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Research Article

The effects of intravenous esmolol on hemodynamic response to endotracheal intubation and rocuronium onset time: A retrospective analysis

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ABSTRACT

Background: Airway instrumentation during induction can elicit acute sympathetic stimulation with transient cardiovascular fluctuations, particularly elevations in arterial blood pressure. Esmolol, an ultra–short-acting β_1-selective antagonist, is often administered peri-induction to blunt these peri-intubation responses. However, its effects on neuromuscular blockade onset in routine clinical practice remain insufficiently explored. This retrospective study evaluated the association between peri-induction intravenous esmolol administration, hemodynamic responses to endotracheal intubation, and the onset time of rocuronium-induced neuromuscular blockade.

Methods: We retrospectively reviewed anesthesia charts of adult patients (18–60 years) with ASA physical status I–II who underwent elective surgery. Patients were classified according to peri-induction esmolol use: an esmolol group receiving a single intravenous bolus of 0.5 mg/kg (500 µg/kg) administered over 1 minute, and a control group without beta-blocker administration (30 patients per group). Anesthesia induction was performed with thiopental, fentanyl, and rocuronium (0.6 mg/kg). Neuromuscular blockade onset time was defined as the time from rocuronium administration to Train-of-Four count 1. Hemodynamic parameters were recorded before and after endotracheal intubation, and intubation conditions were assessed using the Cooper scale.

Results: Demographic characteristics were comparable between groups. The time to Train-of-Four count 1 was significantly longer in the esmolol group compared with controls (129.9 ± 22.8 s vs. 88.5 ± 12.0 s, $p < 0.001$). Between-group differences in systolic and diastolic arterial pressure were observed at specific early peri-intubation time points but were not sustained thereafter. Intubation conditions were significantly better in the esmolol group, with a higher proportion of patients achieving excellent Cooper scale scores ($p < 0.05$).

Conclusions: Peri-induction intravenous esmolol was associated with modulation of early hemodynamic responses to endotracheal intubation and a delayed onset of rocuronium-induced neuromuscular blockade. These findings suggest that esmolol may influence both cardiovascular responses and neuromuscular block onset during anesthesia induction. Future prospective investigations are needed to better delineate the clinical significance and mechanistic basis of this observed association.

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1. Introduction

Endotracheal intubation is an essential component of general anesthesia, providing airway protection and controlled ventilation during surgery. Airway manipulation during induction of general anesthesia commonly triggers sympathetic activation, which may manifest as transient cardiovascular instability, particularly elevations in arterial blood pressure [1,2]. This response is typically characterized by transient increases in arterial blood pressure and other signs of cardiovascular stimulation and may occasionally be exaggerated despite adequate anesthetic depth [3]. Opioids and intravenous local anesthetics such as lidocaine are commonly administered during induction to attenuate this response [3–5]. Nevertheless, excessive hemodynamic reactions to intubation continue to be encountered in clinical practice, particularly in patients with limited cardiovascular reserve.

Esmolol is an ultra–short-acting β1-selective adrenergic antagonist that is frequently administered during anesthetic induction to modulate peri-intubation cardiovascular responses. In addition to its routine use for rhythm regulation, several studies have reported its effectiveness in suppressing the hemodynamic response associated with laryngoscopy and endotracheal intubation, similar to other beta-adrenergic antagonists [6,7]. However, data regarding its peri-induction effects in routine clinical settings remain limited.

Therefore, in this retrospective analysis, we aimed to evaluate the effects of a peri-induction intravenous esmolol bolus administered during induction of general anesthesia on the hemodynamic response to endotracheal intubation and on rocuronium onset time.

2. Materials and Methods

We performed a retrospective record-based study using routinely collected anesthesia data based on data derived from a specialty thesis performed between January 1, 2007, and January 1, 2008. At the time of data collection, formal ethics committee approval was not mandatory under national regulations. The data were obtained during routine clinical practice, with no additional interventions performed. Approval for the retrospective analysis and publication of anonymized patient data was subsequently obtained from the local Ethics Committee (Koşuyolu KAEK approval date: 20.05.2025; decision no: 2025/08/1112). Informed consent was waived by the Ethics Committee because of the retrospective nature of the study.

