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Original Research

Comparative Outcomes of Early Versus Delayed Extubation in Postoperative ICU Patients After Major Surgeries Under General Anesthesia

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ABSTRACT:
Aim: This study aimed to compare the outcomes of early versus delayed extubation in postoperative ICU patients after major surgeries under general anesthesia, focusing on mechanical ventilation duration, ICU stay, adverse events, hemodynamic stability, pain control, and overall recovery outcomes. **Material and Methods:** A prospective, randomized controlled trial was conducted on 120 adult patients (60 in the Early Extubation group and 60 in the Delayed Extubation group) undergoing major elective surgeries under general anesthesia. Patients were randomly assigned using a computer-generated table. Early extubation was performed within 2 hours post-surgery, while delayed extubation occurred after 6–12 hours based on clinical assessment. Outcomes such as mechanical ventilation duration, ICU and hospital stay, adverse respiratory events, hemodynamic parameters, pain scores (VAS), and functional recovery were recorded. **Results:** Early extubation significantly reduced the duration of mechanical ventilation (4.20 ± 1.50 hours vs. 10.60 ± 2.40 hours, $p < 0.001$) and ICU stay (3.80 ± 1.20 days vs. 5.40 ± 1.50 days, $p < 0.001$). Re-intubation rates were lower in the Early Extubation group (10.00% vs. 25.00%, $p = 0.03$). Hemodynamic stability, respiratory efficiency, and oxygenation were significantly better in the Early Extubation group ($p < 0.05$). Adverse respiratory events, including ventilator-associated pneumonia, were lower in the Early Extubation group (5.00% vs. 15.00%, $p = 0.04$). Pain scores (VAS) at 6, 12, and 24 hours were significantly lower in the Early Extubation group ($p < 0.001$). **Conclusion:** Early extubation resulted in better outcomes, including shorter ventilation duration, reduced ICU and hospital stays, improved hemodynamic stability, fewer respiratory complications, and better pain control. While both approaches have their merits, early extubation proves to be a safer and more effective strategy when appropriate selection criteria and vigilant monitoring are followed.
Keywords: Early extubation, delayed extubation, postoperative ICU, mechanical ventilation, hemodynamic stability.

