International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Attenuation Of Cardiovascular Responses to Tracheal Extubation: A Comparative Study Between Intravenous Esmolol and Lignocaine.

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Received: 15-01-2026
Accepted: 04-02-2026
Available online: 07-03-2026

ABSTRACT

Background: Tracheal extubation is associated with significant sympathetic stimulation leading to tachycardia and hypertension, which may be detrimental in susceptible patients. Various pharmacological agents have been used to attenuate this hemodynamic stress response. This study aimed to compare the efficacy of intravenous esmolol and lignocaine in attenuating cardiovascular responses during tracheal extubation.

Methods: This observational comparative study was conducted on 60 adult patients aged 20–50 years, belonging to ASA physical status I and II, undergoing elective surgeries under general anaesthesia. Patients were divided into two groups of 30 each. Group L received intravenous preservative-free lignocaine 1.5 mg/kg, and Group E received intravenous esmolol 1.5 mg/kg at the end of surgery prior to extubation. Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at baseline, after drug administration, and at 1, 5, 15, and 30 minutes post-extubation. Sedation was assessed using the Modified Observer's Assessment of Alertness/Sedation (MOAAS) scale. Statistical analysis was performed using paired and independent t-tests, with $p < 0.05$ considered significant.

Results: Esmolol produced a significant reduction in heart rate and blood pressure immediately after administration and maintained hemodynamic stability during the early post-extubation period. In contrast, lignocaine failed to prevent transient increases in HR and BP at 1 and 5 minutes after extubation. Intergroup comparison demonstrated significantly better attenuation of HR, SBP, and DBP in the esmolol group during early post-extubation intervals. Sedation scores were significantly higher in the esmolol group at 5 and 15 minutes, indicating better early recovery. No clinically significant adverse events were observed in either group.

Conclusion: Intravenous esmolol is more effective than lignocaine in attenuating extubation-induced hemodynamic stress response while maintaining a favorable safety and recovery profile.

Keywords: Extubation; Esmolol; Lignocaine; Hemodynamic response; Stress response; General anaesthesia; Beta-blocker.

INTRODUCTION

Endotracheal extubation is a routine yet critical component of anaesthetic practice. While considerable attention is traditionally directed toward complications during induction and tracheal intubation, the extubation phase has received comparatively less emphasis despite being associated with significant physiological stress [1,2]. Extubation represents a period of transition from controlled ventilation to spontaneous respiration and is frequently accompanied by pronounced hemodynamic and airway reflex responses. Common complications encountered during this phase include coughing, bucking, laryngospasm, tachycardia, hypertension, and cardiac arrhythmias. Although these responses are often transient,

they may have serious consequences in susceptible individuals, particularly those with underlying cardiovascular or cerebrovascular disease.

The hemodynamic alterations observed during extubation are primarily attributed to sympathoadrenal stimulation triggered by airway manipulation and tracheal irritation [1,2]. This reflex activation results in a surge of circulating catecholamines, leading to stimulation of alpha- and beta-adrenergic receptors. Consequently, there is an increase in heart rate, myocardial contractility, and systemic vascular resistance, producing elevations in blood pressure and cardiac workload. In patients with compromised cardiovascular reserve, such exaggerated responses may precipitate pulmonary edema, myocardial ischemia, arrhythmias, or even cerebrovascular accidents. Although these changes are generally short-lived, they are often unpredictable and may pose significant clinical risk [2]. Therefore, timely prevention or attenuation of this stress response is essential to minimize perioperative morbidity [3].

Several strategies have been proposed to blunt the cardiovascular responses associated with extubation. Non-pharmacological methods such as extubation in a deep plane of anaesthesia and superior laryngeal nerve block have been described. However, these techniques may not be universally applicable and can carry their own risks, including airway obstruction or delayed recovery. Pharmacological approaches have therefore gained greater acceptance in routine clinical practice. A wide range of drugs including fentanyl, morphine, propofol, magnesium sulphate, dexmedetomidine, nitroglycerine (NTG), diltiazem, labetalol, esmolol, and lignocaine have been evaluated for this purpose [3,4]. An ideal agent for attenuating extubation response should have a rapid onset of action, short duration, minimal adverse effects, preservation of cerebral blood flow, and should not prolong recovery from anaesthesia. Among the available agents, lignocaine, fentanyl, and esmolol have been found to satisfy many of these criteria.

