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A Comparative Study of Attenuation of Hemodynamic Responses During Tracheal Extubation with Intravenous Magnesium Sulphate and Intravenous Esmolol in Surgeries Under General Anaesthesia

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ABSTRACT

Background: Tracheal extubation is frequently associated with undesirable hemodynamic responses such as tachycardia and hypertension due to sympathetic stimulation. These responses may be detrimental in patients with cardiovascular or cerebrovascular compromise. Various pharmacological agents have been evaluated to attenuate these responses, among which magnesium sulphate and esmolol have shown 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 85 patients aged 18–60 years, classified as ASA physical status I and II, undergoing elective surgeries under general anaesthesia. Patients were randomly allocated into two groups: Group M (magnesium sulphate) and Group E (esmolol). Hemodynamic parameters including heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure were recorded at baseline, at extubation, and at 1, 3, and 5 minutes after extubation. Data were analyzed using appropriate statistical tests.

Results: Both drugs attenuated the hemodynamic response during extubation; however, magnesium sulphate was significantly more effective than esmolol in controlling heart rate and blood pressure at extubation and in the immediate post-extubation period ($p < 0.05$).

Conclusion: Intravenous magnesium sulphate provides superior attenuation of hemodynamic responses during tracheal extubation compared to intravenous esmolol, with minimal adverse effects.

Keywords: *Tracheal extubation; Hemodynamic response; Magnesium sulphate; Esmolol; General anaesthesia*

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1. INTRODUCTION

Tracheal extubation is a critical and often underestimated phase of general anaesthesia, associated with significant hemodynamic fluctuations due to intense sympathetic stimulation. Mechanical irritation of the airway, emergence from anaesthesia, coughing, breath-holding, and straining during extubation lead to increased catecholamine release, resulting in tachycardia and hypertension. These transient responses may precipitate serious complications such as myocardial

ischemia, arrhythmias, cerebrovascular accidents, raised intracranial pressure, and postoperative bleeding, particularly in vulnerable patients.[1–3]

In recent years, growing emphasis has been placed on the recognition that extubation may provoke **equal or even greater hemodynamic stress** compared to laryngoscopy and intubation. Contemporary studies highlight that extubation-related cardiovascular responses are more sustained and unpredictable, necessitating targeted pharmacological interventions.[4–6] The need for optimal attenuation of these responses has become increasingly relevant with the rising surgical burden among elderly patients and those with cardiovascular comorbidities.

Various pharmacological agents have been evaluated to blunt the stress response during airway manipulation, including opioids, alpha-2 agonists, beta-blockers, calcium channel blockers, lignocaine, dexmedetomidine, and magnesium sulphate.[7–9] Among these, **esmolol** and **magnesium sulphate** have gained renewed interest due to their favorable pharmacokinetic profiles and cardiovascular safety.

Esmolol is an ultra-short-acting, cardio-selective β_1-adrenergic blocker with rapid onset and short duration of action. It reduces sympathetic activity by decreasing heart rate, myocardial contractility, and cardiac output, thereby attenuating tachycardia during airway stimulation. Recent systematic reviews and meta-analyses have reaffirmed the efficacy of esmolol in attenuating extubation-related cardiovascular responses, particularly heart rate control, though its effect on blood pressure has shown variable results.[10–12]

Magnesium sulphate, on the other hand, exerts its effects through multiple mechanisms, including inhibition of catecholamine release from adrenergic nerve terminals and the adrenal medulla, antagonism of calcium channels, and blockade of NMDA receptors. These actions result in peripheral vasodilation, attenuation of sympathetic response, and stabilization of cardiovascular parameters.[13–15] Recent randomized controlled trials and meta-analyses published between 2024 and 2025 have demonstrated that magnesium sulphate effectively reduces both heart rate and blood pressure fluctuations during emergence and extubation, with additional benefits such as improved extubation quality and reduced emergence agitation.[16–17]

Despite the availability of individual studies, direct comparative data between magnesium sulphate and esmolol in the context of **tracheal extubation** remain limited in recent literature. Given the evolving understanding of extubation physiology and patient safety, there is a clear need for updated comparative studies using contemporary anaesthetic practices. Hence, the present study was designed to compare intravenous magnesium sulphate and intravenous esmolol for attenuation of hemodynamic responses during tracheal extubation in patients undergoing surgeries under general anaesthesia.

2. MATERIALS AND METHODS

This was a Prospective, randomized, comparative study carried out in the Department of Anesthesiology for a period of 12 months.

