubation, patients were monitored in the post-anesthesia care unit (PACU) and transferred to the Orthopedics Department once a modified Aldrete score of nine or greater was achieved.

Patients are encouraged to mobilize as early as clinically feasible. Active physiotherapy typically begins on postoperative day 0 under the supervision of rehabilitation physicians and physiotherapy nurses. Most patients undergoing elective hip arthroplasty for osteoarthritis are mobilized within several hours after surgery, while mobilization strategies for femoral neck and intertrochanteric fractures are individualized based on functional status, comorbidities,

and surgical factors. Before discharge, all patients receive personalized rehabilitation instructions, printed educational materials, and assistive devices such as crutches to support continued home-based exercises.

Data Collection

Data were extracted from a computerized database of patients hospitalized for hip arthroplasty from January 2022 to December 2024.

Baseline characteristics were assessed pre-operatively, including demographic data, comorbidities, and laboratory parameters. Demographic variables included age, gender, body mass index (BMI), and surgical diagnosis. Comorbidities, nutritional status, and physical status were also collected and evaluated. Comorbidities were assessed using the Charlson Comorbidity Index (CCI), nutritional status with the Nutritional Risk Screening (NRS-2002), and physical status according to the ASA classification. Laboratory characteristics included a cell blood count and coagulation tests, biochemical and electrolyte analyses, and ultrasound ejection fraction measurements.

Intervention variables included characteristics related to the surgery and anesthesia processes. Additional treatments were collected, including analgesic medication and regional techniques, vasopressors and antihypertensive medications, thromboprophylaxis, antibiotics, transfusions, and intra-operative fluid balance.

Outcome Measurements

The primary outcome was post-operative LOS, calculated by counting the days from the end of the surgery until the patient was discharged once discharge criteria were met. These criteria include: (1) removal of drainage tubes, (2) absence of signs of infection, (3) effective pain management using oral analgesics, (4) the ability to perform basic movements without assistance (ambulating safely), and (5) the capability to take oral feedings and breathe without the need for oxygen therapy.

Secondary outcomes focused on complications involving major organ systems, monitored throughout the entire postoperative LOS until discharge. The complications assessed included infections, cardiovascular, respiratory, urinary, gastrointestinal, and neurological disorders, as detailed in Supplement 3. Definitions for complications affecting major organ systems are based on the International Classification of Diseases (ICD) 9/10 medical codes. Further, they are categorized according to the Clavien-Dindo classification system, which stratifies complications into eight categories: no complication, Grade I, Grade II, Grade IIIa, Grade IIIb, Grade IVa, Grade IVb, and Grade V.[22]

Tertiary outcomes included other post-operative clinical events and symptoms. The clinical events we investigated included in-hospital mortality, ICU admission, re-operation, and transfusion, while the clinical symptoms were constipation, insomnia, urinary retention, nausea and vomiting, perioperative anemia and electrolyte disorders. Anemia is defined following WHO guidelines, which vary based on age and gender. Abnormalities in perioperative sodium, potassium, and chloride levels, when outside normal ranges, indicated electrolyte disorders.

Propensity Score Matching

This study utilized propensity score matching (PSM) to equilibrate baseline characteristics between the ERAS and routine groups. The covariates adjusted for included age, gender, BMI, smoking status, comorbidities, CCI, ASA physical status classification, and serum creatinine levels. The surgical variables considered were the indications for surgery and the type of arthroplasty. Propensity scores were derived using logistic regression to predict each patient's probability of being in the ERAS group based on the covariates above. Matching was executed using the nearest-neighbor method with a caliper width set at 0.1 of the logit-transformed propensity score's standard deviation (SD). This approach is noted for achieving balance across groups and minimizing bias in comparative analyses.[23] The matching quality was assessed by examining the absolute standardized mean differences (aSMD) for each covariate post-matching. An aSMD less than 0.1 across all covariates indicated a well-balanced match between the groups.[24]

Sample Size Estimation

The study aimed to assess differences in post-operative LOS as the primary outcome. Referencing data from Nicholas et al, which reported a reduction in LOS from 5.3 days (SD 1.6) to 4.9 days (SD 1.6), the calculation was based on a two-

sample comparison of means.[25] Assuming a two-sided test with a significance level of 0.05 and 80% power, a minimum of 252 patients per group was required. After accounting for an anticipated 30% attrition rate due to PSM, the final target sample size was increased to at least 720 patients.

Statistical Analysis

Statistical analyses were conducted using R software (version 4.3.2, R Foundation for Statistical Computing, Austria) and the RStudio environment (version 2023.06.2 + 561). Patient characteristics, perioperative interventions, and post-operative outcomes were summarized as frequencies and percentages for categorical variables, means and SD for numeric variables with normal distribution, and medians with interquartile ranges for numeric variables without normal distribution. Any differences between the two groups were tested using the Chi-square test or Fisher's exact test for categorical variables, a two-sample *t*-test for numeric variables with normal distribution, and Wilcoxon rank-sum test for numeric variables without normal distribution.

To assess the difference in the central tendency of LOS between the two matched groups, the mean difference was employed for variables that followed a normal distribution, and the Hodges-Lehmann estimate was utilized for variables that did not. Additionally, the Kaplan-Meier curve and the Log rank test were applied to compare the discharge rates between the groups. All tests were two-sided, and a P-value of less than 0.05 was considered statistically significant.

Results

Participants

Participants with complete data from the ERAS group (n=356) and routine group (n=413) were merged into a dataset of 769 participants available for matching. A study flowchart is presented in Figure 2. After matching, there were 274 patients in each group.

Table 1 summarizes the baseline characteristics of the study population. Before matching, significant differences were observed between groups in age, sex, surgical diagnosis, preoperative anemia, comorbidities, CCI, and nutritional and physical status. After matching, the two groups were well balanced, with no significant differences across key variables (all $p > 0.05$). Following PSM, the mean age was 64.1 ± 17.1 years, and BMI was 22.5 ± 3.5 kg/m^2. The most common indications for hip arthroplasty were avascular necrosis (48.7%), femoral neck fractures (31.8%), and intertrochanteric fractures (10.2%), with 94.3% undergoing primary hip arthroplasty. The median CCI was 3.0 (IQR 1.0–4.0).