Esmolol is an ultra-short acting, cardioselective beta-adrenergic antagonist characterized by rapid onset and brief duration of action [4]. Its pharmacokinetic profile makes it particularly suitable for transient periods of sympathetic stimulation such as intubation and extubation. By blocking beta-adrenergic receptors, esmolol attenuates tachycardia and limits the rise in blood pressure resulting from reflex sympathoadrenal discharge. It has been widely used in the management of perioperative tachycardia, supraventricular arrhythmias, atrial fibrillation, and hypertension. Previous studies have suggested that an intravenous dose of 1.5 mg/kg is effective in suppressing cardiovascular responses during airway manipulation without causing prolonged hypotension or bradycardia [5].

Lignocaine, a widely used amide local anaesthetic, exerts its primary action by blocking voltage-gated sodium channels, thereby inhibiting neuronal conduction. In addition to its local anaesthetic properties, lignocaine has systemic effects including myocardial depressant activity, suppression of airway reflexes, and modulation of sympathetic responses. Intravenous lignocaine has been used to attenuate cardiovascular responses during laryngoscopy and intubation, and it has also been employed to blunt airway reflexes during extubation. Its relatively rapid onset and favorable safety profile make it a commonly used agent in anaesthetic practice.

Despite the availability of multiple pharmacological options, the comparative efficacy of esmolol and lignocaine in attenuating extubation-induced hemodynamic responses remains an area of clinical interest. Identifying the more effective agent can help optimize perioperative cardiovascular stability, particularly in patients at risk of adverse cardiac events. Therefore, the present study was undertaken to compare the efficacy of intravenous esmolol and preservative-free intravenous lignocaine in attenuating cardiovascular responses during tracheal extubation.

MATERIALS AND METHODS

Study Design and Setting: This observational comparative study was conducted at Lakeshore Hospital and Research Centre between October 2019 and May 2020. The study was approved by the Institutional Research and Ethics Committee, and written informed consent was obtained from all participants prior to enrolment.

Study Population: Sixty adult patients aged 20–50 years undergoing elective surgery under general anaesthesia were included in the study.

Inclusion Criteria

- American Society of Anesthesiologists (ASA) physical status I and II
- Age between 20 and 50 years
- Body Mass Index (BMI) < 30 kg/m²
- Airway assessment Mallampati grade I or II
- Elective surgeries under sole general anaesthesia lasting up to 4 hours and planned for on-table extubation

Exclusion Criteria

- Refusal to participate
- History of heart block or hypertension on alpha- and/or beta-blockers

- Known allergy to study drugs
- Emergency surgeries
- Difficult airway
- History of bronchospasm

Sample Size Calculation: The sample size was calculated based on a previous study comparing esmolol, lignocaine, and propofol in attenuation of extubation response [3]. Using the standard deviations of heart rate in the two groups ($S_1 = 6.63$; $S_2 = 5.14$), mean difference ($\mu d = 6.16$), significance level ($\alpha = 1\%$), and power ($1 - \beta = 90\%$), the minimum required sample size was calculated as 28 patients per group. To account for possible dropouts, 30 patients were included in each group, making a total sample size of 60.

Study Procedure: All patients underwent a thorough pre-anaesthetic evaluation including detailed history, clinical examination, and relevant investigations. Standard fasting guidelines were followed.

Premedication consisted of oral rabeprazole 20 mg and lorazepam 2 mg administered 90 minutes prior to surgery.

