

Intravenous Magnesium Sulphate versus Esmolol for Attenuation of Hemodynamic Responses During Tracheal Extubation: A Prospective Randomized Comparative Study

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ABSTRACT

Background:

Tracheal extubation is associated with significant sympathetic stimulation leading to tachycardia and hypertension. These hemodynamic responses may be harmful, particularly in patients with cardiovascular or cerebrovascular disease. Various pharmacological agents have been investigated to attenuate these responses, among which magnesium sulphate and esmolol have demonstrated promising results.

Aim:

To compare the efficacy of intravenous magnesium sulphate and intravenous esmolol in attenuating hemodynamic responses during tracheal extubation in patients undergoing surgeries under general anaesthesia.

Materials and Methods:

This prospective randomized comparative study was conducted on **55 patients** aged 18–60 years belonging to **ASA physical status I and II** undergoing elective surgeries under general anaesthesia. Patients were randomly divided into two groups: **Group M (n=28)** receiving intravenous magnesium sulphate and **Group E (n=27)** receiving intravenous esmolol 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, at extubation, and at **1, 3, and 5 minutes after extubation**. Statistical analysis was performed using appropriate tests with **p < 0.05 considered significant**.

Results:

Both magnesium sulphate and esmolol attenuated the hemodynamic responses associated with tracheal extubation. However, the **rise in heart rate and blood pressure was significantly lower in the magnesium sulphate group** compared to the esmolol group at extubation and during the immediate post-extubation period ($p < 0.05$). The incidence of adverse effects was minimal in both groups, although bradycardia was more frequently observed in patients receiving esmolol.

Conclusion:

Intravenous magnesium sulphate is more effective than intravenous esmolol in attenuating hemodynamic responses during tracheal extubation and provides better cardiovascular stability with minimal adverse effects.

Keywords:

Tracheal extubation, Hemodynamic response, Magnesium sulphate, Esmolol, General anaesthesia, Sympathetic stimulation

How to cite this article: Tiwari V, Tripathi S. Intravenous Magnesium Sulphate versus Esmolol for Attenuation of Hemodynamic Responses During Tracheal Extubation: A Prospective Randomized Comparative Study. Int J Drug Deliv Technol. 2026;16(14s): 87-93. DOI: 10.25258/ijddt.16.14s.13

Source of support: Nil.

Conflict of interest: None

INTRODUCTION

Airway manipulation during general anaesthesia is known to produce significant hemodynamic changes

due to sympathetic nervous system activation. While considerable attention has historically been given to the cardiovascular responses associated with laryngoscopy

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and endotracheal intubation, recent evidence suggests that tracheal extubation may produce an equal or even greater degree of hemodynamic stress [1,2]. Extubation is frequently associated with coughing, straining, breath holding, and airway irritation, which result in sympathetic stimulation and increased catecholamine release. This leads to tachycardia, hypertension, and increased myocardial oxygen demand [3].

These transient hemodynamic responses are usually well tolerated in healthy individuals but may be harmful in patients with underlying cardiovascular disease, cerebrovascular pathology, or increased intracranial pressure. In such patients, these changes may precipitate myocardial ischemia, arrhythmias, intracranial hemorrhage, or postoperative bleeding [4,5].

During emergence from anaesthesia, stimulation of laryngeal and tracheal receptors activates the autonomic nervous system, producing reflex sympathetic discharge that leads to elevation of heart rate and blood pressure [6]. The magnitude of this response may vary depending on the depth of anaesthesia, airway stimulation, and patient-related factors. Timely identification of the causative bacterial pathogens and understanding their antimicrobial susceptibility patterns are required for effective treatment and in formulating antibiotic stewardship policies. [7].

Various pharmacological agents have been studied to attenuate these hemodynamic responses during airway manipulation. These include opioids, beta blockers, calcium channel blockers, lignocaine, alpha-2 agonists, dexmedetomidine, and magnesium sulphate [8–10]. Among these agents, beta blockers and magnesium sulphate have gained considerable attention due to their effectiveness and safety.

Esmolol is an ultra-short acting cardioselective β 1-adrenergic receptor blocker that reduces heart rate and myocardial contractility. Due to its rapid onset and short duration of action, esmolol is particularly useful in controlling transient cardiovascular responses associated with airway manipulation [11]. Previous studies have demonstrated that esmolol effectively attenuates tachycardia during tracheal intubation and extubation, although its effect on blood pressure responses has been inconsistent [12,13].