Propensity Score Matching

Before matching, significant differences in some variables were observed, as shown by high aSMD in Figure 3A. After matching, the bias in baseline characteristics was reduced, and all covariates included in the PSM were balanced between two groups, with all aSMD less than 0.1. Figure 3B illustrates the similar distribution across the two groups, with 96.38% overlap in the areas after matching.

Interventions

Table 2 outlines the characteristics of interventions between the two groups, indicating overall balance with no significant differences in most variables. However, exceptions are observed in the anesthesia method, the usage of NMBAs and some specific non-opioid analgesics (acetaminophen, nefopam, and NSAIDs), and the duration of surgery and anesthesia.

Primary Outcome

Figure 4 compares the post-operative LOS between the two groups. Following PSM, the ERAS group demonstrated a shorter LOS than the routine care group, with a median of 6.1 versus 7.0 days ($p<0.001$). The ERAS group had a shorter post-operative LOS than the routine group, with a reduction of 0.8 days (95% confidence interval [CI] 0.2 to 1.0 days).

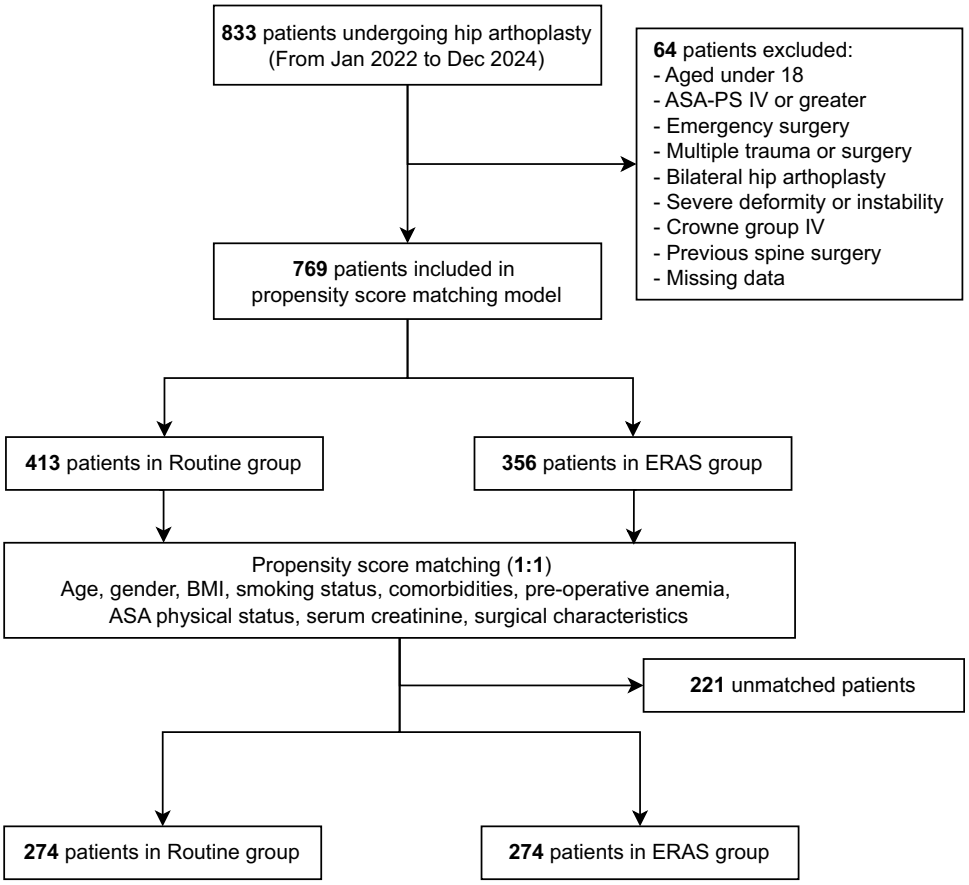


Figure 2 Flow chart of this study.
Abbreviations: ASA, American Society of Anesthesiologists; BMI: body mass index; ERAS, Enhanced Recovery After Surgery.

Secondary Outcomes

The study's overall rate of post-operative composite outcomes was reported as 29.8%. Figure 5A shows that the ERAS group had lower rates of composite complications (25.6% vs 33.9%, p=0.040) and respiratory complications (6.9% vs 13.1%, p=0.023) than the routine group. According to the Dindo-Clavien classification, 61.5% of patients in this study population had complications after PSM (Figure 5B). A higher proportion of patients in the ERAS group were free from post-operative complications than those in the routine group (43.1% vs 33.9%, p=0.025).

Tertiary Outcomes

Figure 6 demonstrates that after PSM, the ERAS group experienced lower rates of post-operative constipation (27.0% vs 38.3%, p=0.006) and perioperative hyponatremia (21.5% vs 29.6%, p=0.040) compared to the routine group. No statistically significant differences were observed in the remaining outcomes.

Discussions

This study explores the impact of ERAS protocols on post-operative results in hip arthroplasty patients in Vietnam, a representative developing country. Here, ERAS implementation remains limited due to insufficient evidence supporting its benefits. The study's findings, controlled for confounding variables, reveal that ERAS protocols effectively reduce the LOS and enhance overall post-operative outcomes. These results suggest that adopting ERAS strategies holds considerable promise for improving patient recovery in resource-constrained settings despite healthcare challenges.

