Journal of Clinical Anesthesia 116 (2027) 112323

Contents lists available at ScienceDirect

Journal of Clinical Anesthesia

journal homepage: www.elsevier.com/locate/jclinane

Original Contribution

Observational study for perioperative intensive care unit (OPICU): Planned and unplanned ICU admissions, follow-up, discharge, and outcomes

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https://doi.org/10.1016/j.jclinane.2026.112323
Received 5 June 2026; Received in revised form 14 August 2026; Accepted 10 September 2026
Available online 27 October 2026
0952-8180/© 2026 Published by Elsevier Inc.

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HIGHLIGHTS

- Large-Scale Multicenter Cohort: This prospective, observational study was conducted across 75 Intensive Care Units (ICUs) in two countries (Türkiye and Azerbaijan), tracking a total of 1980 surgical patients.
- Impact of Surgical Urgency: Multivariable logistic regression revealed that emergency and urgent surgeries increase the likelihood of unplanned ICU admission up to 12.4-fold.
- Intraoperative & Clinical Triggers: An ASA physical status score > 2, intraoperative complications, and sustained intraoperative tachycardia (>140 bpm) were identified as strong, independent risk factors for unplanned ICU admission.
- Protective Interventions: The utilization of central or peripheral regional anesthesia, sedoanalgesia, and minimally invasive laparoscopic techniques significantly increased the number of direct-to-ward patients instead of ICU.
- Age and Operative Duration: Younger age (1.1% increase in odds of avoiding ICU per one-year decrease) and shorter operative durations (each additional hour reduced the odds of avoiding ICU by 22.6%) were robust predictors of a direct-to-ward transfer.
- Physiological Markers: Lower baseline POSSUM scores, lower intraoperative lactate levels, and conservative fluid administration strongly correlated with successful management on regular wards instead of the ICU.
- The Challenge of Overtriage: 25% of all ICU-admitted patients received only basic technological monitoring (ECG, SpO2, NIBP), functions that could ideally be managed in intermediate care or high-dependency units.
- Intensivist Subjective Feedback: Upon discharge, ICU physicians reported that 9.2% of all admitted surgical patients did not have a strict medical necessity for an intensive care bed.
- Mortality Trends: Overall ICU mortality was 5.9%, while the 90-day postoperative mortality rate stood at 7.5%. Standard POSSUM scores consistently over-predicted actual morbidity and mortality across all groups.

ARTICLE INFO

Keywords:
Clinical outcomes
ICU utilization
Intensive care
Postoperative care
Postoperative period
Triage
Triage decision-making
Postoperative unplanned ICU admission.
Postoperative emergency admission

ABSTRACT

Introduction: Due to limited resources, identifying high-risk surgical patients who derive clinical benefit from Intensive Care Unit (ICU) admission is essential. Our primary aim was to characterize resource allocation and evaluate the true clinical benefit of ICU admissions using modified Wang criteria. Secondary aim is to identify independent risk factors for ICU admission; validate clinical scoring systems; and compare inter-group outcomes, including Clavien-Dindo complication rates, lengths of stay, and mortality.

Materials and Methods: This multicenter, prospective, observational study was conducted across 75 ICUs. Adult inpatient surgery cases were categorized into four groups: planned admission (PAG), unplanned admission (UPAG), planned but not admitted (PBNAG), and emergent admission (EAG). Data included preoperative/intraoperative/postoperative(ICU) variables, modified Wang criteria, and mortality rates (ICU, hospital, 30/90-day).

Results: Of 55,963 preoperatively evaluated patients, 2764 (4.9%) were planned for ICU admission; 804/2764 patients could not be admitted because of limited ICU beds, remaining of 1960 patients with a planned ICU admission, 411/1960 did not require postoperative ICU care forming the PBNAG (14.8% of 2764). Overall, 1980 patients (3.09% of all cases) were admitted to the ICU (78.2% PAG, 12.5% EAG, 9.1% UPAG). POSSUM scores effectively differentiated PBNAG (lower) and EAG (higher) from PAG. ICU benefit indicators (e.g., vasopressor need, prolonged ventilation >12 h, arrest events) were significantly higher in UPAG and EAG versus PAG ($p < 0.001$). Emergency surgery (OR 12.4), intraoperative complications (OR 3.1), and ASA >2 (OR 2.7) independently increased UPAG risk, whereas minimally invasive surgery and regional anesthesia reduced ICU admissions. Overall ICU and 90-day mortality rates were 5.9% and 7.5%, respectively, peaking in the EAG group (18.1% and 18.9%).

Conclusion: Integrating modified Wang criteria, POSSUM scores, intraoperative complications, emergency status, and ASA class >2 is effective in predicting the necessity of ICU admission.

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1. Introduction

The postoperative mortality of high-risk surgery is between 5 and 25% [1]. Postoperative mortality contributes to 7.7% of all deaths [2]. Intensive Care Unit (ICU) admission is necessary for close monitoring (which includes invasive monitoring), management, and titration of treatment by the multidisciplinary team [3]. Globally, over 310 million surgical procedures are performed annually [4], and ICU admissions pose a substantial clinical and economic burden [5–10]. High risk surgical patients often treated in an ICU are only 5–10% of surgical patients but consume 35–50% of total hospital expenses [11].

Risk prediction models, such as physiological and operative severity score for the enumeration of mortality and morbidity (POSSUM) [12] and the Surgical Apgar Score (SAS), integrate factors including comorbidities, intraoperative hemodynamic status, surgical site, and operative duration to identify patients with elevated postoperative risk [13,14].

In most cases, decisions regarding ICU admission are made at least one day prior to surgery and are primarily based on clinical judgment, incorporating the patient's physiological status as well as the anticipated type and severity of surgery and overall perioperative risk. Despite this preoperative assessment, patients may experience unexpected clinical deterioration, necessitating unplanned ICU admissions. Additionally, certain patients—particularly those undergoing emergency surgery—may require ICU admissions based on decisions made in close proximity to surgery [15–17].

Our aim is to evaluate the efficiency of ICU bed utilization among post-surgical patients. To determine current utilization patterns, surgical patients were separated into four groups: the planned admitted group (PAG), unplanned admitted group (UPAG), emergency admitted group (EAG), and planned but not ICU admitted group (PBNAG). To correctly determine which patients, derive clinical benefit from ICU admission, post-discharge assessments were conducted using the modified Wang criteria [18]. Secondary objectives include identifying independent risk factors for ICU admission and evaluating clinical scoring systems; POSSUM, Charlson Comorbidity Index (CCI), Rockwood Frailty Scale (RFS), ASA, SAS, Surgical Risk Stratification Score (SRSS), SOFA, APACHE II, and SAPS III. Furthermore, the study compared postoperative complication rates utilizing the Clavien-Dindo classification, both ICU and hospital lengths of stay, ICU /hospital mortality as well as distinct 30-day and 90-day postoperative mortality rates across the defined groups.

2. Materials and methods

This multicenter, prospective observational cohort study was conducted in Türkiye and Azerbaijan. The study received approval from the Koç University Ethics Committee (2023.198.IRB1.065) and was registered at ClinicalTrials.gov (NCT05995925). Ethics committees at each participating institution approved the protocol and informed consent was obtained in accordance with each institute's local regulations. This study adhered to the Declaration of Helsinki and applicable data protection laws. Patient confidentiality was strictly maintained, with private patient data being de-identified and unique number codes assigned in place of patient identification numbers. A confidential subject identification list linking patients' names and private patient information with the study specific codes were securely stored at each study site.

The reporting of this study conforms to the STROBE statement; the specific locations of the required reporting items within this manuscript are detailed in the provided STROBE checklist [19] (Shown in the Supplementary Material).

The Department of Anesthesiology and Intensive Care at Koç University School of Medicine [20] served as the Data Coordinating Center. Each center designated at least one anesthesiologist and one intensive care physician investigator.

Adult patients (≥18 years) undergoing inpatient non-cardiac surgical procedures (gynecologic, neurosurgical, thoracic, urologic, orthopedic/trauma, upper abdominal, hepatobiliary, colorectal, plastic, vascular, and breast surgery) at participating centers were included. Day surgeries, cardio-vascular, pediatric surgeries and interventional procedures were excluded.