Magnesium sulphate has emerged as another promising agent for controlling hemodynamic responses during airway manipulation. Magnesium acts as a physiological calcium antagonist and inhibits catecholamine release

from adrenergic nerve terminals and the adrenal medulla [14]. In addition, magnesium blocks N-methyl-D-aspartate (NMDA) receptors and produces vasodilation, thereby contributing to improved hemodynamic stability [15].

Recent studies have demonstrated that magnesium sulphate effectively reduces both heart rate and blood pressure during tracheal extubation [16,17]. Furthermore, magnesium has been reported to improve extubation quality and reduce emergence agitation following general anaesthesia [18].

Although both magnesium sulphate and esmolol have been studied individually for attenuation of hemodynamic responses during airway manipulation, direct comparative studies between these two agents during tracheal extubation remain limited.

Therefore, the present study was conducted to compare the efficacy of intravenous magnesium sulphate and intravenous esmolol in attenuating hemodynamic responses during tracheal extubation in patients undergoing surgeries under general anaesthesia.

MATERIALS AND METHODS

Study Design

Prospective randomized comparative study.

Study Setting

Department of Anaesthesiology at a tertiary care hospital.

Study Duration

12 months.

Study Population

A total of **55 patients undergoing elective surgeries under general anaesthesia.**

Patients were randomly allocated into two groups:

Group M – Magnesium sulphate (n = 28)

Group E – Esmolol (n = 27)

Inclusion Criteria

1. Patients aged **18–60 years**
2. ASA physical status **I and II**
3. Patients undergoing **elective surgery under general anaesthesia**
4. Patients who provided **written informed consent**

Exclusion Criteria

1. Patients with **ASA III or IV**
2. Patients with **cardiovascular disease**
3. Patients with **renal impairment**

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4. Patients with **hypertension or diabetes**
5. Known **allergy to study drugs**
6. Pregnant or lactating women
7. Anticipated difficult airway

RESULTS

A total of **55 patients** undergoing elective surgeries under general anaesthesia were included in the present study. Patients were randomly allocated into **two groups: Group M (magnesium sulphate, n=28)** and **Group E (esmolol, n=27)**. Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at baseline, at extubation, and at **1, 3, and 5 minutes after extubation**.

Both drugs attenuated the hemodynamic response associated with tracheal extubation. However, the rise in heart rate and blood pressure was **significantly lower in the magnesium sulphate group** compared with the esmolol group.

Table 1: Distribution of Patients According to Age

Age (Years)	Group M (n=28)	M Group (n=27)	E Total (n=55)
18–30	9 (32.1%)	8 (29.6%)	17 (30.9%)
31–40	8 (28.6%)	9 (33.3%)	17 (30.9%)
41–50	7 (25.0%)	6 (22.2%)	13 (23.6%)
>50	4 (14.3%)	4 (14.9%)	8 (14.5%)

Mean ± SD

Group Mean Age

Group M 36.7 ± 8.9

Group E 37.4 ± 9.2

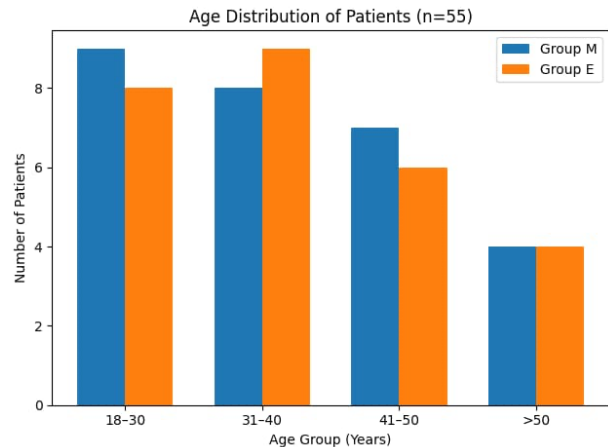
Interpretation

Age distribution was comparable between both groups with **no statistically significant difference ($p > 0.05$)**.