Primary outcome analysis showed the ERAS group had a median post-operative LOS of 6.1 days versus 7.0 days in the control group, with a 0.8-day reduction (95% CI 0.2–1.0 days). This finding is consistent with the POWER2 trial

Table 1 Demographic and Baseline Features of the Study Population Before and After Matching

Variables	Before Matching			After Matching		
	Routine Group (n=413)	ERAS Group (n=356)	p-value	Routine Group (n=274)	ERAS Group (n=274)	p-value
Demographics						
Age, years	72.0 (57.0–82.0)	63.0 (52.0–73.0)	<0.001	64.6 ± 17.1	63.6 ± 17.0	0.460
Male, n (%)	158 (38.3)	174 (48.9)	0.004	120 (43.8)	120 (43.8)	1.000
Surgical diagnosis, n (%)			<0.001			0.724
- Avascular necrosis	137 (33.2)	203 (57.0)		130 (47.4)	137 (50.0)	
- Intertrochanteric fracture	100 (24.2)	27 (7.6)		29 (10.6)	27 (9.9)	
- Femoral neck fracture	142 (34.4)	97 (27.2)		92 (33.6)	82 (29.9)	
- Others	34 (8.2)	29 (8.1)		23 (8.4)	28 (10.2)	
Comorbidities						
Smoking, n (%)	34 (8.2)	34 (9.6)	0.607	25 (9.1)	19 (6.9)	0.432
Alcohol use, n (%)	13 (3.1)	35 (9.8)	<0.001	9 (3.3)	18 (6.6)	0.114
Pre-operative anemia, n (%)	195 (47.2)	121 (34.0)	<0.001	105 (38.3)	100 (36.5)	0.724
Hypertension, n (%)	311 (75.3)	214 (60.1)	<0.001	182 (66.4)	173 (63.1)	0.474
CVD, n (%)	134 (32.4)	62 (17.4)	<0.001	64 (23.4)	58 (21.2)	0.608
CKD, n (%)	60 (14.5)	21 (5.9)	<0.001	26 (9.5)	21 (7.7)	0.542
Pulmonary TB, n (%)	18 (4.4)	21 (5.9)	0.420	11 (4.0)	10 (3.6)	1.000
COPD, n (%)	10 (2.4)	6 (1.7)	0.646	5 (1.8)	5 (1.8)	1.000
Asthma, n (%)	13 (3.1)	11 (3.1)	1.000	9 (3.3)	6 (2.2)	0.601
Diabetes, n (%)	138 (33.4)	89 (25.0)	0.013	76 (27.7)	76 (27.7)	1.000
Dyslipidemia, n (%)	150 (36.3)	95 (26.7)	0.005	77 (28.1)	82 (29.9)	0.707
Heart failure, n (%)	29 (7.0)	12 (3.4)	0.037	17 (6.2)	11 (4.0)	0.332
Cushing syndrome, n (%)	45 (10.9)	38 (10.7)	1.000	31 (11.3)	29 (10.6)	0.891
Stroke sequelae, n (%)	39 (9.4)	25 (7.0)	0.280	22 (8.0)	22 (8.0)	1.000
Atrial fibrillation, n (%)	11 (2.7)	4 (1.1)	0.190	4 (1.5)	4 (1.5)	1.000
Hepatitis, n (%)	26 (6.3)	19 (5.3)	0.681	14 (5.1)	15 (5.5)	1.000
Thyroid disease, n (%)	18 (4.4)	16 (4.5)	1.000	10 (3.6)	13 (4.7)	0.670
Peptic ulcer, n (%)	20 (4.8)	15 (4.2)	0.807	11 (4.0)	9 (3.3)	0.820
Dementia, n (%)	18 (4.4)	6 (1.7)	0.055	6 (2.2)	6 (2.2)	1.000
Cirrhosis, n (%)	5 (1.2)	8 (2.2)	0.406	3 (1.1)	6 (2.2)	0.504
Osteoporosis, n (%)	24 (5.8)	20 (5.6)	1.000	14 (5.1)	16 (5.8)	0.851
Parkinson, n (%)	12 (2.9)	9 (2.5)	0.922	6 (2.2)	7 (2.6)	1.000
Seizure, n (%)	2 (0.5)	3 (0.8)	0.667	1 (0.4)	2 (0.7)	1.000
Obesity, n (%)	78 (18.9)	80 (22.5)	0.255	52 (19.0)	59 (21.5)	0.524
Malnutrition, n (%)	55 (13.3)	37 (10.4)	0.257	32 (11.7)	27 (9.9)	0.581
Connective tissue disease, n (%)	12 (2.9)	5 (1.4)	0.244	10 (3.6)	4 (1.5)	0.174
Cancer, n (%)	19 (4.6)	20 (5.6)	0.634	16 (5.8)	13 (4.7)	0.703
Charlson comorbidity index, scores	4.0 (2.0–5.0)	2.0 (1.0–4.0)	<0.001	3.0 (1.0–4.0)	3.0 (1.0–4.0)	0.521
Nutrition risk screening, scores	2.0 (1.0–3.0)	1.0 (0.0–2.0)	<0.001	1.0 (0.0–2.0)	1.0 (0.0–2.0)	0.485
Physical status, n (%)			0.007			0.785
- ASA-I	76 (18.4)	88 (24.7)		68 (24.8)	75 (27.4)	
- ASA-II	195 (47.2)	180 (50.6)		129 (47.1)	126 (46.0)	
- ASA-III	142 (34.4)	88 (24.7)		77 (28.1)	73 (26.6)	
Laboratory features						
WBC, K.uL-1	9.2 (7.4–11.8)	8.6 (6.9–10.3)	<0.001	9.3 ± 3.1	8.9 ± 2.7	0.145
RBC, K.uL-1	4.2 (3.8–4.7)	4.4 (4.0–4.8)	0.002	4.4 ± 0.7	4.4 ± 0.8	0.750

(*Continued*)

Table 1 (Continued).