In the operating room, standard monitoring was instituted including electrocardiography (ECG), non-invasive blood pressure (NIBP), and pulse oximetry (SpO_2). Baseline hemodynamic parameters were recorded at the end of surgery prior to administration of the study drug.
General anaesthesia was induced with intravenous fentanyl 2 mcg/kg and propofol 2–2.5 mg/kg. Neuromuscular blockade was achieved using atracurium 0.5 mg/kg to facilitate endotracheal intubation, which was confirmed with capnography. Anaesthesia was maintained with a mixture of air, oxygen, and sevoflurane. Additional doses of muscle relaxant were administered based on train-of-four monitoring. Intraoperative analgesia was provided using paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs), and fentanyl as required. The last dose of analgesic and muscle relaxant was administered approximately one hour before the end of surgery.

Group Allocation and Intervention
Patients were divided into two groups of 30 each:
- **Group L**: Received intravenous preservative-free lignocaine 1.5 mg/kg
- **Group E**: Received intravenous esmolol 1.5 mg/kg

The study drug was administered at the end of surgery prior to reversal of neuromuscular blockade. One senior consultant administered esmolol and another administered lignocaine, while the primary investigator recorded the outcomes.

Following drug administration, neuromuscular blockade was reversed using intravenous neostigmine 0.05 mg/kg and glycopyrrolate 0.008 mg/kg. Adequate reversal was confirmed using double-burst stimulation and clinical assessment. Extubation was performed after gentle oropharyngeal suctioning once the patient was fully awake and responsive.

Outcome Measures: Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and SpO_2 were recorded at the following time intervals:
- Baseline (end of surgery before drug administration)
- After drug administration
- 1 minute post-extubation
- 5 minutes post-extubation
- 15 minutes post-extubation
- 30 minutes post-extubation

Sedation level was assessed using the Modified Observer's Assessment of Alertness/Sedation (MOAAS) scale at 1, 5, 15, and 30 minutes after extubation.

Episodes of bradycardia (HR < 60 beats/min) and hypotension (SBP < 90 mm Hg) were recorded and treated with intravenous glycopyrrolate 0.2 mg and ephedrine 6 mg, respectively. Tachycardia (HR > 100 beats/min) was treated with additional fentanyl 50 mcg if required.

Statistical Analysis: Statistical analysis was performed using SPSS version 20. Categorical variables were expressed as frequency and percentage. Continuous variables were presented as mean ±standard deviation (SD). Intergroup comparisons were performed using independent sample t-test (unpaired t-test). Intragroup comparisons were analyzed using paired sample t-test. A p-value < 0.05 was considered statistically significant.

RESULTS

A total of 60 patients were included in the study, with 30 patients in each group (Group L: lignocaine 1.5 mg/kg; Group E: esmolol 1.5 mg/kg). All enrolled patients completed the study and were included in the final analysis.

Baseline Characteristics

The demographic profile and surgical characteristics of the study population are summarized in Table 1. Both groups were comparable with respect to age, gender distribution, and ASA physical status. A statistically significant difference was observed in BMI, which was higher in Group E ($p = 0.028$). The type and duration of surgery were comparable between groups.

Table 1. Baseline Demographic and Surgical Characteristics

Parameter	Group L (n=30)	Group E (n=30)	p-value
Age (years)	37.1 ± 8.03	36.2 ± 6.56	0.429
Male/Female	14 / 16	12 / 18	0.62
BMI (kg/m²)	23.0 ± 1.85	24.5 ± 2.50	0.028
ASA I / II	11 / 19	15 / 15	0.297
Donor Nephrectomy	13	13	—
RIRS	11	7	—
MRM	6	10	—
Duration 2–4 hrs	30	30	—

Heart Rate

Changes in heart rate at various time intervals are presented in Table 2. A significant reduction in heart rate was observed in Group E immediately after drug administration and at all post-extubation intervals ($p < 0.05$). In contrast, Group L showed a significant increase in heart rate at 1 and 5 minutes post-extubation. Intergroup comparison demonstrated significantly better attenuation of heart rate in the esmolol group during the early post-extubation period.