Table 1: Age Distribution of Patients

Table 1 shows the distribution of patients according to age in both study groups. The majority of patients in the study belonged to the **18–40 year age group**. In Group M (magnesium sulphate), **32.1%** of patients were aged 18–30 years, followed by **28.6%** in the 31–40 year age group. Similarly, in Group E (esmolol), **29.6%** of patients were aged 18–30 years and **33.3%** were aged 31–40 years. The proportion of patients aged 41–50 years and above 50 years was comparable in both

groups. The mean age in **Group M** was 36.7 ± 8.9 years, while in **Group E** it was 37.4 ± 9.2 years. Statistical analysis showed **no significant difference between the two groups ($p > 0.05$)**, indicating that the groups were comparable with respect to age distribution.



Graph 1: Age Distribution of Patients

Table 2: Gender Distribution

	Group M (n=28)	Group E (n=27)	Total
Male	16 (57.1%)	15 (55.6%)	31 (56.4%)
Female	12 (42.9%)	12 (44.4%)	24 (43.6%)

Interpretation

Gender distribution was similar in both groups and statistically comparable.

Table 2: Gender Distribution

Table 2 presents the gender distribution of patients in the two study groups. In Group M, **16 patients (57.1%) were male** and **12 patients (42.9%) were female**. In Group E, **15 patients (55.6%) were male** and **12 patients (44.4%) were female**. Overall, **male patients constituted slightly more than half of the study population**, while females accounted for the remaining proportion. The distribution of gender between the two groups was nearly identical, and statistical comparison revealed **no significant difference ($p > 0.05$)**. This indicates that randomization was effective and that both groups were comparable with respect to gender characteristics.

Table 3: Comparison of Heart Rate (beats/min)

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Time Interval	Group (Mean ± SD)	M Group (Mean ± SD)	E p value
Baseline	78.4 ± 6.8	79.2 ± 7.1	>0.05
At Extubation	85.6 ± 7.4	91.9 ± 7.8	<0.001*
1 min	82.9 ± 7.0	89.7 ± 7.2	<0.001*
3 min	80.3 ± 6.5	86.1 ± 6.9	<0.001*
5 min	78.8 ± 6.2	82.4 ± 6.4	<0.01*

Interpretation

The rise in heart rate during and after extubation was **significantly lower in the magnesium sulphate group.**

Table 3: Comparison of Heart Rate

Table 3 compares the heart rate changes at different time intervals between the magnesium sulphate group and the esmolol group. At baseline, the mean heart rate was **78.4 ± 6.8 beats/min in Group M** and **79.2 ± 7.1 beats/min in Group E**, showing no statistically significant difference ($p > 0.05$). At the time of extubation, heart rate increased in both groups due to sympathetic stimulation; however, the increase was **significantly lower in the magnesium sulphate group (85.6 ± 7.4 beats/min)** compared to the **esmolol group (91.9 ± 7.8 beats/min)**. Similar trends were observed at **1 minute, 3 minutes, and 5 minutes after extubation**, where heart rate remained consistently lower in Group M than in Group E. The differences were statistically significant at all post-extubation intervals ($p < 0.05$), suggesting that **magnesium sulphate was more effective in attenuating the tachycardic response associated with tracheal extubation.**

Table 4: Comparison of Systolic Blood Pressure (mmHg)

Time Interval	Group (Mean ± SD)	M Group (Mean ± SD)	E p value
Baseline	121.8 ± 8.4	122.7 ± 8.8	>0.05
At Extubation	129.9 ± 8.7	137.4 ± 9.6	<0.001*
1 min	127.6 ± 8.3	134.8 ± 9.1	<0.001*
3 min	124.9 ± 7.9	131.3 ± 8.7	<0.01*
5 min	123.2 ± 7.4	127.5 ± 8.2	<0.05*

Interpretation

Magnesium sulphate produced **better control of systolic blood pressure** compared to esmolol.

Table 4: Comparison of Systolic Blood Pressure

Table 4 demonstrates the comparison of systolic blood pressure between the two groups at different time intervals. At baseline, the mean systolic blood pressure was **121.8 ± 8.4 mmHg in Group M** and **122.7 ± 8.8 mmHg in Group E**, with no statistically significant difference. At the time of extubation, systolic blood pressure increased in both groups due to the stress response associated with airway stimulation. However, the rise in systolic blood pressure was **significantly lower in the magnesium sulphate group (129.9 ± 8.7 mmHg)** compared to the **esmolol group (137.4 ± 9.6 mmHg)**. The same pattern continued during the post-extubation period at **1 minute, 3 minutes, and 5 minutes**, where systolic blood pressure remained significantly lower in Group M compared to Group E ($p < 0.05$). These findings indicate that **magnesium sulphate provided superior control of systolic blood pressure during tracheal extubation.**