Patients were categorized according to their ICU admission status:

a. Planned Admitted Group (PAG): Patients who underwent surgery with an a priori postoperative ICU admission plan preoperatively and who were subsequently admitted to the ICU.

b. Unplanned Admitted Group (UPAG): Patients for whom postoperative ICU admission was not planned preoperatively (regardless of whether the case was elective, urgent, or emergent) but who required ICU admission at the end of surgery.

c. Planned-But-Not-Admitted Group (PBNAG): Patients with a preoperative ICU admission plan who ultimately did not require ICU care postoperatively.

d. Emergency Admitted Group (EAG): Patients undergoing emergency surgery for whom the ICU admission decision was made in close proximity to surgery and who were subsequently admitted to the ICU postoperatively.

2.1. Data collection

Hospital and ICU Characteristics: Hospital type (university, public, or private), total number of ICU beds, ICU level/specifications, and patient-to-nurse and patient-to-physician ratios were recorded.

Daily records captured the number of all preoperative patients, number of surgeries canceled due to unavailability of ICU beds, and the physicians who were responsible for the ICU admission decision. In addition, data were collected for postoperative surgical patients initially admitted to hospital wards who required escalation to ICU care within the first 48 postoperative hours. We also recorded the number of non-operative critically ill patients who could not be admitted to the ICU due to bed shortages and were transferred from the emergency department.

Patient Data: preoperative (patient characteristics, laboratory data, medications used, vital parameters), intraoperative (surgical details, POSSUM, blood and fluid administration), postoperative (ICU admissions score, outcomes, complications) data and additional information details of all patients are given in Supplement Table 1.

ICU stay benefit criteria and discharge: Following ICU stay, the benefit of this period was assessed using predefined criteria modified from Wang et al. [18] Table 1. Also, ICU physicians' opinions were asked about the necessity of ICU admission of each patient at the discharge.

Discharge from the ICU was based on clinical judgment and local protocols and after the admission reason was addressed, typically requiring stable vital signs, adequate oxygenation, return to preoperative mental status, sufficient urine output, pain control, no further needs for close clinical observation in the ICU and overall clinical stability.

2.2. Study outcomes

The primary outcome of this study was to characterize resource allocation and evaluate the clinical necessity of ICU admissions based on presence and characteristics of PBNAG, UPAG, EAG, PAG and the modified Wang criteria. The secondary outcomes were to determine the independent pre- and perioperative risk factors for ICU admission, validate existing clinical scoring systems, and compare postoperative inter-group outcomes, specifically hospital and ICU lengths of stay, Clavien–Dindo complication rates, and short-term mortality.

2.3. Statistical analyses

Assuming the rate of appropriate ICU admission is 95% in UPAG and 90% in PAG (corresponding to inappropriate ICU admission rates of 5% and 10%, respectively), the anticipated odds ratio (OR) is about 2.0. A power analysis was conducted for the multivariate logistic regression

using G*Power (version 3.1.9.6). Assuming a one-sided type I error rate (alpha) of 0.05, a power (1-β) of 80%, an odds ratio of ≈2.0, a baseline outcome probability of 0.75 ($P(Y = 1 \mid X = 1)$ under H_0), a binary predictor distribution with a proportion of 0.10 (X parm π) and controlling for other covariates ($R^2$of other X = 0.20), the minimum required sample size was calculated as 1281 patients.

Categorical data were documented as number (n) and percentage (%), while numerical data were documented as mean ± standard deviation or medians (quartiles). For group comparisons, chi-square, one-way ANOVA, Welch's ANOVA and Kruskal-Wallis test were used. Two multivariate logistic regression models were constructed. Model I included PAG and UPAG to evaluate predictors of UPAG, whereas Model II included PAG and PBNAG to assess factors associated with PBNAG. In both models, variables entered in the initial step included age, BMI, RFS, CCI, ASA physical status, hemoglobin level (g/dL), surgical approach, POSSUM score, chemotherapy or radiotherapy within the preceding 6 months, duration of surgery, intraoperative blood product administration, estimated blood loss, intraoperative lactate level (mmol/L), sustained intra-operative tachycardia (Intraoperative heart rate > 140 bpm, >5 min), intraoperative complications, operative severity, type of surgery, and type of anesthesia. Variables showing potential associations in univariate analyses were subsequently retained in the multivariate models. Multivariate logistic regression analyses (Model I for predictors of UPAG and Model II for factors associated with PBNAG) were performed as secondary outcomes on mutually exclusive study groups. To identify independent predictors and adjust for confounding, candidate variables with a univariate (p-value<0.05) and clinically relevant factors were entered into the initial multivariate models. Final models were derived using a backward elimination stepwise approach (removal criterion: $p > 0.05$). Multicollinearity among candidate variables was assessed prior to final model construction.

Additionally, these multiple logistic regression models were applied separately to academic and non-academic hospitals to evaluate whether institutional setting influenced the risk factors for unplanned ICU admission (Model I) and non-admission despite planning (Model II).

All analyses were performed using IBM SPSS Statistics for Mac, Version 30 (172)(IBM Corp., Armonk, N.Y., USA) and JAMOVI (version 2.7, The Jamovi Project,2024).

3. Results

3.1. Patient Flow and ICU Admission Patterns

Between January 3rd and February 3rd, 2024, a total of 55,963 patients scheduled for operation across 55 hospitals (whose characteristics were given in Table 2).

Of these 2764 (4.9%) were planned for postoperative admission in a total of 75 ICUs. However, due to unavailability of ICU beds on the day of surgery 804 patients (29.1%) could not be admitted to the ICU as initially planned. Among 804 patients, 727 (90.4%) had their surgeries postponed, (remaining 55,236 patients who were operated), whereas 77 (9.6%) proceeded with surgery and were subsequently admitted to hospital wards postoperatively. Remaining of 1960 patients with a planned ICU admission, 411 did not require postoperative ICU care and were admitted to regular wards, forming the PBNAG. 77 patients are not included in the PBNAG cohort ($n = 411$), as the PBNAG group consists of patients who did not receive ICU admission despite bed availability. The remaining 1549 patients formed PAG. Of the 53,199 patients who underwent surgery without a preoperative ICU plan, 182 (0.34%) admitted as UPAG. 249 patients (0.46%) were admitted to the ICU following emergency surgery, forming EAG. The distribution of 1980 ICU admitted patients was 182 (9.2%) in UPAG, 1549 (78.2%) in PAG and 249 (12.5%) in EAG (Fig. 1).

During the study period, ICU bed shortages caused transfer of 1608 non-surgical patients from the emergency unit to other institutions. Furthermore, 13 surgical patients who were initially planned and admitted to ward required ICU care within 48 h after surgery.

3.2. Pre and peri-operative characteristics of ICU admitted patients

The median age was 65 years (IQR 54–75), with EAG and UPAG being significantly younger compared to PAG. CCI was significantly lower in UPAG, PBNAG and EAG compared to PAG. Hypertension was the most common comorbidity overall (55.1%) but was less prevalent in the UPAG and EAG compared to the PAG. Ischemic heart disease, chronic kidney disease, ASA score > 2, and frailty score were the lowest in the UPAG compared to the PAG. Chronic kidney disease (preop CKD)

Table 1
Criteria for Clinical Benefit of ICU stay (modified from Wang et al 2019).

1.Expected need for intubation/ NIMV exceeding 6 hours postoperatively
2.Unexpected need for reintubation after surgery.
3.Airway patency concerns, requiring close and/or invasive monitoring.
4.Respiratory or circulatory arrest
5.Blood pressure <90/60mmHg for two consecutive hours at any time during the first 48 postoperative hours (regarding their baseline parameters)
6.HR <50/min or >120 /min for two consecutive hours during the first 48 hours (with a ≥20% change from baseline)
7.Administration of vasopressors or inotropes or intravenous vasodilator agents
8.Use of intravenous anticoagulation requiring monitoring
9.Use of advanced hemodynamic monitoring devices postoperatively (Transpulmonary thermodilutional techniques, echocardiography)
10.Requirement for basic hemodynamic postoperative monitoring, including

a. Invasive arterial blood pressure, saturation (SpO2)
b. Prolonged monitoring due to pre/perioperative ECG abnormalities (e.g. severe bradycardia, tachycardia, PR/QT interval prolongation)
11.New onset of cardiac arrhythmia that deteriorates hemodynamic status.
12.Need for neurologic monitoring
13.Acute myocardial infarction
14.Reoperation indication within first 48 hours postoperatively
15.Blood transfusion exceeding 4 units within the first 48 postoperative
16.Severe electrolyte imbalance (<120 meq/L Sodium, >155 meq/L Sodium, <2.5 meq/L Potassium, >5.5 meq/L Potassium)
17.Altered level of consciousness or new onset neurologic deficit.
18.Requirement for sedation and/or intensive pain management
19.Readmission to ICU within 48 hours of discharge
20.Initiation of renal replacement therapy (RRT)
21.Requirement for total plasma exchange (TPE)
22.Need for extracorporeal membrane oxygenation (ECMO)
23.Exacerbation of pre-existing neuromuscular diseases
24.Others

Table 2
Participant hospital characteristics.