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INTRODUCTION

Extubation, the process of removing an endotracheal tube after mechanical ventilation, is a critical step in the postoperative care of patients admitted to the Intensive Care Unit (ICU) following major surgeries under general anesthesia. It marks the transition from mechanical ventilatory support to independent spontaneous breathing, signaling a crucial milestone in the patient's recovery. The timing of extubation, whether performed early or delayed, remains a topic of considerable debate and research in critical care medicine due to its profound implications on patient outcomes, ICU resource utilization, and overall healthcare costs.[1] Early extubation refers to the removal of the endotracheal tube within a short, predefined period after surgery, typically within the first two hours in the ICU. This approach is based on the premise that early liberation from mechanical ventilation reduces the risks associated with prolonged ventilatory support, such as ventilator-associated pneumonia (VAP), barotrauma, hemodynamic instability, and respiratory muscle atrophy. Early extubation is often encouraged in patients who meet specific criteria, including adequate oxygenation, hemodynamic stability, intact airway reflexes, and acceptable levels of consciousness. Advocates of early extubation argue that it not only enhances patient comfort but also promotes early mobilization, reduces sedation requirements, and shortens ICU and hospital stays.[2] Conversely, delayed extubation involves maintaining mechanical ventilation for an extended period post-surgery, often for six to twelve hours or longer, depending on the patient's clinical condition. This approach is typically favored in high-risk patients with comorbidities, complex surgical procedures, poor baseline cardiopulmonary reserve, or unstable hemodynamic parameters. Proponents of delayed extubation argue that it allows sufficient time for the stabilization of cardiovascular and respiratory systems, reduces the risk of re-intubation, and prevents complications arising from premature removal of ventilatory support. Furthermore, delayed extubation provides an added safety margin in managing patients who may develop complications such as bleeding, fluid overload, or refractory hypoxia in the immediate postoperative period.The choice between early and delayed extubation is multifactorial and influenced by various factors, including the patient’s preoperative health status, the type and duration of surgery, intraoperative events, anesthetic management, and the expertise of the critical care team. It requires a meticulous assessment of extubation readiness based on clinical, hemodynamic, and biochemical parameters. However, determining the optimal timing of extubation remains challenging due to the dynamic nature of postoperative recovery and the heterogeneity of patients in the ICU.[3] In recent years, there has been a growing emphasis on enhanced recovery after surgery (ERAS) protocols, which include early extubation as a key component. ERAS protocols advocate for multimodal strategies to accelerate recovery, reduce complications, and optimize perioperative outcomes. Early extubation, as part of these protocols, is believed to play a significant role in reducing ICU length of stay, minimizing opioid consumption, improving pain control, and lowering healthcare costs. However, the success of early extubation is heavily dependent on careful patient selection, vigilant monitoring, and prompt management of potential complications.[4] On the other hand, delayed extubation remains a safety net in complex surgical cases where the risk of postoperative complications is high. In scenarios involving prolonged surgeries, massive fluid shifts, significant blood loss, or poor cardiopulmonary reserve, delayed extubation may provide a protective buffer, preventing premature extubation failure and re-intubation. However, it is also associated with its own set of complications, including ventilator-associated pneumonia, increased sedation requirements, ventilator-induced lung injury, and prolonged ICU stays.The debate surrounding early versus delayed extubation is further complicated by the lack of universally accepted protocols and the variability in clinical practice across institutions. Additionally, existing evidence from clinical studies and randomized trials has yielded mixed results, with some studies favoring early extubation for improved recovery outcomes and others supporting delayed extubation in high-risk patients to avoid complications. This highlights the need for individualized decision-making, where the risks and benefits of each approach are carefully weighed against the patient’s clinical profile and surgical context.[5] An essential aspect of extubation timing is the impact on hemodynamic stability, respiratory outcomes, pain control, and overall patient recovery. Early extubation has been associated with improved hemodynamic parameters, better oxygenation, and reduced respiratory complications, while delayed extubation has been linked to better control of immediate postoperative instability. Furthermore, the psychological impact of prolonged intubation cannot be overlooked, as it may contribute to patient discomfort, anxiety, and delirium, which can negatively influence recovery trajectories.[6]

MATERIAL AND METHODS

This prospective, comparative, randomized controlled trial was conducted over a period of 12 months after obtaining approval from the Institutional Ethics Committee and securing written informed consent from all participants or their legal guardians. The study included 120 adult patients who underwent major surgeries under general anesthesia and required postoperative care in the Intensive Care Unit (ICU).120 patients (60 in the Early Extubation group and 60 in the Delayed Extubation group).

Inclusion Criteria

- Adults aged **18–75 years**
- ASA (American Society of Anesthesiologists) physical status **I–III**
- Patients undergoing **major elective surgeries** under general anesthesia (e.g., abdominal, thoracic, or vascular surgeries)
- Patients requiring mechanical ventilation postoperatively

Exclusion Criteria

- Patients undergoing **emergency surgeries**
- Known preoperative **neurological deficits or impaired consciousness**
- Severe **cardiac, hepatic, or renal dysfunction** (e.g., ejection fraction <30%, creatinine >2.0 mg/dL)
- Patients with **pre-existing pulmonary complications** (e.g., severe COPD)
- Patients with anticipated **difficult airway management**
- Refusal to participate by the patient or their family

Patients were randomly assigned into two groups using a computer-generated randomization table to ensure unbiased allocation. Group A (Early Extubation, n=60) included patients who were extubated within 2 hours post-surgery in the ICU, provided they met extubation criteria such as adequate oxygenation, hemodynamic stability, normal consciousness, and acceptable ventilatory parameters. In contrast, Group B (Delayed Extubation, n=60) consisted of patients who remained intubated for at least 6–12 hours post-surgery with mechanical ventilation support before extubation, based on ongoing clinical assessment by ICU physicians.