Table 2. Comparison of Heart Rate (beats/min)

Time Point	Group L (Mean ± SD)	Group E (Mean ± SD)	p-value
Baseline	78.90 ± 15.57	101.9 ± 11.76	—
After Drug	79.30 ± 12.64	82.53 ± 8.41	<0.001*
1 min	98.33 ± 8.60	85.83 ± 11.26	<0.001*
5 min	94.00 ± 8.69	85.30 ± 8.86	<0.001*
15 min	84.00 ± 8.58	85.00 ± 11.11	<0.001*
30 min	73.27 ± 10.13	88.40 ± 8.57	<0.001*

*Statistically significant

Systolic Blood Pressure

Systolic blood pressure values and intergroup comparisons are shown in Table 3. Esmolol produced a significant reduction in SBP immediately after drug administration and maintained stable values during the post-extubation period. Lignocaine group demonstrated significant elevations in SBP at 1, 5, and 15 minutes after extubation. The intergroup difference was statistically significant at 1, 5, and 15 minutes.

Table 3. Comparison of Systolic Blood Pressure (mm Hg)

Time Point	Group L (Mean ± SD)	Group E (Mean ± SD)	p-value
Baseline	115.1 ± 13.39	124.9 ± 14.39	—
After Drug	115.2 ± 12.67	115.8 ± 13.23	<0.001*
1 min	126.6 ± 13.13	127.6 ± 14.25	0.005*
5 min	130.8 ± 13.15	122.2 ± 13.78	<0.001*
15 min	124.2 ± 13.57	121.3 ± 12.49	0.003*
30 min	120.9 ± 17.05	121.4 ± 11.99	0.153

*Statistically significant

Diastolic Blood Pressure and Mean Arterial Pressure

Diastolic blood pressure and mean arterial pressure changes are summarized in Table 4. Group E demonstrated significant attenuation immediately after drug administration. Group L showed significant increases at early post-extubation intervals. Intergroup comparison revealed statistically significant differences primarily at 5 minutes post-extubation.

Table 4. Comparison of DBP and MAP

Time Point	DBP L	DBP E	p-value	MAP L	MAP E	p-value
Baseline	75.60 ± 12.15	80.60 ± 10.25	—	88.57 ± 13.11	95.47 ± 11.55	—
After Drug	76.53 ± 10.25	75.43 ± 11.71	0.022*	88.57 ± 11.88	90.03 ± 9.82	0.003*
1 min	80.70 ± 11.83	82.20 ± 11.75	0.294	96.43 ± 16.22	97.10 ± 11.04	0.992
5 min	81.83 ± 10.50	77.70 ± 10.06	0.012*	97.77 ± 12.07	92.80 ± 11.01	0.091
15 min	77.33 ± 9.61	76.90 ± 10.77	0.126	92.47 ± 11.23	91.07 ± 10.70	0.544
30 min	76.50 ± 9.02	77.77 ± 11.43	0.280	90.10 ± 12.19	93.67 ± 11.70	0.334

*Statistically significant

Oxygen Saturation

Oxygen saturation remained clinically stable in both groups throughout the study period. No clinically significant intergroup differences were observed (Table 5).

Table 5. Comparison of SpO_2 (%)

Time Point	Group L	Group E	p-value
Baseline	100.0 ± 0.00	99.37 ± 0.61	—
After Drug	100.0 ± 0.00	99.43 ± 0.57	0.677
1 min	98.07 ± 1.36	98.77 ± 1.17	0.012
5 min	98.63 ± 1.07	99.13 ± 0.90	0.282
15 min	98.10 ± 1.30	99.27 ± 0.69	0.573
30 min	98.47 ± 1.22	98.27 ± 1.20	0.000

Sedation Score (MOAAS)

Sedation scores are presented in Table 6. Group E demonstrated significantly higher MOAAS scores at 5 and 15 minutes, indicating faster recovery and lower sedation compared to Group L. At 30 minutes, scores were comparable.