Participant Hospitals, n (%)	55 (100.0)
University	37 (67.3)
Public	10 (18.2)
Private	8 (14.5)
Participant ICUs, n (%)	75 (100.0)
General ICU	63 (84)
Surgical	7 (9.3)
Emergency	3 (4.1)
Neurosurgical	1 (1.3)
Cardiovascular	1 (1.3)
Levels of ICUs, n (%)	75 (100.0)
Level 2	3 (4.1)
Level 3	64 (85.3)
PACU	8 (10.6)
Systems for ICU, n (%)	75 (100.0)
Close	63 (84.0)
Open	12 (16.0)
The number of ICU beds, n (%)	1699
≤5	1 (1.2)
5-10	17 (22.1)
11-20	30 (39.0)
21-30	16 (20.8)
31-50	8 (10.4)
>50	5 (6.5)
Nurse:patient ratio (in one shift), n (%)	
1:2	59 (78.7)
1:3	16 (21.3)
Doctor:patient ratio, (in one shift), n (%)	
<1:10	17 (22.7)
1:10 - 1:15	34 (45.3)
>1:15	24 (32.0)
The total number of patients operated, n	55.236
The number of patients planned to be admitted to the ICU, n (%)	2391 (100.0)
Planned	1549 (64.8)
Unplanned	182 (7.6)
Planned/no admission	411 (17.2)
Emergency surgery	249 (10.4)
Length of ICU stay, day (min-max)	1 (1-104)
1 day admissions, n (%)	1361 (68.7)

Abbreviations: ICU: intensive care unit, PACU: post-operative anesthesia care. Categorical data were documented as number (n) and percentage (%).

was more common in EAG compared to the PAG (Table 3). Gender, BMI, total number of preoperatively used medications, and preoperative laboratories were given in supplement Table 2.

Surgical severity scores (POSSUM, SAS, SRSS) were lowest in PBNAG and UPAG and highest in PAG ($p < 0.001$). The number of surgical procedures (as stated in POSSUM score) was lower in PBNAG than PAG ($p = 0.002$). Physiological POSSUM were lowest in PBNAG and highest in EAG, Operative POSSUM also followed a similar pattern ($p < 0.001$). Open surgery was the predominant approach overall, while laparoscopic surgery was more frequent in PBNAG and open surgery in EAG. General anesthesia was used more commonly in EAG and UPAG than in PAG. Intraoperatively, total fluid administration was similar across groups, except for PBNAG, which received significantly lower total intra-operative fluid volume. The intraoperative lactate levels were present in 1556 of the patients. PBNAG also had the lowest intraoperative blood loss and lactate levels, while urine output did not differ between groups (Table 3).

Intraoperative complications were more frequent in UPAG (36.3%) than in PAG (18.4%), ($p < 0.001$). Compared to PAG; UPAG and EAG showed more common intraoperative procedural changes and major intraoperative bleeding (>500 mL), with bleeding being particularly higher in UPAG. In contrast, bleeding, hypotension, and arrhythmias were less frequent in PBNAG. Severe intraoperative events, including cardiac or respiratory arrest and embolism, occurred more often in UPAG than PAG. The median SAS was highest in PBNAG, with SAS >5 being more frequent in this group and least frequent in EAG. Operative duration was shorter in PBNAG and EAG compared with PAG (Table 3).

In the Model 1 multivariate regression analysis, we found that sustained intra-operative tachycardia (Intraoperative heart rate > 140 bpm, >5 min), major vs minor surgery and major vs. moderate surgery were more common in the UPAG compared to PAG (Table 4).

Emergent and urgent surgery significantly increased the likelihood of unplanned ICU admission, for procedures performed within ≤2 h and 2–24 h. Intraoperative complications were also independently associated with unplanned ICU admission, as was ASA class >2. Conversely, the use of central or peripheral regional anesthesia or sedoanalgesia was associated with a reduced risk of unplanned ICU admission (Table 4).

In the Model II multivariable logistic regression analysis identified factors associated with classification as PBNAG versus PAG (Table 4). Younger age was independently associated with avoiding ICU admission, with a 1.1% increase in odds per one-year decrease in age. Higher POSSUM scores were associated with lower odds of avoiding ICU admission. Longer operative duration was a strong predictor, with each additional hour reducing the odds of avoiding ICU admission by 22.6%. Minimally invasive surgery was associated with 1.5-fold higher odds of avoiding ICU admission compared with open surgery. Similarly, regional anesthesia or sedation increased the odds of avoiding ICU admission compared to general anesthesia (Table 4).

Multiple logistic regression models applied separately to academic and non-academic hospitals to evaluate whether institutional setting influenced the risk factors for UPAG compared to PAG (Model I) demonstrated homogenous risk profiles across center types. However, PBNAG compared to PAG (Model II) showed statistically significant differences only for ASA > 2 (Supplement Table 4).

3.3. Characteristics of ICU admitted patients, benefit criteria, intensivist opinion on ICU admission necessity and outcomes

ICU admission APACHE II and SAPS III scores were higher in UPAG and EAG compared to PAG. SOFA score was higher in EAG compared to PAG. At the time of ICU admission 61% of EAG patients were intubated. In UPAG lower MAP, pH, HCO_3 and higher hematocrit (HCT) values were detected compared to PAG. In EAG, heart rate (HR), FiO2, PaO2, and WBC levels were higher, and MAP, pH, HCO3, and HCT were lower compared to PAG (Table 5).

Basic hemodynamic monitoring emerged as the most frequently marked event defining benefit [17], while sedation and pain control ranked secondly, and advanced hemodynamic monitoring thirdly. Overall, 25% of all ICU patients were admitted to the ICU only because of basic hemodynamic monitoring. Vasopressor use, SAP <90 mmHg in the first 48 h, invasive and non-invasive mechanical ventilation more than 12 h, new neurological deficits, re-operation in the first 48 h, and respiratory or circulatory arrest, were statistically more prevalent in UAG and EAG compared to PAG. *Re*-intubation and echocardiography indications were also higher in UAG compared to PAG (Table 6).

The subjective assessments of intensivists at the participating centers on ICU admission necessity was (1798) 90.8% for all patients, and higher in EAG (235) 94.4% and UPAG (170) 93.4% compared to PAG (1393) 89.9% ($p < 0.035$).

EAG had required significantly more fluids during the ICU stay (median 2500 mL in the first 24 h) and had higher total fluid balances and higher FiO_2 requirements. Longer duration of IMV in EAG and UPAG compared to PAG (supplement Table 3).

ICU length of stay median value was 1 and ranged from 1 to 104 days, with 1-day stays accounting for the majority (68.7%; $n = 1361$).