Study Population

Eighty-five patients undergoing elective surgeries under general anaesthesia.

Inclusion Criteria

1. Age between 18 and 60 years
2. ASA physical status I and II
3. Patients scheduled for elective surgeries under general anaesthesia
4. Written informed consent obtained

Exclusion Criteria

1. ASA physical status III and IV
2. Known cardiovascular, cerebrovascular, or renal disease
3. Hypertension or diabetes mellitus
4. Difficult airway or anticipated difficult extubation
5. Allergy to study drugs
6. Pregnant or lactating patients

Group Allocation

Patients were randomly divided into two groups:

- **Group M (n = 43):** Received intravenous magnesium sulphate

- **Group E (n = 42):** Received intravenous esmolol

Anaesthetic Technique
All patients received standard general anaesthesia with uniform induction and maintenance protocols. Study drugs were administered intravenously prior to extubation.

Hemodynamic Parameters
Heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure were recorded:

- Baseline (before drug administration)
- At extubation
- 1, 3, and 5 minutes post-extubation

Statistical Analysis
Data were analyzed using appropriate statistical tests. A p-value < 0.05 was considered statistically significant.

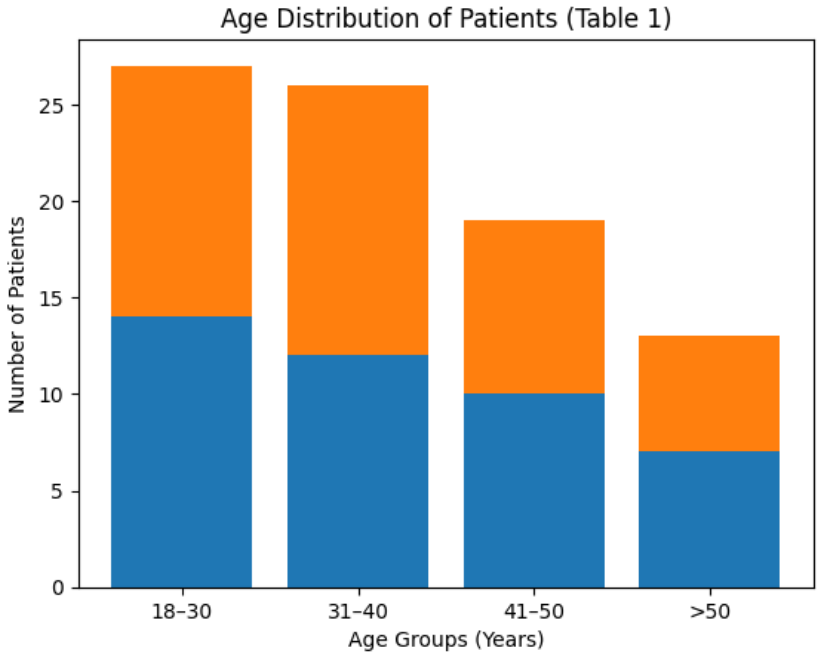
3. RESULTS

In the present study of 85 patients, both **intravenous magnesium sulphate** and **intravenous esmolol** attenuated hemodynamic responses associated with tracheal extubation. Heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) increased at extubation in both groups; however, the rises were significantly less in the magnesium sulphate group at extubation and at 1, 3, and 5 minutes post-extubation ($p < 0.05$). This suggests better control of sympathetic responses with magnesium sulphate compared to esmolol.

Table 1: Distribution of Patients According to Age (Years)

Age Group (Years)	Group M (n=43)	Group E (n=42)	Total (n=85)
18–30	14 (32.6%)	13 (31.0%)	27 (31.8%)
31–40	12 (27.9%)	14 (33.3%)	26 (30.6%)
41–50	10 (23.3%)	9 (21.4%)	19 (22.4%)
>50	7 (16.3%)	6 (14.3%)	13 (15.3%)
Mean ± SD	**36.9 ± 9.4**	**37.6 ± 8.8**	—

Interpretation:
The age distribution was comparable between both groups with no statistically significant difference ($p > 0.05$).