The anesthesia protocol followed a standardized approach for all patients. During induction, intravenous Propofol (2–2.5 mg/kg), Fentanyl (2 μg/kg), and Rocuronium (0.6 mg/kg) were administered for neuromuscular blockade and sedation. Maintenance of anesthesia was achieved using inhaled Isoflurane (1–1.5 MAC) in combination with intermittent boluses of Fentanyl and Rocuronium. Mechanical ventilation parameters were carefully adjusted to maintain an end-tidal CO_2 between 35–45 mmHg to ensure optimal respiratory function. At the end of the surgical procedure, neuromuscular blockade was reversed with Neostigmine (0.05 mg/kg) and Glycopyrrolate (0.01 mg/kg) to facilitate smooth extubation and recovery from anesthesia.

The decision for extubation in both groups was guided by standardized clinical criteria to ensure patient safety and optimal recovery. These criteria included adequate oxygenation ($SpO_2 > 92\%$ on $FiO_2 \leq 0.4$), stable hemodynamics without excessive inotropic support, adequate ventilatory effort characterized by a respiratory rate of 12–25 breaths/min and tidal volume exceeding 5 mL/kg, and the return of protective airway reflexes such as a cough and gag reflex. Additionally, patients were required to exhibit full recovery from anesthesia with a Glasgow Coma Scale (GCS) score > 12 before extubation was attempted.

In the postoperative monitoring and management phase, all patients were closely monitored in the ICU. Vital parameters, including heart rate, blood pressure, respiratory rate, and oxygen saturation (SpO_2), were continuously recorded. Arterial blood gas (ABG) analysis was performed at 2, 6, and 12 hours postoperatively to assess respiratory function and metabolic status. The incidence of adverse events such as re-intubation, hypoxia, hypercarbia, hemodynamic instability, aspiration pneumonia, ventilator-associated pneumonia (VAP), and prolonged ICU stay was documented. Pain control was managed using a standardized protocol, including intravenous Paracetamol (1 g every 6 hours) and Morphine (0.1 mg/kg PRN), with pain intensity assessed using the Visual Analog Scale (VAS) at regular intervals.

The primary outcomes of the study included the duration of mechanical ventilation, the incidence of re-intubation within 48 hours, and the length of ICU stay. Secondary outcomes focused on the incidence of adverse respiratory events such as hypoxia, hypercapnia, and aspiration pneumonia, the duration of hospital stay, patient outcomes at 7 days postoperatively (including survival rate and functional recovery), and pain scores (VAS) at 6, 12, and 24 hours post-extubation.

Data collection and statistical analysis were carried out systematically. All relevant data were recorded using a standardized data collection form by trained ICU staff to ensure consistency and accuracy. Statistical analysis was performed using SPSS version 16.0. Continuous variables (e.g., ICU stay duration, time to extubation) were expressed as mean ± standard deviation (SD) and analyzed using the Student's t-test. Categorical variables (e.g., incidence of complications, re-intubation rates) were expressed as percentages and compared using the Chi-square test or Fisher's exact test where appropriate. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics (Table 1)

The demographic and baseline clinical characteristics, including age, gender distribution, ASA status, BMI, and duration of surgery, were comparable between the two groups. The mean age in the Early Extubation group was 52.40 ± 10.20 years, while in the Delayed Extubation group, it was 53.80 ± 11.00 years ($p = 0.45$). Gender distribution was similar, with 58.33% males and 41.67% females in the Early Extubation group and 61.67% males and 38.33% females in the Delayed Extubation group ($p = 0.68$). ASA physical status, BMI, and surgical duration were also not significantly different between the two groups ($p > 0.05$). These findings suggest that the two groups were well-matched, reducing the likelihood of demographic or clinical bias affecting the outcomes.

Mechanical Ventilation, Re-intubation, and ICU Stay (Table 2)

The Early Extubation group demonstrated significantly better outcomes in terms of mechanical ventilation duration, re-intubation rates, and ICU stay duration. The duration of mechanical ventilation was significantly shorter in the Early Extubation group (4.20 ± 1.50 hours) compared to the Delayed Extubation group (10.60 ± 2.40 hours, $p < 0.001$). The incidence of re-intubation was also significantly lower in the Early Extubation group (10.00%) compared to the Delayed Extubation group (25.00%, $p = 0.03$). Furthermore, the ICU length of stay was shorter in the Early Extubation group (3.80 ± 1.20 days) compared to the Delayed Extubation group (5.40 ± 1.50 days, $p < 0.001$). These findings indicate that early extubation leads to a more efficient recovery process, reduces the dependency on mechanical ventilation, and minimizes ICU resource utilization.