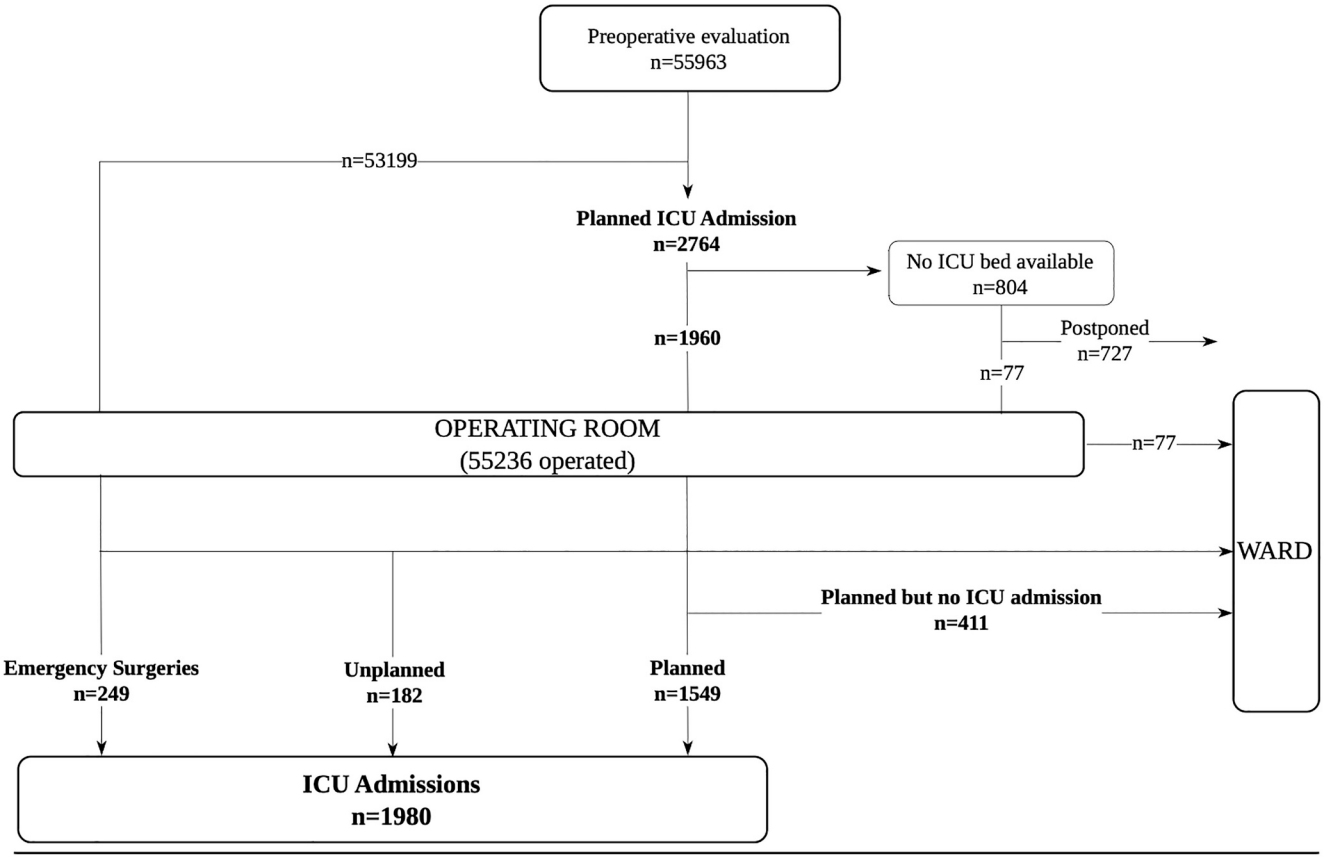


Fig. 1. Study Flowchart.

Mortality in ICU was 118 (5.9%), in hospital 138 (6.9%). The overall 30- and 90-day mortality rate were 7.5% and 7.5%, respectively ($n = 149$) (Table 7). POSSUM-predicted mortality and morbidity were 19 ∓ 20%, 55 ∓ 22% respectively (Table 3).

Crucially, EAG demonstrated significantly higher mortality rates than PAG across all evaluated time intervals. Postoperative complications, Clavien-Dindo classification and frailty scores, details of mortality were given in Table 7.

4. Discussion

This is the first prospective observational study that evaluated postoperative ICU admissions in a structured manner including planned, unplanned admissions, as well as planned but not admitted patients and emergency cases. We used this design to pinpoint patients who missed out on ICU care due to lack of space, specifically those with canceled surgeries and emergency patients needing admission. These aspects represent an important feature that distinguishes our study from previous reports.

In our study 1980 postoperative patients admitted to the ICU, which made up 3.4% of all surgical patient population at our study centers during the study period. EuSOS study [15] found out that after non-cardiac surgery 8% of the patients were admitted to the ICU, in the ISOS study this percentage was 16.4% [21]. EuSOS study states that the number of critical care admissions differed substantially across 28 countries (rates ranging from 1.2 to 16.1%). The wide variability observed may also be attributed to notable discrepancies in the definitions of patient groups, demographics, comorbidities, different surgical cohorts, monitoring capabilities of postoperative care units which may affect ICU admission.

In our study, POSSUM scores effectively distinguished both PBNAG (lower scores) and EAG (higher scores) from PAG, whereas no significant difference was observed between UPAG and PAG. Similarly, while SAS failed to demonstrate a significant difference between UPAG and PAG, it successfully differentiated EAG from PAG at a threshold of SAS >5. These findings suggest that relying solely on POSSUM and SAS is insufficient for identifying UPAG patients, highlighting the need to incorporate additional clinical variables. Indeed, as demonstrated in our Model 1, emergency surgery (OR 12.4), intraoperative complications (OR 3.1), and ASA class >2 (OR 2.7) emerged as independent risk factors for UPAG admission, whereas minimally invasive surgery and regional anesthesia exerted a strong protective effect.

Haller Guy et al. [22] defined unplanned ICU admissions as cases in which patients were not initially scheduled for postoperative ICU admission at the beginning of the procedure but were subsequently admitted within 24 h postoperatively. They found out that increasing age, comorbidities like anemia, hypertension, ischemic heart disease, cerebrovascular disease, shock, ASA status >2, and emergency procedures were the risk factors for unplanned ICU admissions.

Onwochei DN. et al. in a review [23] stated that patients with a predicted mortality risk greater than 5% were admitted to the ICU as planned cases. Advanced age, anemia, higher ASA physical status, elevated BMI, comorbidities, emergency and high-risk surgical procedures, greater intraoperative blood loss, and prolonged operative

Table 3
Comparison between patients' characteristics, surgical features, preoperative laboratories and intraoperative parameters of the groups.