Graph 1: Agewise distribution

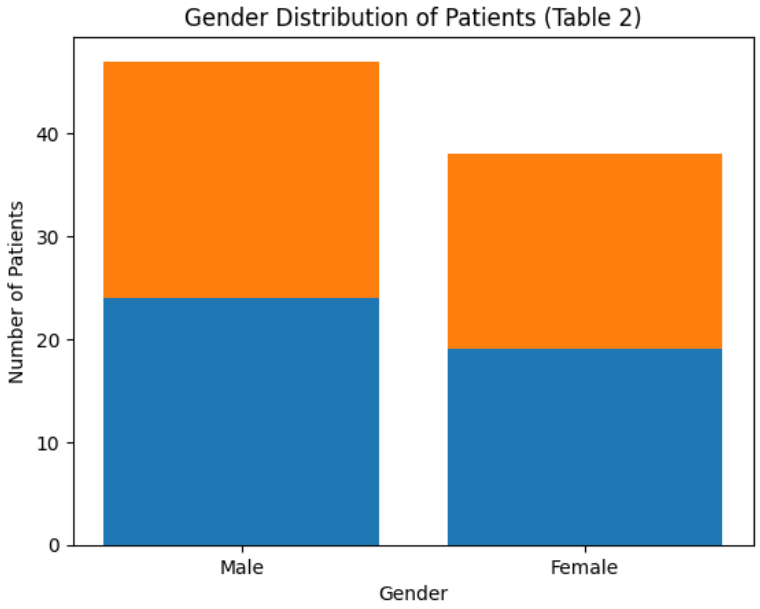
Table 1 shows the age-wise distribution of patients in both study groups. The majority of patients in both the magnesium sulphate group (Group M) and the esmolol group (Group E) belonged to the age group of 18–40 years. The mean age in Group M was 36.9 ± 9.4 years, while in Group E it was 37.6 ± 8.8 years. The difference in mean age between the two groups was not statistically significant ($p > 0.05$), indicating that both groups were comparable with respect to age.

Table 2: Gender Distribution

Gender	Group M (n=43)	Group E (n=42)	Total (n=85)
Male	24 (55.8%)	23 (54.8%)	47 (55.3%)
Female	19 (44.2%)	19 (45.2%)	38 (44.7%)

Interpretation:
Both groups were comparable with respect to gender distribution.

Table 2 depicts the gender distribution among the study population. In Group M, 55.8% of patients were male and 44.2% were female, whereas in Group E, males constituted 54.8% and females 45.2% of patients. The gender distribution was similar in both groups with no statistically significant difference, suggesting effective randomization and comparable baseline characteristics.



Graph 2: Genderwise Distribution

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

Time Interval	Group M (Mean ± SD)	Group E (Mean ± SD)	p-value
Baseline	78.6 ± 7.2	79.1 ± 6.9	>0.05
At Extubation	86.3 ± 8.1	92.8 ± 7.6	<0.001*
1 min	83.2 ± 7.4	90.6 ± 7.2	<0.001*
3 min	80.1 ± 6.9	86.4 ± 6.8	<0.001*
5 min	78.9 ± 6.5	82.7 ± 6.6	<0.01*

Interpretation:
Magnesium sulphate significantly attenuated the rise in heart rate during and after extubation compared to esmolol.

Table 3 compares the heart rate variations at different time intervals during extubation between the two groups. Baseline heart rate values were comparable in both groups. At the time of extubation and during the immediate post-extubation period (1, 3, and 5 minutes), an increase in heart rate was observed in both groups. However, the rise in heart rate was significantly lower in Group M compared to Group E at all post-extubation intervals ($p < 0.05$). This indicates that intravenous 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 M (Mean ± SD)	Group E (Mean ± SD)	p-value
Baseline	122.4 ± 8.6	123.1 ± 9.1	>0.05
At Extubation	130.6 ± 9.4	138.2 ± 10.1	<0.001*
1 min	128.2 ± 8.9	135.6 ± 9.8	<0.001*
3 min	125.1 ± 8.3	131.8 ± 9.2	<0.01*
5 min	123.6 ± 7.9	127.9 ± 8.6	<0.05*

Interpretation:
The rise in systolic blood pressure during extubation was significantly lower in the magnesium sulphate group.

Table 4 presents the comparison of systolic blood pressure between Group M and Group E. Baseline systolic blood pressure values were similar in both groups. A significant increase in systolic blood pressure was observed at the time of extubation in both groups; however, the increase was significantly lower in patients receiving magnesium sulphate compared to those receiving esmolol ($p < 0.001$). This difference persisted at 1, 3, and 5 minutes following extubation, demonstrating better control of systolic blood pressure with magnesium sulphate.