Table 6. Comparison of MOAAS Scores

Time Point	Group L	Group E	p-value
5 min	2.93 ± 0.52	3.87 ± 0.35	<0.001*
15 min	4.00 ± 0.00	4.90 ± 0.31	<0.001*
30 min	5.00 ± 0.00	5.00 ± 0.00	1.000

*Statistically significant

Intravenous esmolol provided superior attenuation of heart rate and blood pressure responses following tracheal extubation compared to lignocaine. The effect was most pronounced during the early post-extubation period (1–5 minutes), thereby fulfilling the primary objective of assessing changes in HR and BP. Additionally, esmolol demonstrated better early recovery characteristics with higher sedation scores, addressing the secondary objectives of duration of attenuation and safety assessment.

DISCUSSION

Tracheal extubation, like laryngoscopy and intubation, is associated with a significant sympathetic stress response characterized by tachycardia, hypertension, and occasionally arrhythmias. Although the hemodynamic consequences of intubation have been extensively studied, extubation-related responses are often underestimated despite comparable physiological perturbations. Airway manipulation during extubation acts as a noxious stimulus, triggering reflex sympathoadrenal activation and a surge in circulating catecholamines [4]. This catecholamine-mediated response increases myocardial oxygen demand and systemic vascular resistance, predisposing susceptible individuals to pulmonary edema, myocardial insufficiency, and cerebrovascular events. Tachycardia at the end of surgery is particularly concerning because it elevates myocardial oxygen consumption at a time when patients are emerging from anaesthesia and physiological reserve may be limited.

Wohlner et al. studied hemodynamic responses following tracheal extubation in post-coronary artery bypass graft patients and demonstrated significant increases in heart rate, mean arterial pressure, cardiac index, and systemic vascular resistance beginning at 1 minute and persisting up to 10 minutes after extubation [6]. These findings underscore the clinical relevance of blunting extubation-induced stress responses, particularly in high-risk populations. Pretreatment with opioids or beta-blockers has been shown to mitigate catecholamine-mediated responses [7], and several pharmacological agents have been investigated for this purpose.

In the present study, intravenous esmolol (1.5 mg/kg) and preservative-free 2% lignocaine (1.5 mg/kg) were compared for their efficacy in attenuating cardiovascular responses to extubation. The demographic variables including age, sex distribution, and ASA physical status were comparable between groups. Although BMI was statistically higher in the esmolol group, this difference was not clinically significant and did not appear to influence hemodynamic trends.

Heart Rate Response

Esmolol produced an immediate and sustained reduction in heart rate following drug administration, which persisted up to 15 minutes post-extubation. In contrast, lignocaine failed to prevent the early post-extubation tachycardia observed at 1 and 5 minutes. The superior performance of esmolol can be attributed to its rapid onset and selective β1-adrenergic blockade, which directly counteracts sympathetic stimulation. Importantly, no episodes of severe bradycardia requiring intervention were observed.

An additional clinically relevant observation was the stabilization of heart rate during reversal of neuromuscular blockade. Anticholinergic agents such as glycopyrrolate, administered with neostigmine, frequently induce tachycardia, which may be compounded by extubation stress. Esmolol effectively attenuated this drug-induced tachycardia, providing smoother hemodynamic transition during emergence. Its ultra-short half-life offers an advantage over longer-acting beta-blockers and lignocaine, ensuring transient negative chronotropic effects without prolonged cardiovascular depression.

These findings are consistent with Kovac et al., who demonstrated that esmolol effectively attenuates heart rate response during extubation [5]. Similarly, Patel et al. reported significant reductions in heart rate and blood pressure with esmolol in the immediate post-extubation period [1].

Blood Pressure Response

In our study, systolic and diastolic blood pressures decreased significantly in the esmolol group immediately after administration and remained stable during the early post-extubation period. In contrast, the lignocaine group demonstrated significant increases in SBP and DBP up to 15 minutes after extubation.

These findings align with those of Patel et al., who observed significant reductions in SBP, DBP, and MAP within the first two minutes after extubation with esmolol [1]. Nagrale et al., in a comparative study of esmolol, propofol, and lignocaine, reported sustained attenuation of SBP and DBP for up to 10 minutes in the esmolol group, whereas the lignocaine group showed significant post-extubation increases [3]. The hemodynamic trends observed in our study closely parallel these reports, reinforcing the consistency of esmolol's efficacy across different study populations.