	Total (n=2391)	Planned (n=1549)	Unplanned (n=182)	Planned/no admission (n=411)	Emergency Surgery (n=249)	p
Age years (min-max)	65 (54-75)	66 (55-76)	62 (50-73)$^{\#\#}$	65 (54-75)	64 (50-76)*	***0.006***
CCI	4 (2-6)	4 (3-7)	3 (1-6)$^{\#\#\#}$	4 (2-6)$^{\beta\beta\beta}$	4 (1-6)***	***<0.001***
Comorbidities n (%)						
Hypertension	1317 (55.1)	887 (57.3)	89 (48.9)$^{\#}$	220 (53.5)	121 (48.6)*	***0.015***
Diabetes Mellitus	702 (29.4)	459 (29.6)	44 (24.2)	121 (29.4)	78 (31.3)	0.411
COPD	314 (13.1)	210 (13.6)	18 (9.9)	57 (13.9)	29 (11.6)	0.458
Heart failure	192 (8.0)	139 (9.0)	10 (5.5)	27 (6.6)	16 (6.4)	0.124
Ischemic heart disease	381 (15.9)	267 (17.2)	15 (8.2)$^{\#\#}$	67 (16.3)	32 (12.9)	***0.004***
Chronic kidney disease	181 (7.6)	119 (7.7)	7 (3.8)$^{\#}$	27 (6.6)	28 (11.2)*	***0.029***
Chronic liver failure	10 (0.4)	9 (0.6)	0 (0.0)	1 (0.2)	0 (0.0)	0.377
Cerebrovascular disease	96 (4.0)	62 (4.0)	4 (2.2)	16 (3.9)	14 (5.6)	0.339
CT/RT in the last 6 months	278 (11.6)	196 (12.7)	17 (9.3)	42 (10.2)	23 (9.2)	0.184
ASA scale >2, n (%)	1406 (58.8)	900 (58.1)	70 (38.5)$^{\#\#\#}$	268 (65.2)	168 (67.5)	***<0.001***
Frailty scale (preoperative)	3 (2-4)	3 (2-4)	2 (2-4)$^{\#}$	3 (2-4)	3 (2-4)	***0.046***
SRSS (High/very high risk), n (%)	1133 (47.4)	809 (52.2)	66 (36.3)$^{\#\#\#}$	120 (29.2)$^{\beta\beta\beta}$	138 (55.4)	***<0.001***
♦ Procedures>1, n (%)	133 (5.6)	98 (6.3)	15 (8.2)	10 (2.4)$^{\beta\beta\beta}$	10 (4.0)	***0.002***
Possum score	37±9	37±8	38±11	33±8$^{\beta\beta\beta}$	46±11***	***<0.001***
Possum calculated mortality (%)	19±20	18±18	21±23	12±14$^{\beta\beta\beta}$	38±26***	***<0.001***
Possum calculated morbidity (%)	55±22	55±25	55±29	43±25$^{\beta\beta\beta}$	78±20***	***<0.001***
Possum (physiological)	25±7	25±7	25±8	24±7$^{\beta\beta}$	29±7***	***<0.001***
Possum (operative)	12±5	12±5	13±6	10±4$^{\beta\beta\beta}$	17±6***	***<0.001***
Surgery area, n (%)						
Upper abdomen	460 (19.2)	282 (18.2)	33 (18.1)	61 (14.8)	84 (33.7)***	***<0.001***
Lower abdomen	486 (20.3)	272 (17.6)	55 (30.2)$^{\#\#\#}$	53 (12.9)$^{\beta}$	106 (42.6)***	***<0.001***
Hepatobiliary	62 (2.6)	53 (3.4)	6 (3.3)	2 (0.5)$^{\beta\beta\beta}$	1 (0.4)**	***<0.001***
Orthopedic	485 (20.3)	339 (21.9)	25 (13.7)$^{\#\#}$	84 (20.4)	37 (14.9)*	***0.006***
Gynecologic/obstetric	109 (4.6)	60 (3.9)	14 (7.7)$^{\#}$	26 (6.3)$^{\beta}$	9 (3.6)	***0.026***
Urologic	243 (10.2)	141 (9.1)	18 (9.9)	76 (18.5)$^{\beta\beta\beta}$	8 (3.2)***	***<0.001***
Neurosurgery	404 (16.9)	299 (19.3)	25 (13.7)$^{\#}$	31 (7.5)$^{\beta\beta\beta}$	49 (19.7)	***<0.001***
Thoracic	172 (7.2)	136 (8.8)	9 (4.9)$^{\#}$	22 (5.4)$^{\beta}$	5 (2.0)***	***<0.001***
Plastic surgery	45 (1.9)	26 (1.7)	6 (3.3)	12 (2.9)	1 (0.4)	0.053
Type of surgery, n (%)						
Open	1966 (82.2)	1297 (83.7)	151 (83.0)	293 (71.3)$^{\beta\beta\beta}$	225 (90.4)**	***<0.001***
Laparoscopic	365 (15.3)	215 (13.9)	25 (13.7)	105 (25.5)$^{\beta\beta\beta}$	20 (8.0)*	***<0.001***
Robotic	38 (1.6)	21 (1.4)	6 (3.3)	10 (2.4)	1 (0.4)	0.055
Laparoscopic+Unplanned Open	22 (0.9)	16 (1.0)	0 (0.0)	3 (0.7)	3 (1.2)	0.267
Type of anesthesia, n (%)						
General	1878 (78.6)	1188 (76.7)	157 (86.3)$^{\#\#}$	299 (72.7)	234 (94.0)***	***<0.001***
CR	311 (13.0)	204 (13.2)	9 (4.9)$^{\#\#\#}$	87 (21.2)$^{\beta\beta\beta}$	11 (4.4)***	***<0.001***
PR	9 (0.4)	5 (0.3)	1 (0.5)	2 (0.2)	1 (0.4)	0.940
Sedation	20 (0.8)	7 (0.5)	1 (0.5)	10 (2.4)$^{\beta\beta\beta}$	2 (0.8)	***0.008***
General + CR	98 (4.1)	83 (5.4)	8 (4.4)	7 (1.7)$^{\beta\beta\beta}$	0 (0.0)***	***<0.001***
General + PR	75 (3.1)	62 (4.0)	6 (3.3)	6 (1.5)$^{\beta}$	1 (0.4)***	***<0.001***
Total administered fluids, L	2.0 (1.1-3.0)	2.0 (1.3-3.5)	2.2 (1.5-3.5)	1.5 (1.0-2.3)$^{\beta\beta\beta}$	2.0 (1.1-3.0)	***<0.001***
Crystalloids	2.0 (1.0-3.0)	2.0 (1.1-3.0)	2.0 (1.5-3.5)	1.4 (1.0-2.0)$^{\beta\beta\beta}$	1.9 (1.2-2.5)	***<0.001***
Colloids	0 (0-0)	0 (0-0.9)	0 (0-0.4)	0 (0-0)$^{\beta\beta\beta}$	0 (0-0.8)	***<0.001***
Blood products, U						
Erythrocyte suspension	0 (0-0)	0 (0-2)	0 (0-2)	0 (0-1)$^{\beta\beta\beta}$	0 (0-2)	***<0.001***
FFP	0 (0-0)	0 (0-2)	0 (0-2)	0 (0-0)$^{\beta\beta\beta}$	0 (0-2)	***<0.001***
Bleeding, ml	200 (50-400)	200 (100-450)	200 (50-500)	100 (0-200)$^{\beta\beta\beta}$	200 (50-400)	***<0.001***
Lactate, (mmol/L) median (min-max)	1.3 (0.02-15)	1.3 (0.2-13)	1.3 (0.2-15)	1.0 (0.3-4.3)$^{\beta\beta}$	1.5 (0.5-15)	***<0.001***
Urine output, ml/kg/h	1.7 (1.0-3.1)	1.7 (1.0-3.3)	1.6 (1.0-2.7)	1.7 (0.9-2.9)	1.5 (0.9-2.9)	0.106
Intraoperative complications, n (%)	416 (17.4)	285 (18.4)	66 (36.3)$^{\#\#\#}$	14 (3.4)$^{\beta\beta\beta}$	51 (20.5)	***<0.001 <0.001***
Bleeding	156 (6.5)	101 (6.5)	24 (13.2)$^{\#\#\#}$	7 (1.7)$^{\beta\beta\beta}$	24 (9.7)	***<0.001***
Unplanned surgical procedures	41 (1.7)	20 (1.3)	9 (5.0)$^{\#\#}$	2 (0.5)	10 (4.0)**	***<0.001***
Hypotension	213 (8.9)	157 (10.1)	23 (12.6)	10 (2.4)$^{\beta\beta\beta}$	23 (9.2)	***0.013***
Arrhythmia	46 (1.9)	30 (1.9)	8 (4.4)	2 (0.5)$^{\beta}$	6 (2.4)	0.137
Hypoxia	14 (0.6)	8 (0.5)	3 (1.6)	0 (0.0)	3 (1.2)	**0.006**
Cardiac arrest	5 (0.2)	1 (0.1)	2 (1.1)$^{\#}$	0 (0.0)	2 (0.8)	**0.003**
Embolism	3 (0.1)	1 (0.1)	2 (1.1)$^{\#}$	0 (0.0)	0 (0.0)	
Surgical Apgar score	6 (5-7)	6 (5-7)	6 (5-7)	7 (6-8)$^{\beta\beta\beta}$	6 (5-7)	***<0.001***
Surgical Apgar score > 5, n (%)	1666 (69.7)	1072 (69.2)	116 (63.7)	336 (81.8)$^{\beta\beta\beta}$	142 (57.0)***	***<0.001***
1	3 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	3 (1.2)**	***0.003***
2	5 (0.2)	2 (0.1)	1 (0.6)	0 (0.0)	2 (0.8)	0.144
3	18 (0.8)	11 (0.7)	3 (1.7)	0 (0.0)	4 (1.6)	***0.023***
4	119 (5.0)	79 (5.1)	13 (7.1)	7 (1.7)$^{\beta\beta}$	20 (8.0)*	***<0.001***
5	580 (24.3)	385 (24.9)	49 (26.8)	68 (16.5)$^{\beta\beta\beta}$	78 (31.3)*	***<0.001***
6	667 (27.9)	431 (27.8)	54 (29.7)	110 (26.8)	72 (28.9)	0.917
7	546 (22.8)	354 (22.8)	39 (21.4)	109 (26.5)	44 (17.8)	0.073
8	324 (13.6)	206 (13.3)	18 (9.9)	82 (20.0)$^{\beta\beta}$	18 (7.2)**	***<0.001***
9	107 (4.5)	66 (4.3)	5 (2.8)	28 (6.8)	8 (3.2)	0.057
10	22 (0.8)	15 (1.0)	0 (0.0)	7 (1.7)	0 (0.0)	0.079
Duration of operation, h	2.5 (1.7-4.0)	3.0 (2.0-4.5)	2.6 (1.9-4.0)	2.0 (1.2-3.0)$^{\beta\beta\beta}$	2.0 (1.5-3.0)***	***<0.001***

Abbreviations: ASA: American Society of Anesthesiology, CCI: Charlson comorbidity index, COPD: chronic obstructive pulmonary disease, CR: central regional, CT: chemotherapy, PR: peripheric regional, RT: radiotherapy, SRSS: Surgical risk stratification score, L: litre, U: unite, FFP: fresh frozen plasma, h: hour.
♦Number of procedures defined within the POSSUM score. Percentages may exceed 100% due to overlappings in some variables. Categorical data are presented as numbers and percentages [n (%)]. Numerical data are expressed as mean ± standard deviation or median (interquartile range [IQR] or min–max range).
[#] comparison between Planned and Unplanned groups.
[ß] comparison between Planned and Planned/no admission groups.
* comparison between Planned and Emergency Surgeries groups.
###, ßßß and ***; p<0.001.
##, ßß and **; p=0.01-0.001.
#, ß and *; p=0.05-0.01.