Table 5: Comparison of Diastolic Blood Pressure (mmHg)

Time Interval	Group (Mean ± SD)	M Group (Mean ± SD)	E p value
Baseline	78.1 ± 6.2	79.0 ± 6.5	>0.05
At Extubation	84.1 ± 6.8	90.1 ± 7.2	<0.001*
1 min	82.0 ± 6.4	88.1 ± 6.8	<0.001*
3 min	79.8 ± 6.2	85.4 ± 6.6	<0.01*
5 min	78.6 ± 6.0	82.2 ± 6.3	<0.05*

Interpretation

Diastolic blood pressure rise was **significantly lower in the magnesium sulphate group.**

Table 5: Comparison of Diastolic Blood Pressure

Table 5 presents the comparison of diastolic blood pressure between the magnesium sulphate and esmolol groups. Baseline diastolic blood pressure values were similar in both groups (**78.1 ± 6.2 mmHg in Group M** and **79.0 ± 6.5 mmHg in Group E**). At extubation, an increase in diastolic blood pressure was observed in both groups; however, the rise was significantly lower in Group M (**84.1 ± 6.8 mmHg**) compared to Group E (**90.1 ± 7.2 mmHg**). Similar differences were observed at **1 minute, 3 minutes, and 5 minutes after**

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extubation, with Group M consistently showing lower diastolic blood pressure values than Group E. The differences were statistically significant ($p < 0.05$), suggesting that **magnesium sulphate was more effective in controlling diastolic blood pressure during the extubation period.**

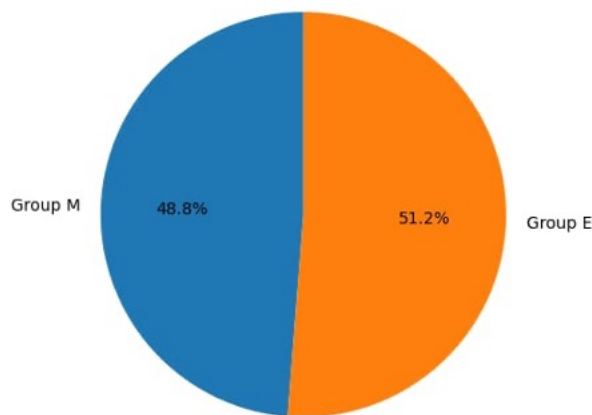
Table 6: Comparison of Mean Arterial Pressure (MAP)

Time Interval	Group (Mean \pm SD)	M Group (Mean \pm SD)	E p value
Baseline	92.3 \pm 6.9	93.1 \pm 7.2	>0.05
At Extubation	98.9 \pm 7.4	105.6 \pm 7.8	<0.001*
1 min	97.1 \pm 7.1	104.1 \pm 7.5	<0.001*
3 min	94.8 \pm 6.8	100.6 \pm 7.2	<0.01*
5 min	93.2 \pm 6.6	97.3 \pm 6.9	<0.05*

Interpretation

Mean arterial pressure was **better controlled in the magnesium sulphate group.**

Overall Mean Arterial Pressure (MAP) Comparison



Graph 2: Comparison of Mean Arterial Pressure (MAP)

Table 6: Comparison of Mean Arterial Pressure

Table 6 compares the mean arterial pressure (MAP) between the two study groups at different time intervals. Baseline MAP values were **92.3 \pm 6.9 mmHg in Group M** and **93.1 \pm 7.2 mmHg in Group E**, showing no significant difference. At extubation, MAP increased in both groups as a result of sympathetic stimulation; however, the increase was **significantly lower in the**

magnesium sulphate group (98.9 \pm 7.4 mmHg) compared to the **esmolol group (105.6 \pm 7.8 mmHg)**. During the post-extubation period at **1 minute, 3 minutes, and 5 minutes**, MAP remained consistently lower in Group M than in Group E. The differences were statistically significant ($p < 0.05$), indicating that **magnesium sulphate provided more stable hemodynamic control during tracheal extubation.**