Variables	Before Matching			After Matching		
	Routine Group (n=413)	ERAS Group (n=356)	p-value	Routine Group (n=274)	ERAS Group (n=274)	p-value
Hb, g.dL-1	12.5 ± 1.9	13.0 ± 1.9	<0.001	12.8 ± 1.8	12.8 ± 1.9	0.936
Hct, %	0.4 (0.3–0.4)	0.4 (0.4–0.4)	<0.001	0.4 (0.4–0.4)	0.4 (0.4–0.4)	0.047
PLT, G.L-1	267 (214–338)	269 (220–330)	0.954	276 (217–339)	270 (213–329)	0.428
INR, ratio	1 (1.0–1.1)	1 (0.9–1.1)	0.054	1 (0.9–1.1)	1 (1.0–1.1)	0.391
Fibrinogen, g.L-1	4.3 (3.4–5.2)	4.1 (3.4–4.7)	0.030	4.2 (3.3–5.1)	4.1 (3.3–4.7)	0.175
Albumin, g.dL-1	3.5 ± 0.5	3.8 ± 0.5	<0.001	3.6 ± 0.6	3.8 ± 0.5	0.002
Creatinine, mg.dL-1	0.8 (0.6–0.9)	0.8 (0.6–0.9)	0.450	0.8 (0.6–0.9)	0.8 (0.6–0.9)	0.350
Urea, mmol.L-1	5.2 (4.0–6.7)	4.6 (3.5–5.9)	<0.001	5.0 (3.7–6.6)	4.6 (3.4–5.8)	0.005
eGFR, mL.min-1	86 (71–102)	95 (81–106)	<0.001	88 (73–105)	93 (77–106)	0.183
AST, IU.L-1	27 (20–35)	26.0 (21–33)	0.749	26.0 (20–35)	26 (21–32)	0.636
ALT, IU.L-1	21 (14–31)	22.0 (14–35)	0.217	21.0 (15–33)	21 (14–33)	0.901
HbA1c, %	7.0 (6.0–8.6)	6.7 (5.8–8.7)	0.128	6.7 (5.9–8.3)	6.7 (6.0–8.1)	0.659
Glucose, mmol.L-1	6.0 (5.0–8.1)	5.4 (4.7–6.4)	<0.001	5.7 (4.9–7.4)	5.4 (4.7–6.6)	0.042
CRP, mg.L-1	18.7 (5.4–51.6)	12.1 (3.8–36.6)	0.025	14.2 (4.4–43.9)	16.4 (4.3–42.1)	0.988
hs-TnT, ng.L-1	10.4 (6.1–16.0)	8.9 (6.1–15.3)	0.553	9.4 ± 5.6	13.8 ± 10.5	0.052
Sodium, mmol.L-1	139 (137–141)	140 (138–142)	<0.001	139 (137–141)	140 (138–142)	<0.001
Potassium, mmol.L-1	3.8 (3.5–4.1)	3.8 (3.6–4.0)	0.339	3.8 (3.5–4.1)	3.8 (3.6–4.0)	0.511
Chlor, mmol.L-1	104 (101–106)	104 (102–106)	0.004	104 (101–106)	104 (102–107)	0.014
Ejection fraction, %	67.3 ± 8.9	67.2 ± 8.2	0.812	68.4 ± 8.3	67.2 ± 8.3	0.168

Abbreviations: ALT, alanine aminotransferase; ASA, American Society of Anesthesiologists; AST, aspartate aminotransferase; BMI, body mass index; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CRP, C-reactive protein; CVD, cardiovascular disease; eGFR, estimated glomerular filtration rate; ERAS, enhanced recovery after surgery; Hb, hemoglobin; HbA1c, hemoglobin A1C; Hct, hematocrit; INR, international normalized ratio; NRS, Nutritional Risk Screening; PLT, platelet count; RBC, red blood cell count; TB, tuberculosis; WBC, white blood cell count.

conducted in Spain, a developed country, which reported a shorter median LOS in the ERAS group (4 vs 5 days, odds ratio [OR] 0.97, 95% CI 0.96 to 0.99, p<0.001).[7] Similarly, studies on hip arthroplasty surgeries from China, a neighboring developing country, have shown that ERAS or fast-track protocols significantly reduce LOS compared to conventional care.[13,14,26] A subgroup analysis from a meta-analysis focusing on orthopedic surgeries—primarily based on studies from China—reported that ERAS reduced LOS by an average of 3.37 days (95% CI, –1.21 to 7.95).[27] Additionally, two other meta-analyses by Morrell and Chen, which included data from both developed and developing countries, confirmed that ERAS protocols significantly shorten LOS in patients undergoing hip and knee arthroplasty.[8,9] Collectively, these findings add to the growing body of evidence supporting ERAS as an effective strategy to reduce postoperative LOS across diverse healthcare settings.

Previous studies suggest that LOS tends to be longer in developing countries and among lower-income patient populations.[10–17] Our findings are consistent with studies conducted in comparable regions, including Southeast Asia, East Asia, and South Africa, where reported average LOS values closely align with ours.[12–14,16] Consequently, post-operative LOS in our study was generally more prolonged, and complication rates were notably higher than those reported in reference studies from developed countries. In our study, 61.5% of patients experienced complications classified according to the Dindo-Clavien scale after PSM. In contrast, the complication rate was significantly lower, at approximately 27.3%, among patients undergoing total hip arthroplasty in the United States.[28] The higher complication rates likely contributed to the prolonged LOS observed in our study. Additionally, limited healthcare resources, under-developed infrastructure, and less effective multidisciplinary collaboration may have further exacerbated this issue compared to studies conducted in developed nations.

For secondary and tertiary outcomes, the ERAS group had lower incidences of post-operative composite complications, respiratory complications, constipation, and perioperative hyponatremia. The effectiveness of the ERAS program in reducing complications has shown inconsistency across studies. A meta-analysis by Chen reported that about 50% (5