Table 4
Multiple logistic regression analysis of predictors for unplanned ICU admission (Model I) and planned but not admitted group (Model II).

Variables	OR (95% CI)	p
Model I		
Timing of surgery procedure		
Urgent Surgery (within 2 - 24 hours)-(Ref:Planned)	6.9 (4.2-11.4)	***<0.001***
Emergency Surgery (within <2hours)-(Ref:Planned)	12.7 (7.1-23.0)	***<0.001***
Intraoperative heart rate >140bpm, >5min	3.4 (1.4-8.3)	***0.007***
Intraoperative complication	3.1 (2.1-4.5)	***<0.001***
ASA>2	2.7 (1.9-3.9)	***<0.001***
Operative severity		
Moderate -(Ref: Major /Major plus)	1.8 (1.3-2.7)	***0.001***
Minor -(Ref: Major /Major plus)	2.9 (1.6-5.2)	***<0.001***
Type of anesthesia		
Central/Peripheric regional or Sedoanalgesia-(Ref: GA)	0.48 (0.24-0.97)	***0.040***
GA plus central/peripheric regional-(Ref: GA)	0.94 (0.51-1.7)	0.938
MODEL II		
Age	0.99 (0.98-0.99)	***0.011***
Hemoglobin g/dL	1.1 (0.99-1.13)	0.100
POSSUM score	0.97 (0.95-0.99)	***0.001***
CT or RT in the last 6 months	1.4 (0.94-2.1)	0.094
Duration of surgery	0.77 (0.71-0.85)	***<.001***
Blood product transfusion	0.84 (0.69-1.02)	0.079
Intraoperative complication	2.3 (1.4-3.6)	***<0.001***
ASA I-II (ref: ASA III-IV)	0.77 (0.59-1.02)	0.068
Operative severity		
Moderate - (Ref:Major/Major Plus)	1.2 (0.9-1.6)	0.158
Minor - (Ref:Major/Major Plus)	2.6 (1.7-3.8)	***<0.001***
Type of surgery		
Minimal invasive surgery - (Ref: Open)	1.5 (1.1-1.9)	***0.012***
Type of Anesthesia		
Central/peripheric regional/sedation- (Ref: GA)	1.7 (1.2-2.4)	***0.001***
GA plus central/ peripheric regional- (Ref: GA)	0.5 (0.3-1.0)	0.050

Na: sodium, SAPS: simplified acute physiology score, SB: spontaneous breathing, SOFA: sequential organ failure assessment, PaO2: partial arterial oxygen pressure, WBC: white blood cell. Categorical data are presented as numbers and percentages [n (%)]. Numerical data are expressed as mean ± standard deviation or median (interquartile range [IQR] or min–max range).
[#] comparison between Planned and Unplanned groups.
* comparison between Planned and Emergency Surgeries groups.
or ***; p<0.001.
or **; p=0.01-0.001.
or *; p=0.05-0.01.

duration were all independent risk factors for unplanned admission.

In our study EAG similar to UPAG, patients were younger and had lower CCI scores compared to the PAG. In EAG a lower proportion of scores for SAS > 5 and higher POSSUM scores were observed compared to PAG. While the SAS reflects only three intraoperative parameters, the POSSUM incorporates a broader range of both perioperative and intraoperative variables. The higher incidence of unplanned surgical procedures during the intraoperative period, along with elevated surgical severity scores, suggests that intraoperative complications played a significant role in the ICU admissions in our cohort. ClassIntra study is a validated classification for assessing intraoperative adverse events in a standardized way, but we have used bleeding, unplanned surgical procedures, hypotension, arrhythmia, hypoxia, cardiac arrest, embolism as intraoperative complications [24].

Postoperatively UPAG and EAG also demonstrated higher APACHE II, SAPS III scores, along with an elevated requirement for blood products, reoperation, multi-organ failure, pneumonia, and were more frequently classified as Grade-V according to the Clavien-Dindo classification on ICU admission.

Patients in the PBNAG group predominantly received laparoscopic procedures and central neuraxial anesthesia, highlighting a distinct management strategy for this cohort. This observation is consistent with findings from previous studies: [22,25] highlighted the benefits of regional anesthesia in reducing postoperative complications, while demonstrating that minimally invasive laparoscopic procedures are associated with improved postoperative recovery and lower ICU admission rates [22,26]. Although some patient-related risk factors were identified preoperatively, intraoperative lower lactate levels and lower total fluid administration, use of minimally invasive surgical techniques, and preference for regional anesthesia may likely contribute to the decision to transfer these patients to the ward instead of the ICU postoperatively.

Regional anesthesia and minimally invasive techniques are usually picked for lower-risk patients and minor surgeries. This introduces a selection bias, as these patients are naturally more likely to go straight to the ward. However, we tried to account for this by adjusting for baseline comorbidities, ASA status, and surgical complexity in our model, and these techniques still came out as independent predictors of bypassing the ICU. While selection bias is at play, our findings suggest that these methods might also play a practical role in fast-tracking recovery—possibly by reducing the physiological stress of surgery—rather than just reflecting a healthier group of patients.

Multiple logistic regression models applied separately to academic and non-academic hospitals to evaluate PBNAG compared to PAG (Model II) showed statistically significant differences for ASA > 2.

4.1. ICU Benefit criteria, and intensivist opinion on ICU admission

Benefit ranking from ICU stay basic hemodynamic monitoring was identified as the most frequent reasoning parameter. 25% of all ICU admissions were based solely on the need for basic hemodynamic monitoring. Ohbe Hirokuyi et al. [27] have also found out that ICU admission after major elective surgery was largely for monitoring rather than for active treatment. Thus, Zimmerman Jack E. et al. in their study showed that among 17,440 admissions to the ICU 8040 (46%) received only technological monitoring and concentrated nursing during their first day in ICU which can be done in the intermediate care unit [28].

Notably, our analysis revealed a markedly higher incidence of ICU benefit indicators—such as vasopressor requirement, prolonged mechanical ventilation (>12 h), and cardiac arrest events—in the UPAG and EAG cohorts compared with the PAG ($p < 0.001$). When combined with the increased acuity, these interventions support the increased

Table 5
Comparison of ICU admission scores, respiratory status, vital signs and laboratory values.

	Total (n=1980)	Planned (n=1549)	Unplanned (n=182)	Emergency Surgeries (n=249)	p
ICU admission scores					
APACHE II	8 (6-10)	7 (6-10)	8 (6-11)$^{\#}$	10 (8-13)***	**<0.001**
SAPS III	50 (44-57)	49 (43-56)	53 (46-60)$^{\#\#\#}$	59 (49-67)***	**<0.001**
SOFA score	0 (0-1)	0 (0-1)	0 (0-1)	2 (1-3)***	**<0.001**
Respiratory status, n (%)					**<0.001**
SB	1294 (65.4)	1087 (70.3)	115 (63.9)	92 (37.0)***	
Intubated	650 (32.8)	434 (28.1)	64 (35.6)	152 (61.0)***	
Tracheotomized with SB	7 (0.4)	6 (0.4)	0 (0.0)	1 (0.4)	
Tracheotomized with MV	24 (1.4)	19 (1.2)	1 (0.6)	4 (1.6)	
Vital parameters,					
Temperature (^{0}C)	36.4 (36.0-36.7)	36.4 (36.0-36.7)	36.3 (36.0-36.8)	36.4 (36.0-36.7)	0.47
HR/min	87 (75-100)	86 (75-99)	88 (78-100)	90 (78-105)***	**<0.001**
MAP, mmHg	80 (70-93)	80 (70-95)	75 (65-88)$^{\#\#\#}$	75 (67-89)***	**<0.001**
Laboratories,					
FiO_2 (%)	40 (30-40)	35 (30-40)	40 (30-40)	40 (40-50)***	**<0.001**
pH	7.37 (7.33-7.41)	7.38 (7.34-7.41)	7.35 (7.31-7.39)$^{\#\#\#}$	7.35 (7.30-7.41)***	**<0.001**
PaO_2, mmHg	99 (81-137)	98 (80-135)	98 (81-125)	109 (85-153)**	**0.005**
HCO_3, mmol/L	22.4 (20.1-24.6)	22.8 (20.8-24.7)	21.8 (19.0-24.0)$^{\#\#\#}$	21.4 (19.0-24.9)***	**<0.001**
Lactate, mmol/L median (min-max)	1.6 (0.1-10.0)	1.6 (0.4-10.0)	1.7 (0.3-10.0)	1.7 (0.3-10.0)	0.635
HCT, (%)	33.0 (29.0-37.0)	33.0 (30.0-37.0)	34.0 (30.0-39.0)$^{\#}$	32.0 (28.0-36.0)***	**<0.001**
Na, mmol/L	138 (136-141)	138 (136-141)	139 (137-141)	138 (135-141)	0.456
K, mmol/L	4.1 (3.7-4.5)	4.1 (3.8-4.5)	4.0 (3.7-4.4)	3.9 (3.6-4.4)	0.132
Creatinine, mg/dL	0.8 (0.63-1.1)	0.80 (0.63-1.07)	0.80 (0.60-103)	0.83 (0.61-1.30)	0.394
WBC, ($x10^3$)	11.1 (8.4-14.8)	11.0 (8.4-14.5)	11.4 (8.3-15.1)	12.0 (8.6-17.0)*	**0.035**