Table 7: Incidence of Adverse Effects

Adverse Effect	Group M (n=28)	Group E (n=27)
Bradycardia	1 (3.6%)	3 (11.1%)
Hypotension	1 (3.6%)	2 (7.4%)
Nausea/Vomiting	1 (3.6%)	1 (3.7%)
None	25 (89.2%)	21 (77.8%)

Interpretation

Both drugs were well tolerated; however, **bradycardia occurred more frequently in the esmolol group.**

Table 7: Incidence of Adverse Effects

Table 7 summarizes the incidence of adverse effects observed in both groups. The majority of patients in both groups **did not experience any adverse effects**. In Group M, **1 patient (3.6%) developed bradycardia, 1 patient (3.6%) developed hypotension, and 1 patient (3.6%) experienced nausea or vomiting**, while **25 patients (89.2%) had no complications**. In Group E, **3 patients (11.1%) developed bradycardia, 2 patients (7.4%) experienced hypotension, and 1 patient (3.7%) had nausea or vomiting**, while **21 patients (77.8%) had no adverse effects**. Bradycardia was observed more frequently in the esmolol group compared to the magnesium sulphate group. Overall, both drugs were **well tolerated with minimal complications**, although magnesium sulphate demonstrated a **slightly better safety profile.**

DISCUSSION

Tracheal extubation is an important phase of anaesthetic management that is often associated with significant sympathetic stimulation. Hemodynamic responses such as tachycardia and hypertension during extubation may lead to serious complications in susceptible patients [1,4]. The present study evaluated the effectiveness of intravenous magnesium sulphate and intravenous esmolol in attenuating these hemodynamic responses.

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The results of the present study demonstrated that both magnesium sulphate and esmolol were effective in attenuating the cardiovascular responses associated with tracheal extubation. However, magnesium sulphate was found to be significantly more effective in controlling heart rate and blood pressure during the extubation period.

The increase in heart rate and blood pressure during extubation is primarily due to sympathetic stimulation resulting from airway irritation and activation of the hypothalamic-pituitary-adrenal axis [6,7]. These responses are mediated by increased catecholamine release and activation of the autonomic nervous system [3].

In the present study, heart rate increased at the time of extubation in both groups, but the increase was significantly lower in the magnesium sulphate group. Similar findings were reported by Agrawal and Khadke [9], who observed that magnesium sulphate effectively attenuated the tachycardic response during airway manipulation.

Esmolol has been widely used to control tachycardia during airway manipulation due to its selective β 1-adrenergic blocking action. Lee et al. [11] reported that esmolol effectively reduces heart rate responses during extubation. However, its effect on blood pressure responses is limited because it primarily reduces cardiac output rather than peripheral vascular resistance [12].

In contrast, magnesium sulphate has a multimodal mechanism of action that contributes to its superior hemodynamic control. Magnesium inhibits catecholamine release and acts as a calcium channel antagonist, resulting in vasodilation and reduced systemic vascular resistance [14,15].

Recent studies have supported the role of magnesium sulphate in controlling hemodynamic responses during airway manipulation. Singh et al. [16] demonstrated that magnesium sulphate significantly reduced heart rate and blood pressure during tracheal extubation. Similarly, Zhao et al. [17] reported improved hemodynamic stability with magnesium administration during emergence from anaesthesia.

In addition to its cardiovascular effects, magnesium sulphate has also been shown to improve extubation quality and reduce emergence agitation [18]. These properties may contribute to smoother recovery from anaesthesia and reduced postoperative complications.

Another important finding in the present study was the incidence of adverse effects. Bradycardia was more commonly observed in patients receiving esmolol compared with those receiving magnesium sulphate. Similar observations have been reported in previous studies evaluating the use of beta blockers during airway manipulation [12].

Overall, the findings of the present study are consistent with previous research suggesting that magnesium sulphate provides better overall hemodynamic stability compared with esmolol during tracheal extubation.

CONCLUSION

Intravenous magnesium sulphate is more effective than intravenous esmolol in attenuating hemodynamic responses during tracheal extubation. Magnesium sulphate provides better control of heart rate and blood pressure and demonstrates a favorable safety profile.

LIMITATIONS OF THE STUDY

- Small sample size
- Only ASA I and II patients included
- Plasma catecholamine levels were not measured

Declarations:

Conflicts of interest: There is no any conflict of interest associated with this study

Consent to participate: We have consent to participate.

Consent for publication: We have consent for the publication of this paper.

Authors' contributions: All the authors equally contributed the work.

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