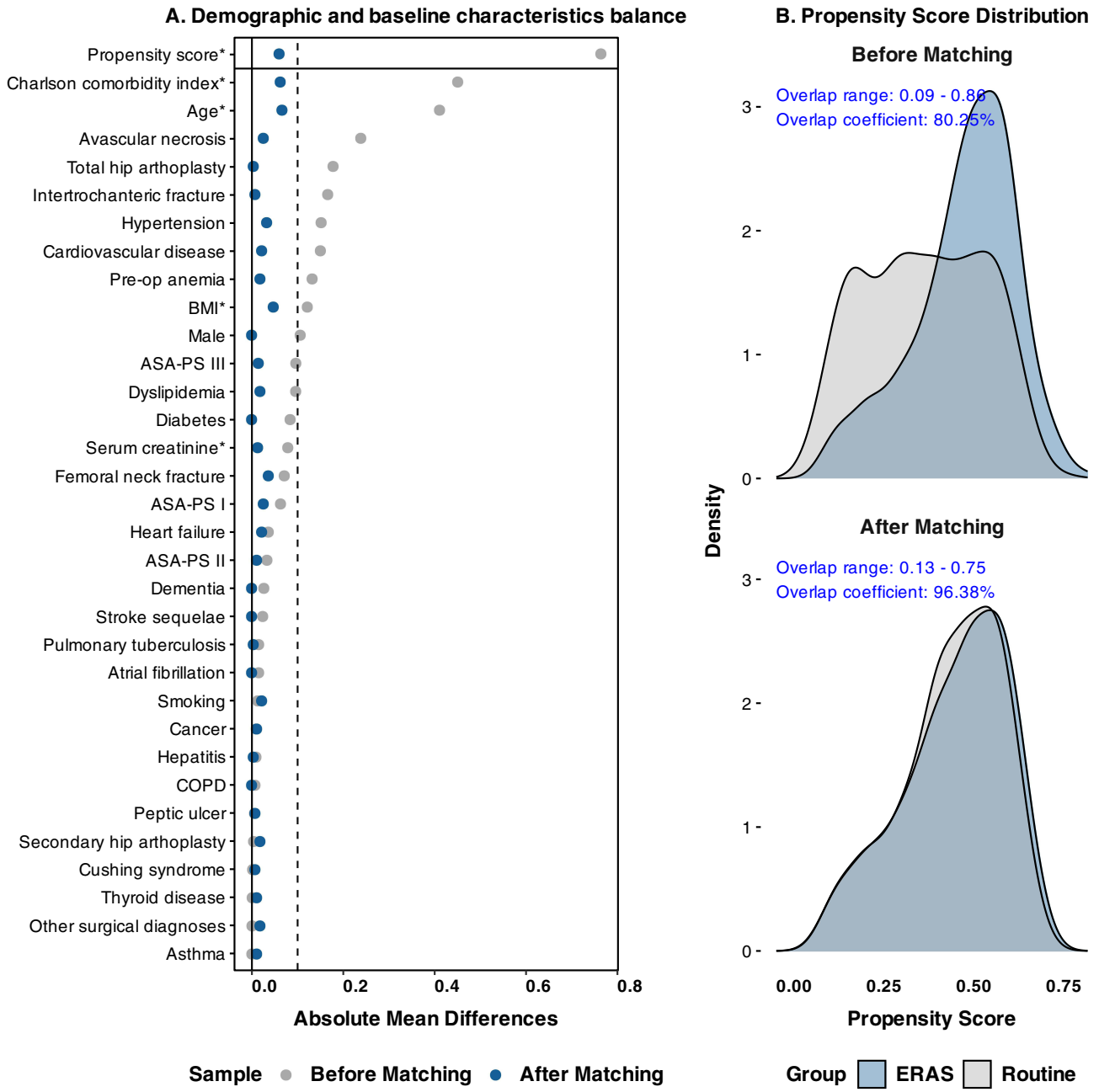


Figure 3 Propensity score matching model assessment. (**A**). Balance of demographic and baseline characteristics before and after matching. (**B**). Distribution of propensity scores before and after matching.

Abbreviations: ASA-PS, American Society of Anesthesiologists physical status; BMI, Body mass index; COPD, Chronic obstructive pulmonary disease; ERAS, Enhanced Recovery After Surgery.

out of 10 studies) supported the role of the ERAS protocol in reducing complications in patients undergoing total joint arthroplasty.[9] The Shibai's study demonstrated statistical differences in complication rates between ERAS and conventional care (OR 0.77, 95% CI 0.61 to 0.98, p=0.03).[29] Conversely, the POWER2 trial found no significant differences in the overall complication rates between the ERAS and non-ERAS groups (10.2% vs 11.4%, OR 0.89, 95% CI 0.74–1.07, p=0.22).[7] Morrell's meta-analysis also reported a limited role of ERAS in improving post-operative complications.[14] In our study, up to 29.8% of patients experienced composite complications, exceeding reference studies. Theoretically, with a high complication rate, especially when the prevalence nears 50%, the standard error is maximized, allowing more minor absolute differences to achieve statistical significance with the same sample size.[30] This may facilitate the

Table 2 Intervention and Treatment Comparisons Before and After Propensity Score Matching