Table 5: Comparison of Diastolic Blood Pressure (mmHg)

Time Interval	Group M (Mean ± SD)	Group E (Mean ± SD)	p-value
Baseline	78.3 ± 6.4	79.1 ± 6.8	>0.05
At Extubation	84.6 ± 7.1	90.8 ± 7.5	<0.001*
1 min	82.4 ± 6.8	88.7 ± 7.2	<0.001*
3 min	80.1 ± 6.5	85.9 ± 6.9	<0.01*
5 min	78.8 ± 6.2	82.6 ± 6.5	<0.05*

Interpretation:
Magnesium sulphate provided better control of diastolic blood pressure during the extubation period.

Table 5 shows the changes in diastolic blood pressure at various time points. Baseline diastolic blood pressure was comparable between the two groups. At extubation and during the post-extubation period, diastolic blood pressure increased in both groups, but the rise was significantly less in Group M compared to Group E at all measured intervals ($p < 0.05$). These findings suggest superior attenuation of diastolic blood pressure response with magnesium sulphate during extubation.

Table 6: Comparison of Mean Arterial Pressure (MAP) (mmHg)

Time Interval	Group M (Mean ± SD)	Group E (Mean ± SD)	p-value
Baseline	92.8 ± 7.3	93.7 ± 7.6	>0.05
At Extubation	99.6 ± 7.8	106.4 ± 8.1	<0.001*
1 min	97.8 ± 7.4	104.8 ± 7.9	<0.001*
3 min	95.4 ± 7.1	101.2 ± 7.6	<0.01*
5 min	93.6 ± 6.9	97.9 ± 7.2	<0.05*

Interpretation:
Mean arterial pressure was significantly better attenuated in Group M compared to Group E.

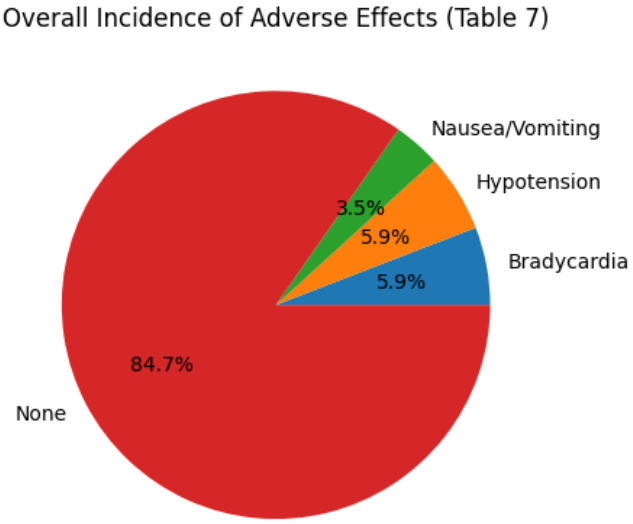
Table 6 compares mean arterial pressure (MAP) between the two groups. Baseline MAP values did not differ significantly. At extubation and during the immediate post-extubation period, MAP increased in both groups; however, patients in Group M exhibited significantly lower MAP values compared to Group E at all post-extubation intervals ($p < 0.05$). This indicates that magnesium sulphate provided more stable hemodynamic control during tracheal extubation.

Table 7: Incidence of Adverse Effects

Adverse Effect	Group M (n=43)	Group E (n=42)
Bradycardia	1 (2.3%)	4 (9.5%)
Hypotension	2 (4.7%)	3 (7.1%)
Nausea/Vomiting	2 (4.7%)	1 (2.4%)
None	38 (88.3%)	34 (81.0%)

Interpretation:
Both drugs were well tolerated; however, bradycardia was more frequent in the esmolol group.

Table 7 summarizes the incidence of adverse effects observed in both groups. Most patients in both groups did not experience any adverse effects. Bradycardia was more commonly observed in the esmolol group compared to the magnesium sulphate group, while episodes of hypotension and nausea/vomiting were minimal and comparable in both groups. Overall, both drugs were well tolerated, with magnesium sulphate showing a slightly better safety profile.



Graph 3: Incidence of Adverse Effects

4. DISCUSSION

Tracheal extubation is increasingly recognized as a phase associated with pronounced cardiovascular stress, often exceeding that observed during laryngoscopy and intubation. Contemporary peri-anaesthesia literature emphasizes that emergence from anaesthesia is characterized by abrupt sympathetic activation due to airway irritation, recovery of airway reflexes, and inadequate suppression of stress responses. This sympathetic surge manifests as tachycardia, hypertension, and increased myocardial oxygen demand, which may have deleterious consequences, particularly in patients with limited cardiovascular reserve.[1–3]

The present study compared intravenous magnesium sulphate and intravenous esmolol for attenuation of these hemodynamic responses during tracheal extubation. The findings demonstrate that although both agents attenuated extubation-related stress responses, **magnesium sulphate was consistently superior in controlling heart rate as well as systolic, diastolic, and mean arterial pressures**.