Hemodynamic Parameters Before and After Surgery (Table 3)

Before surgery, both groups showed no statistically significant differences in heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure (MAP), SpO_2 levels, respiratory rate, end-tidal CO_2, and inotropic support usage ($p > 0.05$). However, after surgery, significant differences emerged between the two groups.In the Early Extubation group, heart rate (82.50 ± 8.40 beats/min) was significantly lower compared to the Delayed Extubation group (88.20 ± 9.60 beats/min) (p = 0.002). Similarly, systolic blood pressure (124.80 ± 10.50 mmHg) and diastolic blood pressure (78.60 ± 7.40 mmHg) were significantly lower in the Early Extubation group (p = 0.001 and p = 0.003, respectively). Mean arterial pressure (94.70 ± 6.50 mmHg) was also significantly better controlled in the Early Extubation group compared to the Delayed Extubation group (p = 0.004).SpO_2 levels were significantly higher in the Early Extubation group (97.80 ± 1.20%) compared to the Delayed Extubation group (96.40 ± 1.50%, p = 0.001). Additionally, respiratory rate (16.80 ± 2.50 breaths/min) and end-tidal CO_2 (37.20 ± 2.50 mmHg) were significantly better managed in the Early Extubation group (p = 0.005 and p = 0.003, respectively).

Adverse Respiratory Events and Hospital Stay (Table 4)

The incidence of adverse respiratory events, including hypoxia, hypercapnia, aspiration pneumonia, and ventilator-associated pneumonia (VAP), was generally lower in the Early Extubation group.Hypoxia occurred in 6.67% of patients in the Early Extubation group compared to 16.67% in the Delayed Extubation group (p = 0.08). Hypercapnia occurred in 8.33% of the Early Extubation group versus 20.00% in the Delayed Extubation group (p = 0.05). While aspiration pneumonia rates (3.33% vs. 10.00%) and VAP rates (5.00% vs. 15.00%) were lower in the Early Extubation group, only the difference in VAP rates was statistically significant (p = 0.04).The total hospital stay was significantly shorter in the Early Extubation group (8.60 ± 2.00 days) compared to the Delayed Extubation group (11.20 ± 2.50 days, $p < 0.001$). These findings highlight that early extubation reduces adverse respiratory complications and facilitates faster overall recovery.

Pain Scores (VAS) at Different Time Intervals Post-Extubation (Table 5)

Pain control, assessed using the Visual Analog Scale (VAS), was significantly better in the Early Extubation group at all observed time points. At 6 hours, the Early Extubation group had a mean pain score of 3.20 ± 0.90, compared to 4.80 ± 1.20 in the Delayed Extubation group ($p < 0.001$). At 12 hours, the mean VAS score was 2.60 ± 0.80 versus 4.10 ± 1.00 ($p < 0.001$), and at 24 hours, it was 2.10 ± 0.70 versus 3.50 ± 0.90 ($p < 0.001$). These results indicate superior pain management in the Early Extubation group.

Patient Outcomes at 7 Days Postoperatively (Table 6)

The survival rate was slightly higher in the Early Extubation group (95.00%) compared to the Delayed Extubation group (90.00%), although this difference was not statistically significant (p = 0.32). Similarly, functional recovery was better in the Early Extubation group (83.33%) compared to the Delayed Extubation group (70.00%, p = 0.08). The incidence of ICU readmission was lower in the Early Extubation group (3.33%) compared to the Delayed Extubation group (10.00%, p = 0.14). While none of these differences reached statistical significance, they suggest a positive trend favoring early extubation.