Abbreviations: APACHE: acute physiology and chronic health evaluation, FiO2: inspiratory oxygen fraction, HCO3: bicarbonate, Htc: hematocrit, HR: heart rate, K: potassium, MAP: mean arterial pressure, MV: mechanical ventilation, Na: sodium, SAPS: simplified acute physiology score, SB: spontaneous breathing, SOFA: sequential organ failure assessment, PaO2: partial arterial oxygen pressure, WBC: white blood cell. Categorical data are presented as numbers and percentages [n (%)]. Numerical data are expressed as mean ± standard deviation or median (interquartile range [IQR] or min–max range).
$^{\#}$ comparison between Planned and Unplanned groups.
* comparison between Planned and Emergency Surgeries groups.
$^{\#\#\#}$ or ***; p<0.001.
$^{\#\#}$ or **; p=0.01-0.001.
$^{\#}$ or *; p=0.05-0.01.

complexity during the perioperative course. According to a retrospective cohort study utilizing machine learning, which compared appropriately triaged patients with those over triaged to the ICU, the rates of mechanical ventilation, vasopressor administration within two hours after surgery, and the need for advanced organ support were found to be higher in appropriately triaged group among the 8592 ICU admissions [29].

In our study, at the discharge of ICU, intensivist reported that 9.2% of patients did not have admission necessity to the ICU. The presence of PNBAG group may further suggest that current practices may contribute to unnecessary ICU utilization. Indicating that intensive care units may be under considerable resource pressure. These findings underscore the critical need for alternative critical care environments—including high-dependency units (HDUs), post-anesthesia care units (PACUs), and intermediate care units (IMCUs)—to serve as viable clinical pathways to mitigate ICU over-utilization. While these specialized settings offer comparable physiological monitoring with enhanced institutional cost-effectiveness, robust prospective studies are urgently required. Further evidence is needed to comprehensively define appropriate alternative care frameworks and validate their precise financial and clinical efficacy for postoperative patient cohorts managed outside the traditional ICU.

4.2. Outcomes in the ICU

The median ICU length of stay (LOS-ICU) was 1 day in both the PAG (range: 1–75 days) and the UPAG (range: 1–102 days) with slightly longer duration noted in the UPAG, consistent with the findings reported by M.M.E.M. Bos et al. [30].

In the current literature, ICU mortality ranged from 1.4 to 11.5% [4,9,23], and hospital mortality ranged from 1.5 to 19.2% [9,23,29,31]. Consistent with previous reports, the overall ICU and in-hospital mortality rates in our cohort were 5.9% and 6.9%, respectively. It's important to note that generally, POSSUM scores over predicted mortality and morbidity rates for each group as in our study [13].

Several logistical and systemic issues were identified during the study. Due to the unavailability of ICU beds, 1608 non-surgical patients had to be transferred to external facilities, and 727 patients had their elective surgeries postponed. 77 patients underwent surgery despite the lack of available ICU beds and were instead admitted to hospital wards postoperatively raising concerns about patient safety and optimal resource allocation.

Artificial intelligence (AI) holds significant promise as a predictive tool for evaluating postoperative ICU admission, thereby optimizing clinical resource utilization and patient outcomes. However, a recent scoping review emphasizes that the safe, equitable, and effective implementation of AI models in critical care fundamentally depends on seamless access to diverse, high-quality clinical data managed through ethical distributed frameworks [32]. Therefore, validating predictive algorithms across multi-center datasets requires secure data-sharing environments to prevent selection biases and ensure generalizability.

4.3. Limitations

We were unable to capture all emergency cases; our dataset included only those emergency patients who were admitted to the ICU (EAG). Moreover, the study population was limited to cases from two countries, potentially affecting the generalizability of the findings. Preop and follow-up data for patients who were not admitted to the ICU postoperatively were not collected, which restricts our ability to perform a comprehensive comparison across the entire surgical population. This

Table 6
Events defining benefit from ICU stay.

	Total (n=1980)	Planned (n=1549)	Unplanned (n=182)	Emergency Surgeries (n=249)	p
Events defining benefit from ICU stay (ranking), n (%)					
The necessity of basic hemodynamic monitoring(arterial, SpO_2, ECG)	1459 (73.7)	1144 (73.9)	129 (70.9)	186 (74.7)	0.640
The management of sedation and pain	508 (25.7)	441 (28.5)	33 (18.1)$^{\#\#}$	34(13.7)***	**<0.001**
Advanced hemodynamic monitoring	488 (24.6)	375 (24.2)	44 (24.2)	69 (27.7)	0.487
Management and monitoring of the airway	475 (24.0)	354 (22.9)	45 (24.7)	76 (30.5)**	**0.031**
IMV/NIMV requirement over 12 hours	243 (12.3)	141 (9.1)	28 (15.4)$^{\#\#}$	74 (29.7)***	**<0.001**
The use of vasopressor/inotropes/ iv. vasodilator agents	214 (10.8)	140 (9.0)	28 (15.4)$^{\#}$	46(18.5)***	**<0.001**
SAP< 90 mmHg in the first 48 hours	125 (6.3)	77 (5.0)	17 (9.3)$^{\#}$	31(12.4)***	**<0.001**
The use and monitoring of the anticoagulant agent	61 (3.1)	51 (3.3)	6 (3.3)	4 (1.6)	0.355
HR>120/min in the first 48 hours	57 (2.9)	36 (2.3)	7 (3.8)	14 (5.6)**	**0.011**
New neurologic deficit	54 (2.7)	25 (1.6)	7 (3.8)$^{\#}$	22 (8.8)***	**<0.001**
Re-intubation	39 (2.0)	22 (1.4)	12 (6.6)$^{\#\#\#}$	5 (2.0)	**<0.001**
Re-operation in the first 48 hours	39 (2.0)	17 (1.1)	7 (3.8)$^{\#\#}$	15 (6.0)***	**<0.001**
New arrhythmia with unstable hemodynamics	37 (1.9)	24 (1.5)	7 (3.8)	6 (2.4)	0.077
Severe electrolyte disturbances	31 (1.6)	19 (1.2)	4 (2.2)	8 (3.2)	0.050
Erythrocyte suspension transfusion over 4U in the first 48 hours	26 (1.3)	17 (1.1)	3 (1.6)	6 (2.4)	0.220
Renal replacement therapy	24 (1.2)	20 (1.3)	0 (0.0)	4 (1.6)	0.268
Respiratory or circulatory arrest	16 (0.8)	4 (0.3)	6 (3.3)$^{\#\#\#}$	6 (2.4)***	**<0.001**
ECHO indication in the first 48 hours (not routinely)	15 (0.8)	8 (0.5)	5 (2.7)$^{\#\#}$	2 (0.8)	**0.005**
Readmission in the first 48 hours	5 (0.3)	3 (0.2)	1 (0.5)	1 (0.4)	0.586
Myocardial infarction	2 (0.1)	1 (0.1)	1 (0.5)	0 (0.0)	0.130
TPE	1 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)	0.870
Events defining benefit from ICU stay, (presence of *only one),* n (%)					
The necessity of basic hemodynamic monitoring(arterial,respiratory, ECG)	495 (25.0)	407 (26.3)	35 (19.2)$^{\#}$	53 (21.3)	**0.041**
Management and monitoring of the airway	57 (2.9)	48 (3.1)	5 (2.7)	4 (1.6)	0.423
Advanced hemodynamic monitoring	48 (2.4)	40 (2.6)	3 (1.6)	5 (2.0)	0.667
IMV/NIMV requirement over 12 hours	26 (1.3)	16 (1.0)	6 (3.3)$^{\#}$	4 (1.6)	**0.036**
The management of sedation and pain	11 (0.6)	9 (0.6)	2 (1.1)	0 (0.0)	0.304
New neurologic deficit	7 (0.4)	5 (0.3)	1 (0.5)	1 (0.4)	0.880
HR>120/min in the first 48 hours	5 (0.3)	5 (0.3)	0 (0.0)	0 (0.0)	0.498
SAP< 90 mmHg in the first 48 hours	3 (0.2)	1 (0.1)	2 (1.1)$^{\#}$	0 (0.0)	**0.044**
New arrhythmia with unstable hemodynamics	3 (0.2)	3 (0.2)	0 (0.0)	0 (0.0)	0.658
Erythrocyte suspension transfusion over 4U in the first 48 hours	3 (0.2)	0 (0.0)	2 (1.1)$^{\#}$	1 (0.4)	**0.007**
Renal replacement therapy	1 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)	0.782
The use and monitoring of the anticoagulant agent	1 (0.1)	1 (0.1)	0 (0.0)	0 (0.0)	0.782