Variables	Before Matching			After Matching		
	Routine Group (n=413)	ERAS Group (n=356)	p-value	Routine Group (n=274)	ERAS Group (n=274)	p-value
Pre-operative stage						
Prophylactic antibiotic use, n (%)	402 (97.3)	351 (98.6)	0.334	268 (97.8)	269 (98.2)	1.000
Pre-op transfusion, n (%)	24 (5.8)	14 (3.9)	0.302	6 (2.2)	9 (3.3)	0.601
Intra-operative stage						
Total hip arthroplasty, n (%)	249 (60.3)	278 (78.1)	<0.001	202 (73.7)	203 (74.1)	1.000
Primary hip arthroplasty, n (%)	388 (93.9)	336 (94.4)	0.918	256 (93.4)	261 (95.3)	0.460
Right-side hip arthroplasty, n (%)	192 (46.5)	172 (48.3)	0.665	123 (44.9)	125 (45.6)	0.932
Daytime surgery, n (%)	395 (95.6)	344 (96.6)	0.604	262 (95.6)	263 (96.0)	1.000
General anesthesia, n (%)	364 (88.1)	319 (89.6)	0.596	231 (84.3)	250 (91.2)	0.019
Ephedrine use, n (%)	152 (36.8)	119 (33.4)	0.367	94 (34.3)	95 (34.7)	1.000
Epinephrine use, n (%)	1 (0.2)	2 (0.6)	0.599	1 (0.4)	1 (0.4)	1.000
Phenylephrine use, n (%)	56 (13.6)	24 (6.7)	0.003	29 (10.6)	20 (7.3)	0.231
Noradrenaline use, n (%)	25 (6.1)	11 (3.1)	0.077	10 (3.6)	11 (4.0)	1.000
Nicardipine use, n (%)	25 (6.1)	22 (6.2)	1.000	13 (4.7)	20 (7.3)	0.281
Tranexamic acid use, n (%)	107 (25.9)	142 (39.9)	<0.001	82 (29.9)	120 (43.8)	0.001
Regional analgesia, n (%)	189 (45.8)	158 (44.4)	0.756	129 (47.1)	124 (45.3)	0.732
Acetaminophen use, n (%)	343 (83.1)	305 (85.7)	0.370	214 (78.1)	237 (86.5)	0.014
NSAID use, n (%)	30 (7.3)	78 (21.9)	<0.001	18 (6.6)	58 (21.2)	<0.001
Nefopam use, n (%)	269 (65.1)	206 (57.9)	0.046	171 (62.4)	161 (58.8)	0.431
Morphine use, n (%)	19 (4.6)	7 (2.0)	0.069	13 (4.7)	6 (2.2)	0.161
Tramadol use, n (%)	153 (37.0)	154 (43.3)	0.093	100 (36.5)	122 (44.5)	0.068
NMBA use, n (%)			<0.001			<0.001
- None	82 (19.9)	58 (16.3)		70 (25.5)	43 (15.7)	
- Neostigmine	105 (25.4)	177 (49.7)		77 (28.1)	132 (48.2)	
- Sugammadex	226 (54.7)	121 (34.0)		127 (46.4)	99 (36.1)	
Fluid input, mL	800 (600–1100)	900 (700–1200)	<0.001	800 (600–1100)	900 (700–1200)	0.005
Blood loss, mL	200 (100–350)	200 (150–400)	0.007	200 (100–375)	200 (150–350)	0.121
Urine output, mL	200 (100–400)	250 (100–400)	0.271	200 (100–335)	250 (100–450)	0.066
Fluid balance, mL.kg-1	8.3 (4.2–14.3)	10.9 (7.3–16.3)	<0.001	10.4 ± 8.8	11.6 ± 7.9	0.080
Surgery time, minutes	75 (60–90)	80 (70–95)	<0.001	75 (60–90)	80 (70–91)	0.017
Anesthesia time, minutes	124 (105–145)	135 (115–150)	<0.001	125 (105–145)	135 (115–150)	<0.001
Intra-op transfusion, n (%)	22 (5.3)	8 (2.2)	0.044	12 (4.4)	8 (2.9)	0.494
Post-operative stage						
Acetaminophen use, n (%)	408 (98.8)	356 (100.0)	0.065	272 (99.3)	274 (100.0)	0.499
Nefopam use, n (%)	325 (78.7)	209 (58.7)	<0.001	212 (77.4)	163 (59.5)	<0.001
NSAID use, n (%)	73 (17.7)	118 (33.1)	<0.001	54 (19.7)	89 (32.5)	<0.001
Tramadol use, n (%)	193 (46.7)	252 (70.8)	<0.001	127 (46.4)	190 (69.3)	<0.001
Morphine use, n (%)	89 (21.5)	79 (22.2)	0.899	67 (24.5)	58 (21.2)	0.415
Pregabalin use, n (%)	238 (57.6)	221 (62.1)	0.238	157 (57.3)	169 (61.7)	0.338
Enoxaparin use, n (%)	406 (98.3)	349 (98.0)	0.992	272 (99.3)	269 (98.2)	0.450
NOACs use, n (%)	387 (93.7)	338 (94.9)	0.561	255 (93.1)	259 (94.5)	0.595
Heparin use, n (%)	9 (2.2)	6 (1.7)	0.816	4 (1.5)	6 (2.2)	0.752
Aspirin use, n (%)	40 (9.7)	20 (5.6)	0.050	26 (9.5)	17 (6.2)	0.204
P2Y12 inhibitors use, n (%)	46 (11.1)	24 (6.7)	0.047	28 (10.2)	23 (8.4)	0.556
Post-op transfusion, n (%)	126 (30.5)	71 (19.9)	0.001	64 (23.4)	64 (23.4)	1.000

Abbreviations: Intra-op, intra-operative; ERAS, enhanced recovery after surgery; NOACs, novel oral anticoagulants; NSAID, non-steroidal anti-inflammatory drugs; NMBA, neuromuscular blocking agent; Post-op, Post-operative; Pre-op, pre-operative.

detection of significant differences in complication rates between the two groups. These findings suggest that developing countries with similar healthcare conditions and high complication rates may benefit most from ERAS implementation.

From a clinical practice perspective, the results of this study suggest several actionable points for improving post-operative outcomes in patients undergoing hip arthroplasty within the context of developing countries. Clinicians should