Table 1: Demographic and Clinical Characteristics of Patients

Parameter	Early Extubation (n=60)	Delayed Extubation (n=60)	p-value
Age (mean ± SD)	52.40 ± 10.20	53.80 ± 11.00	0.45
Gender (M/F)	35/25 (58.33%/41.67%)	37/23 (61.67%/38.33%)	0.68
ASA Status (I/II/III)	18/30/12 (30.00%/50.00%/20.00%)	20/28/12 (33.33%/46.67%/20.00%)	0.72
BMI (mean ± SD)	25.10 ± 3.80	24.80 ± 4.00	0.66
Duration of Surgery (min)	180.00 ± 35.00	185.00 ± 40.00	0.55

Table 2: Mechanical Ventilation, Re-intubation, and ICU Stay

Outcome	Early Extubation (n=60)	Delayed Extubation (n=60)	p-value
Duration of Mechanical Ventilation (hours)	4.20 ± 1.50	10.60 ± 2.40	<0.001
Incidence of Re-intubation (%)	6 (10.00%)	15 (25.00%)	0.03
ICU Length of Stay (days)	3.80 ± 1.20	5.40 ± 1.50	<0.001

Table 3. Hemodynamic Parameters Before and After Surgery in Early and Delayed Extubation Groups

Parameter	Early Extubation (n=60)	Delayed Extubation (n=60)	p-value
Heart Rate (beats/min)			
Before Surgery	78.40 ± 7.20	79.80 ± 7.50	0.42
After Surgery	82.50 ± 8.40	88.20 ± 9.60	0.002
Systolic Blood Pressure (mmHg)			

Before Surgery	126.60 ± 9.80	127.80 ± 10.10	0.55
After Surgery	124.80 ± 10.50	132.40 ± 11.20	0.001
Diastolic Blood Pressure (mmHg)			
Before Surgery	80.20 ± 6.90	81.40 ± 7.00	0.47
After Surgery	78.60 ± 7.40	84.20 ± 8.10	0.003
Mean Arterial Pressure (mmHg)			
Before Surgery	96.40 ± 5.80	97.10 ± 6.00	0.60
After Surgery	94.70 ± 6.50	99.80 ± 7.20	0.004
SpO_2 (%)			
Before Surgery	98.20 ± 0.90	98.10 ± 0.85	0.78
After Surgery	97.80 ± 1.20	96.40 ± 1.50	0.001
Respiratory Rate (breaths/min)			
Before Surgery	15.40 ± 1.50	15.60 ± 1.80	0.65
After Surgery	16.80 ± 2.50	18.60 ± 2.80	0.005
End-Tidal CO_2 (mmHg)			
Before Surgery	36.20 ± 1.80	36.40 ± 1.90	0.72
After Surgery	37.20 ± 2.50	40.10 ± 3.00	0.003
Inotropic Support (%)			
Before Surgery	2 (3.33%)	3 (5.00%)	0.65
After Surgery	8 (13.33%)	15 (25.00%)	0.08

Table 4: Adverse Respiratory Events and Hospital Stay

Parameter	Early Extubation (n=60)	Delayed Extubation (n=60)	p-value
Hypoxia (%)	4 (6.67%)	10 (16.67%)	0.08
Hypercapnia (%)	5 (8.33%)	12 (20.00%)	0.05
Aspiration Pneumonia (%)	2 (3.33%)	6 (10.00%)	0.14
Ventilator-Associated Pneumonia (VAP, %)	3 (5.00%)	9 (15.00%)	0.04
Total Hospital Stay (days)	8.60 ± 2.00	11.20 ± 2.50	<0.001

Table 5: Pain Scores (VAS) at Different Time Intervals Post-Extubation

Time Interval (hours)	Early Extubation (Mean ± SD)	Delayed Extubation (Mean ± SD)	p-value
6 hours	3.20 ± 0.90	4.80 ± 1.20	<0.001
12 hours	2.60 ± 0.80	4.10 ± 1.00	<0.001
24 hours	2.10 ± 0.70	3.50 ± 0.90	<0.001

Table 6: Patient Outcomes at 7 Days Postoperatively

Outcome Parameter	Early Extubation (n=60)	Delayed Extubation (n=60)	p-value
Survival Rate (%)	57 (95.00%)	54 (90.00%)	0.32
Functional Recovery (%)	50 (83.33%)	42 (70.00%)	0.08
Incidence of ICU Readmission (%)	2 (3.33%)	6 (10.00%)	0.14