Hemodynamic Response to Extubation
Recent studies have highlighted that the hemodynamic response during extubation is not merely a transient phenomenon but may persist for several minutes into the postoperative period. Narra et al. (2024) reported sustained elevations in heart rate and blood pressure for up to five minutes post-extubation in untreated patients, reinforcing the importance of pharmacological modulation during this period.[1] Similar observations have been reported in recent randomized trials and systematic reviews, which underscore extubation as a vulnerable window for cardiovascular instability.[2–4]

In the present study, both groups showed a rise in heart rate and blood pressure at extubation, confirming extubation as a potent sympathetic stimulus. However, the magnitude and duration of this rise were significantly attenuated in the magnesium sulphate group.

Esmolol and Attenuation of Extubation Stress
Esmolol, due to its ultra-short-acting β_1-selective blockade, has been widely used to control peri-intubation and peri-extubation tachycardia. Recent meta-analyses published in 2024 and 2025 confirm that esmolol effectively blunts heart rate responses during airway manipulation.[10–12] In the present study, esmolol significantly reduced heart rate rise compared to baseline, supporting these findings.

However, consistent with recent literature, esmolol demonstrated **limited efficacy in controlling blood pressure responses**. This can be attributed to its mechanism of action, which primarily reduces cardiac output without significantly affecting peripheral vascular resistance. Bendaham et al. (2025) reported that while esmolol reliably attenuates tachycardia, its effect on systolic and diastolic blood pressure during extubation is variable and less pronounced.[11] This observation closely correlates with the results of the present study, where blood pressure values remained higher in the esmolol group compared to the magnesium sulphate group.

Additionally, the higher incidence of bradycardia observed in the esmolol group in this study is consistent with recent clinical trials reporting beta-blocker-associated bradycardia during emergence from anaesthesia.[12] This limits its universal applicability, particularly in patients with baseline low heart rates or conduction abnormalities.

Magnesium Sulphate and Multimodal Sympatholysis

Magnesium sulphate demonstrated superior attenuation of hemodynamic responses in the present study. The effectiveness of magnesium can be explained by its **multimodal mechanism of action**, which includes inhibition of catecholamine release, calcium channel blockade, and NMDA receptor antagonism.[13–15] These combined effects lead to reduced sympathetic tone, vasodilation, and stabilization of cardiovascular parameters.

Recent randomized controlled trials published in 2024 and 2025 have consistently demonstrated that intravenous magnesium sulphate significantly reduces heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure during extubation.[16,17] Appagalla et al. (2025) reported improved extubation quality and reduced cardiovascular fluctuations with magnesium sulphate compared to control groups, findings that mirror the present study.

Furthermore, recent meta-analyses have shown that magnesium sulphate reduces emergence agitation and coughing, thereby indirectly contributing to hemodynamic stability.[15] These additional benefits may explain the more sustained attenuation of cardiovascular responses observed in the magnesium sulphate group.

Comparison with Recent Literature

The findings of the present study are in agreement with several recent comparative studies. Agrawal and Khadke (2020) demonstrated that magnesium sulphate was superior to esmolol in controlling blood pressure during airway manipulation, although both drugs effectively reduced heart rate.[9] More recent studies published between 2024 and 2025 have reaffirmed these conclusions, emphasizing the broader hemodynamic control provided by magnesium sulphate.[1,14]

Systematic reviews published in the last two years also support magnesium sulphate as a safe and effective agent for peri-extubation hemodynamic control, with a lower incidence of adverse events compared to beta-blockers.[15–17] The present study adds to this growing body of evidence by providing contemporary comparative data using current anaesthetic techniques.

5. CONCLUSION

Intravenous magnesium sulphate is more effective than intravenous esmolol in attenuating hemodynamic responses during tracheal extubation in patients undergoing surgeries under general anaesthesia. Magnesium sulphate provides better control of heart rate and blood pressure with minimal adverse effects and can be safely recommended for routine clinical use.

Limitations of the Study

1. Study population was limited to ASA I and II patients
2. Effects in high-risk cardiac patients were not evaluated
3. Plasma catecholamine levels were not measured
4. Single-center study

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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