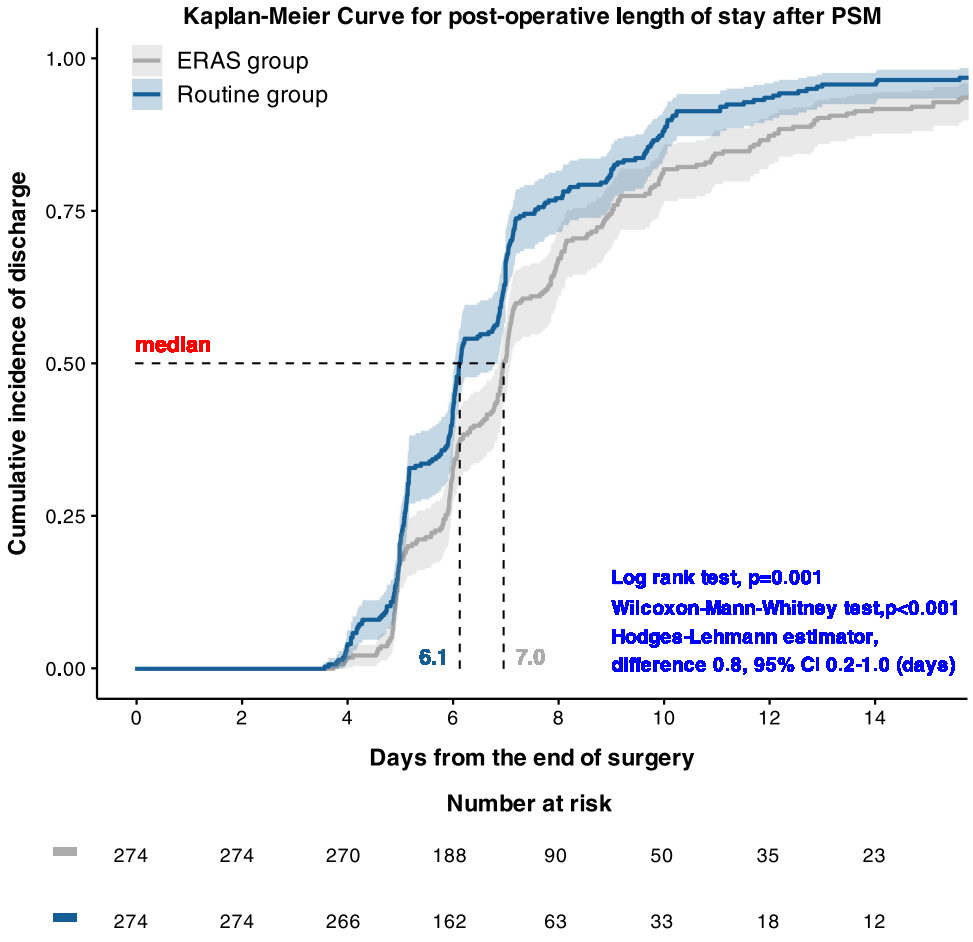


Figure 4 Post-operative primary complication comparisons after propensity score matching.
Abbreviations: ERAS, Enhanced Recovery After Surgery; PSM, Propensity score matching.

consider the integration of ERAS protocols into standard care, primarily focusing on feasible elements within their specific resource constraints. The high complication rates emphasize the need for robust post-operative management and potential adjustments in perioperative care strategies. Ensuring multidisciplinary involvement and patient education about the benefits and processes of ERAS can enhance adherence and efficacy. However, the generalizability of these results should be approached with caution. The context of healthcare in developing countries, particularly in Vietnam, introduces unique challenges that may not necessarily reflect other regions or settings. Several factors, including constrained healthcare resources, adherence to standard protocols, and variations in patient baselines, anesthesia strategies, and surgical procedures, can impact the effectiveness of the ERAS program.

The role of ERAS programs in orthopedic surgery is a growing area of study, attracting more research attention. ERAS programs could also be a potential solution in developing countries with high complication rates and limited health resources, though they have not been extensively studied. With an effective sample size and diverse variables, our research confirmed the effectiveness of ERAS in reducing both the post-operative LOS and complications. Although PSM was utilized to minimize confoundings and biases in this observational study, several limitations remain. First, post-matching residual differences were present, and it is impossible to rule out the possibility of unmeasured confounding variables completely. Secondly, although PSM improves the robustness of comparisons in a retrospective study, it still does not allow for definitive conclusions about causal relationships. Finally, the dichotomous grouping does not accurately represent adherence to ERAS components between the groups, and there may be overlap in the implementation of ERAS elements between the two groups. Future research should focus on ERAS adherence to optimize outcomes

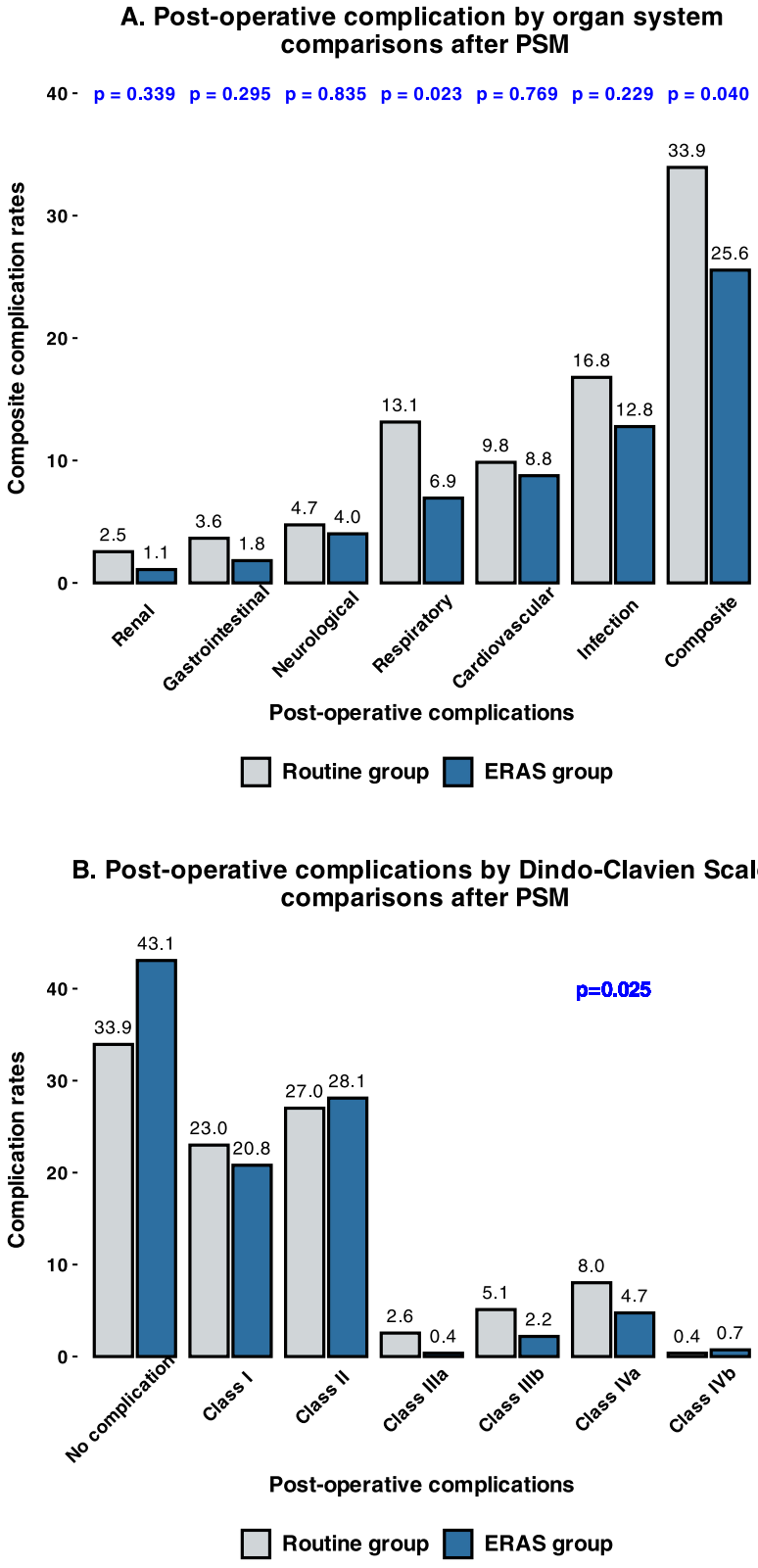


Figure 5 Post-operative secondary complication comparisons after propensity score matching. (**A**) Complications were classified by major organ complications. (**B**) Complications were classified by the Dindo-Clavien scale.
Abbreviations: ERAS, Enhanced Recovery After Surgery; PSM, Propensity score matching.