Mean arterial pressure followed a similar pattern, with better immediate attenuation in the esmolol group. The rapid β1-blockade limits myocardial contractility and heart rate, thereby reducing cardiac output and stabilizing blood pressure during peak sympathetic stimulation.

Sedation and Recovery Profile

Sedation was assessed using the MOAAS scoring system [8-10]. Patients receiving esmolol demonstrated higher scores at 5 and 15 minutes, indicating earlier return to alertness compared to the lignocaine group. Although lignocaine effectively suppresses airway reflexes and deepens anaesthetic plane—beneficial during intubation—its sedative effects may delay full recovery during extubation.

From a clinical standpoint, an awake patient with intact airway reflexes is preferable following extubation. Excessive sedation may mask airway obstruction and delay recognition of respiratory compromise, particularly in patients with difficult airways. While none of our patients required airway adjuncts postoperatively, the observed difference in early recovery profile favors esmolol in facilitating smoother and safer emergence.

Safety Profile
No episodes of clinically significant bradycardia, hypotension, hypertension, or tachycardia requiring pharmacological intervention were recorded in either group. The absence of adverse events highlights the safety of both drugs at the studied doses. The short half-life of esmolol further enhances its safety margin by minimizing prolonged cardiovascular depression.

Clinical Implications
The findings of this study support the use of intravenous esmolol for effective attenuation of extubation-induced hemodynamic stress response. The rapid onset, predictable duration of action, and favorable recovery profile make esmolol particularly suitable for routine clinical practice, especially in patients with cardiovascular risk factors.

While lignocaine demonstrated some attenuation of hemodynamic responses, its effect was delayed and less pronounced during the critical early post-extubation period. Given that peak sympathetic responses occur within the first few minutes after extubation [6], immediate control of heart rate and blood pressure is essential.

LIMITATIONS
The present study was an observational study conducted in a relatively small sample of 60 patients belonging to ASA grades I and II, which limits the generalizability of the findings to broader patient populations. A larger study involving a more diverse cohort would be necessary to establish stronger statistical significance and to conclusively determine the superiority of esmolol over lignocaine in attenuating hemodynamic responses to tracheal extubation. Additionally, patients with significant cardiovascular disease were excluded; therefore, the potential benefits and safety of these drugs in high-risk or vulnerable populations could not be assessed.

CONCLUSION
Tracheal extubation is associated with significant sympathetic stimulation that may result in tachycardia and hypertension, potentially increasing perioperative cardiovascular risk. The present study demonstrates that intravenous esmolol at a dose of 1.5 mg/kg provides superior attenuation of heart rate and blood pressure responses during the early post-extubation period compared to intravenous lignocaine at the same dose. Esmolol produced immediate and sustained stabilization of hemodynamic parameters up to 15 minutes following extubation without causing clinically significant bradycardia or hypotension. In contrast, lignocaine showed delayed and less pronounced attenuation of cardiovascular responses. Additionally, patients receiving esmolol exhibited better early recovery profiles with higher sedation scores. Both drugs were safe and well tolerated. Based on these findings, intravenous esmolol appears to be a more effective agent for attenuating extubation-induced hemodynamic stress response, particularly in patients where cardiovascular stability is of concern.

DECLARATIONS

Ethical Approval and Consent to Participate:
The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee of Lakeshore Hospital and Research Centre prior to commencement of the study (vide Letter no. LHRC/EC/10/2019 dated 04.20.2019). Written informed consent was obtained from all participants before their inclusion in the study.

Availability of Data and Materials:
The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests:
The authors declare that they have no competing interests.

Funding:
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors 'Contributions:
All authors contributed to the conception and design of the study. Data collection, analysis, interpretation of results, manuscript preparation, and critical revision were performed collaboratively. All authors read and approved the final manuscript.

Acknowledgements:
The authors acknowledge the support of the Department of Anaesthesia and Critical Care, Lakeshore Hospital and Research Centre, for their cooperation and assistance during the study.

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