Abbreviations: ECG: electrocardiography, ECHO: echocardiography, HR: heart rate, ICU: intensive care unit, IMV: invasive mechanical ventilation, NIMV: non-invasive mechanical ventilation, SAP: systolic arterial pressure, SpO_2: peripheral oxygen saturation TPE: therapeutic plasma exchange, U: unit. Categorical data are presented as numbers and percentages [n (%)].
$^{\#}$ Comparison between Planned and Unplanned groups.
* Comparison between Planned and Emergency Surgeries groups.
$^{\#\#\#}$ or ***; p<0.001, $^{\#\#}$ or **; p=0.01-0.001, $^{\#}$ or *; p=0.05-0.01.

missing data introduces potential selection bias, as patients not admitted to the ICU postoperatively likely represented a lower-risk cohort with fewer comorbidities and fewer intraoperative complications.

5. Conclusions

This study underscores the clinical and systemic implications of perioperative ICU admission patterns. Integrating modified Wang criteria, POSSUM scores, intraoperative complications, emergency status, and ASA class >2 is effective in predicting the necessity of ICU admission. Our findings overscore the critical need for a more selective approach to ICU admission post-surgically. By precisely identifying patients genuinely likely to benefit from intensive care, healthcare systems can optimize resource allocation, enhance cost-effectiveness, and potentially improve patient flow without compromising safety [33]. We suggest that more refined risk-stratification tools that integrate preoperative, intraoperative, and immediate postoperative variables are necessary to accurately identify patients who may require ICU admission. Improving our ability to distinguish patients suitable for high level care from those who truly need ICU would help minimize over-triage and optimize resource utilization.

CRediT authorship contribution statement

Evren Şentürk: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Nahit Çakar:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Investigation. **Perihan Ergin Özcan:** Writing – original draft, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Bülent Güçyetmez:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision. **Lerzan Dogan:** Methodology, Formal analysis, Data curation, Conceptualization. **Ata Murat Kaynar:** Writing – review & editing, Writing – original draft, Visualization, Validation. **Asu Özgültekin:** Methodology, Investigation, Data curation, Conceptualization. **İlkay Anaklı:** Methodology, Formal analysis, Data curation, Conceptualization. **Özlem Polat:** Methodology, Data curation, Conceptualization. **Gülay Kır:** Methodology, Data curation, Conceptualization. **Tülay Hoşten Çardaközü:** Methodology, Data curation, Conceptualization. **Volkan Alparslan:** Methodology, Data curation, Conceptualization. **Osman Ekinci:** Methodology, Data curation, Conceptualization. **Özlem Ersoy Karka:** Methodology, Data curation, Conceptualization. **Gizem Demir Şenoğlu:** Methodology, Data curation, Conceptualization. **Sibel Büyükçoban:** Methodology, Data curation, Conceptualization. **Ali Necati Gökmen:** Methodology, Data curation, Conceptualization. **Çağın Tanrıverdi:** Methodology, Data curation, Conceptualization. **Necati Alper Erdoğmuş:** Methodology, Data curation, Conceptualization. **Akın Akbulut:** Methodology, Data curation, Conceptualization.

Table 7
Complications and outcomes in the ICU.

	Total (n=1980)	Planned (n=1549)	Unplanned (n=182)	Emergency Surgeries (n=249)	p
Complications,in ICU n (%)	293 (14.8)	196 (12.7)	31 (17.0)	66 (26.5)***	***<0.001***
Hemodynamic instability	46 (2.3)	37 (2.4)	5 (2.7)	4 (1.6)	0.692
Erythrocyte requirement (>1U)	75 (3.8)	45 (2.9)	11 (6.0)$^{\#}$	19 (7.6)***	***<0.001***
Reoperation	19 (1.0)	9 (0.6)	4 (2.2)$^{\#}$	6 (2.4)*	***0.005***
Multiorgan failure	22 (1.1)	7 (0.5)	5 (2.7)$^{\#\#}$	10 (4.0)***	***<0.001***
Pneumonia	14 (0.7)	5 (0.3)	4 (2.2)$^{\#}$	5 (2.0)**	***<0.001***
Sepsis	32 (1.6)	13 (0.8)	3 (1.6)	16 (6.4)***	***<0.001***
Acute kidney injury	31 (1.6)	18 (1.2)	3 (1.6)	10 (4.0)**	***0.003***
Delirium	20 (1.0)	13 (0.8)	3 (1.6)	4 (1.6)	0.354
Clavien-Dindo classification, n (%)					
Grade I	74 (3.7)	70 (4.5)	1 (0.5)$^{\#\#}$	3 (1.2)**	***<0.001***
Grade II	3 (0.2)	2 (0.1)	1 (0.5)	0 (0.0)	0.379
Grade IIIa	1 (0.1)	1 (0.1)	0 (0)	0 (0.0)	0.782
Grade IIIb	4 (0.2)	2 (0.1)	1 (0.5)	1 (0.4)	0.452
Grade IVa	11 (0.6)	7 (0.5)	2 (1.1)	2 (0.8)	0.517
Grade IVb	7 (0.4)	2 (0.1)	1 (0.5)	4 (1.6)**	***0.011***
Grade V	37 (1.9)	13 (0.8)	7 (3.8)$^{\#\#}$	17 (6.8)***	***<0.001***
Frailty scale (ICU discharge)	3 (2-5)	3 (2-5)	3 (2-5)	5 (3-7)***	**<0.001**
LOS-ICU, days (min-max)	1 (1-104)	1 (1-75)	1 (1-102)$^{\#}$	2 (1-104)***	**<0.001**
Readmission (in the first 48 hours), n (%)	31 (1.6)	25 (1.6)	1 (0.6)	5 (2.0)	0.463
ICU mortality	117 (5.9)	61(3.9)	11 (6.0)	45(18.1)***	**<0.001**
Hospital mortality	135 (7.0)	74 (4.8)	15(8.2)	46 (18.5)***	**<0.001**
30th day mortality, n (%)	148 (7.5)	85 (5.5)	16 (8.8)	47 (18.9)***	**<0.001**
90th day mortality, n (%)	149 (7.5)	86 (5.6)	16 (8.8)	47 (18.9)***	**<0.001**

Abbreviations: ICU: intensive care unit, LOS-ICU: length of ICU stay, U: unit. Categorical data are presented as numbers and percentages [n (%)]. Numerical data are expressed as median (interquartile range [IQR] or min–max range).
$^{\#}$ Comparison between Planned and Unplanned groups.
* Comparison between Planned and Emergency Surgeries groups.
$^{\#\#\#}$or ***; p<0.001.
$^{\#\#}$ or **; p=0.01-0.001.
$^{\#}$ or *; p=0.05-0.01.

Ozan Akça: Methodology, Data curation, Conceptualization.

Consent to participate

Written informed consent was obtained from all individual participants or their legal guardians included in the study prior to their enrollment.

Consent for publication

Written informed consent was obtained from the patients (or their legal next of kin) for the publication of this study and any accompanying data. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Koc University on 22.05.2023, Approval No: 2023.198.IRB 1.065.

Funding

None.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Turkish Society of Cardiovascular Thoracic Anesthesia and Intensive Care (GKDA). We thank GKDA for supporting the IREANET group in conducting this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclinane.2026.112323.

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