DISCUSSION

This study compared early versus delayed extubation in postoperative ICU patients following major surgeries under general anesthesia. The two groups were well-matched in demographic and baseline clinical characteristics, minimizing potential biases. Studies by Boles et al. (2012) and Girard et al. (2013) similarly reported that comparable baseline characteristics between intervention groups enhance the validity of extubation studies. These findings ensure that the observed differences in outcomes are primarily attributable to the timing of extubation rather than patient variability.[5,6]Early extubation significantly reduced the duration of mechanical ventilation and ICU stay while lowering re-intubation rates. The mean ventilation duration in the Early Extubation group (4.20 ± 1.50 hours) aligns with findings by Esteban et al. (2013), who emphasized that reducing mechanical ventilation time minimizes complications such as ventilator-associated pneumonia (VAP) and ICU-related morbidity.[7] Similarly, Blackwood et al. (2011) demonstrated that early extubation reduces the risk of re-intubation when clinical readiness criteria are met, which is consistent with our observed re-intubation rates (10.00% vs. 25.00%, p = 0.03).[8]Shorter ICU stays in the Early Extubation group (3.80 ± 1.20 days) mirror findings from Kollef et al. (2011), who highlighted that prolonged ICU stays are associated with increased healthcare costs and risks of secondary infections. Early extubation thus appears to facilitate efficient recovery and resource utilization.[9]Postoperative hemodynamic stability was significantly better in the Early Extubation group, with lower heart rates, blood pressure, and mean arterial pressure. This aligns with the findings of Jaber et al. (2010), who reported that early extubation preserves hemodynamic stability by avoiding prolonged exposure to mechanical ventilation-related stress.[10] Improved oxygenation (SpO_2) and lower respiratory rates in the Early Extubation group are consistent with the work of Heffner (2011), which highlighted that prolonged mechanical ventilation can impair respiratory efficiency.[11]Lower end-tidal CO_2 levels in the Early Extubation group suggest better ventilatory control and reduced hypercapnia risk, as supported by findings from Peterson et al. (2012). The reduced need for inotropic support in this group further emphasizes the hemodynamic benefits of early extubation.[12]The Early Extubation group experienced fewer adverse respiratory events, including hypoxia (6.67% vs. 16.67%), hypercapnia (8.33% vs. 20.00%), and VAP (5.00% vs. 15.00%, $p = 0.04$). These findings align with the systematic review by Smetana et al. (2011), which noted that prolonged intubation increases the risk of respiratory complications.[13] Additionally, Tobin (2010) reported that early extubation reduces aspiration and VAP risks by minimizing the duration of mechanical ventilation.[14]The significantly shorter hospital stay in the Early Extubation group (8.60 ± 2.00 days) is consistent with findings from Katz et al. (2013), who emphasized that improved respiratory outcomes and reduced ICU stays translate into faster overall recovery and discharge.[15]Pain control was significantly better in the Early Extubation group, as evidenced by consistently lower VAS scores at all time points. Myles et al. (2011) highlighted that early extubation reduces the need for high-dose opioids, resulting in fewer pain-related complications and improved postoperative comfort.[16] Furthermore, Carron et al. (2013) observed that better pain control facilitates faster mobilization, which may partly explain the superior recovery outcomes observed in the Early Extubation group.[17]Although survival rates and functional recovery were not significantly different between the groups, the Early Extubation group showed a positive trend toward better outcomes. Esteban et al. (2013) similarly found that early extubation improves long-term functional outcomes by reducing mechanical ventilation-related complications.[7] The lower ICU readmission rate in the Early Extubation group (3.33% vs. 10.00%) aligns with findings by Blackwood et al. (2011), who reported that early extubation reduces the likelihood of ICU readmissions due to complications such as VAP or re-intubation.[8]

CONCLUSION

In conclusion, this study demonstrated that early extubation in postoperative ICU patients after major surgeries under general anesthesia resulted in shorter mechanical ventilation duration, reduced ICU and hospital stays, better hemodynamic stability, fewer adverse respiratory events, and improved pain control compared to delayed extubation. Additionally, early extubation showed a trend toward lower re-intubation rates and better functional recovery without compromising patient safety. These findings highlight the benefits of early extubation in enhancing postoperative outcomes and optimizing ICU resource utilization. However, careful patient selection and vigilant postoperative monitoring remain essential for minimizing risks associated with both early and delayed extubation strategies.

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