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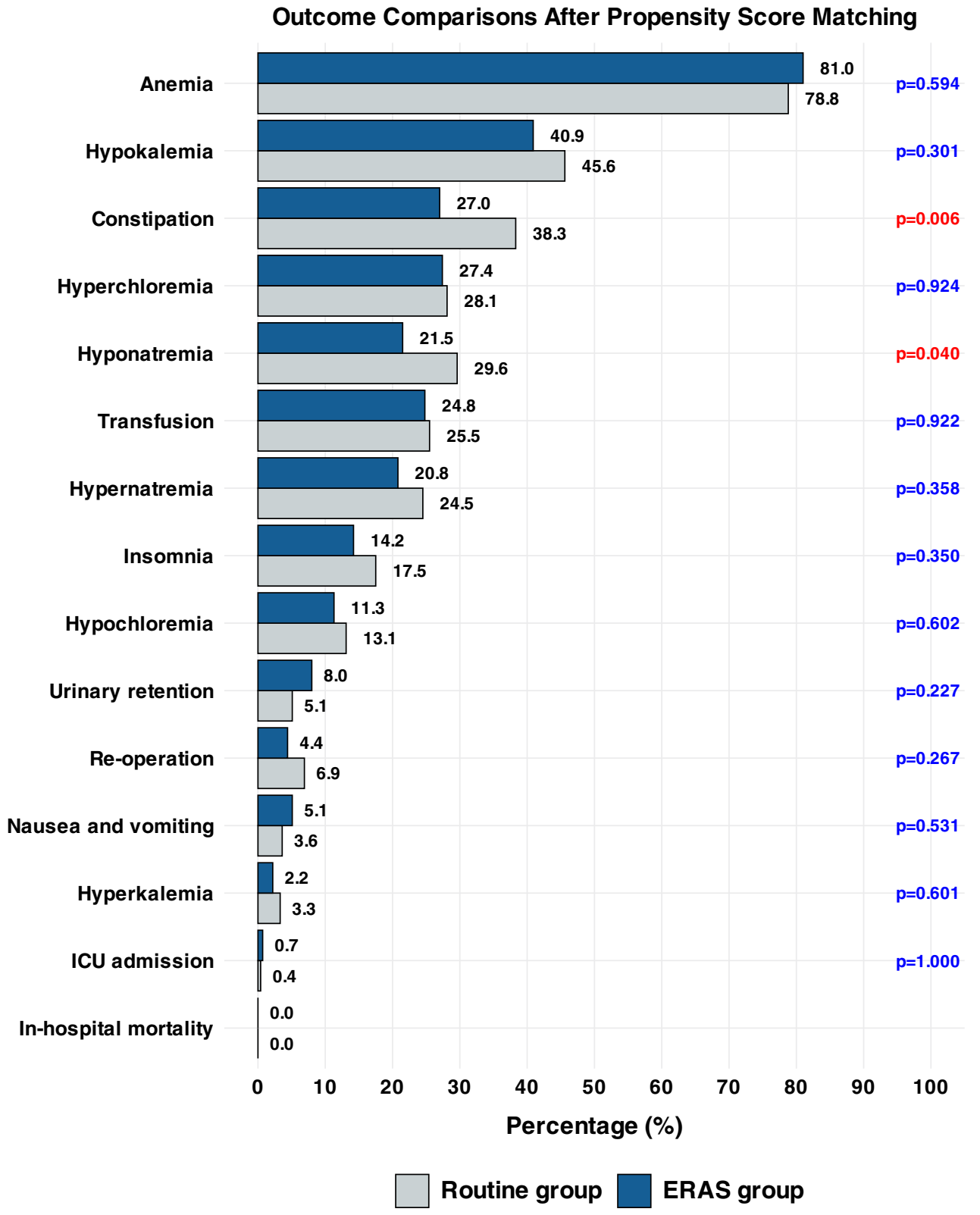

Figure 6 Post-operative tertiary complication comparisons after propensity score matching.
Abbreviation: ERAS, Enhanced Recovery After Surgery.

and consider conducting Strengths, Weaknesses, Opportunities, and Threats (SWOT) analyses to support ERAS implementation in developing countries. Moreover, future studies should expand the scope of outcome assessments by incorporating patient-centered endpoints, such as pain levels, functional recovery, and satisfaction, as well as by evaluating the effectiveness of specific ERAS components, including counseling, early mobilization, pain management, opioid-sparing strategies, and the management of drains and urinary catheters.

Conclusion

The ERAS program is associated with improved outcomes for hip arthroplasty patients in developing countries, including shorter LOS and reduced adverse outcomes. These findings advocate for the broader implementation of ERAS protocols. Given the significant health burden, limited resources, and high rates of complications in such settings, the ERAS program could serve as a feasible solution. Future research should explore strategies to enhance ERAS adherence and assess individual ERAS components' impact on clinical and patient-centered outcomes. Additionally, prospective studies are needed to validate the scalability and sustainability of ERAS programs across diverse healthcare environments.

Data Sharing Statement

The datasets used in this study can be obtained from the corresponding author upon a reasonable request.

Ethical Statement

The authors are accountable for all aspects of the work and ensure that any questions related to the accuracy or integrity of any part of the study are appropriately addressed. This retrospective study did not influence patients' diagnosis, treatment, or follow-up. The study protocol was reviewed and approved by the Ethics Council in Biomedical Research of University Medical Center Ho Chi Minh City (Approval No. 07/GCN-HĐĐĐ, dated January 24th, 2025). The Ethics Council waived individual patient consent due to the study's retrospective nature. In accordance with institutional and ethical standards, all patient data were anonymized and handled with strict confidentiality to protect participant privacy.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

All authors report no conflicts of interest in this work.

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