We extracted peri-induction variables from anesthesia charts of adult patients (18–60 years, ASA I–II) undergoing elective surgery. Patients with incomplete records were excluded, as were those with chronic medication use, anticipated difficult airway, morbid obesity, cardiovascular or central nervous system disease, neuromuscular disorders, diabetes mellitus, or hypovolemia

Patients were retrospectively classified according to the administration of esmolol during anesthesia induction as part of routine clinical practice. In the esmolol group, esmolol was administered according to the institutional protocol as a single intravenous bolus of 500 μg/kg delivered over 1 minute during anesthetic induction. No continuous esmolol infusion was used. The decision to administer esmolol was at the discretion of the attending anesthesiologist. Anesthesia induction in both groups was performed using thiopental (4–7 mg/kg) and fentanyl (1 μg/kg), followed by rocuronium (0.6 mg/kg) for neuromuscular blockade. Train-of-Four stimulation was applied at the ulnar nerve, with neuromuscular response measured at the adductor pollicis muscle.

The depth and onset of neuromuscular blockade were evaluated using peripheral nerve stimulation with Train-of-Four methodology. Arterial pressures (SAP, DAP, and MAP) were recorded at predefined time points before and after endotracheal intubation. Routine monitoring included pulse oximetry (SpO_2). Intubation conditions were evaluated using the Cooper scale.

2.1. Statistical analysis

Statistical evaluation was undertaken with NCSS 2007 (Kaysville, UT, USA). The distributional characteristics of continuous variables were examined using the Shapiro–Wilk test. When normality was supported, results were reported as mean ± SD and between-group comparisons were made with a two-sample t test. For variables deviating from normality, data were summarized as median (IQR) and assessed using the Mann–Whitney U test. Proportions were compared with the chi-square test, with Fisher's exact test applied when expected cell counts were small. Serial hemodynamic measurements obtained at predefined peri-intubation time points were analyzed using repeated-measures ANOVA. All tests were two-sided, and statistical significance was set at $p < 0.05$.

3. Results

A total of 60 patients were included in the analysis, with 30 patients in the esmolol group and 30 in the control group. Demographic characteristics and ASA physical status were comparable between groups, and no statistically significant differences were observed (Table 1).

The time to Train-of-Four count 1 was significantly longer in the esmolol group than in the control group (129.9 ± 22.8 s vs. 88.5 ± 12.0 s, $p < 0.001$) (Fig. 1).

To address potential selection bias related to clinician-directed esmolol administration, we compared pre-induction arterial blood pressure between groups. Baseline systolic and diastolic arterial pressures were comparable between the esmolol and control groups (Table 2), suggesting no evidence of higher baseline blood pressure–related risk in patients who received esmolol.

Baseline hemodynamic variables were comparable between groups. In between-group comparisons at each predefined time point, systolic arterial pressure differed significantly at post-induction, post-rocuronium, 1 min, and 3 min (all $p < 0.05$), whereas no significant difference was observed at baseline, immediately after intubation, or at 5 min. Diastolic arterial pressure differed significantly at post-rocuronium and 1 min ($p < 0.05$), while other time points were not significantly different (Table 2). Intubation conditions assessed by the Cooper scale were significantly better in the esmolol group, with a higher proportion of patients rated as having excellent intubation conditions compared with the control group ($p < 0.05$).

Table 1. Demographic characteristics and ASA physical status of the study groups.

	Esmolol group (n = 30)	Control group (n = 30)	p value
Age (years)	33.2 ± 10.1	33.7 ± 11.7	0.869
Body weight (kg)	72.7 ± 10.5	69.9 ± 8.3	0.257
Height (cm)	169.3 ± 7.7	167.1 ± 9.1	0.301
Body mass index (kg/m^2)	25.3 ± 2.6	25.0 ± 1.2	0.555
Sex (male/female)	17 / 13	15 / 15	0.605
ASA physical status (I / II)	22 / 8	22 / 8	0.872

Note: Data are presented as mean ± standard deviation or number of patients.

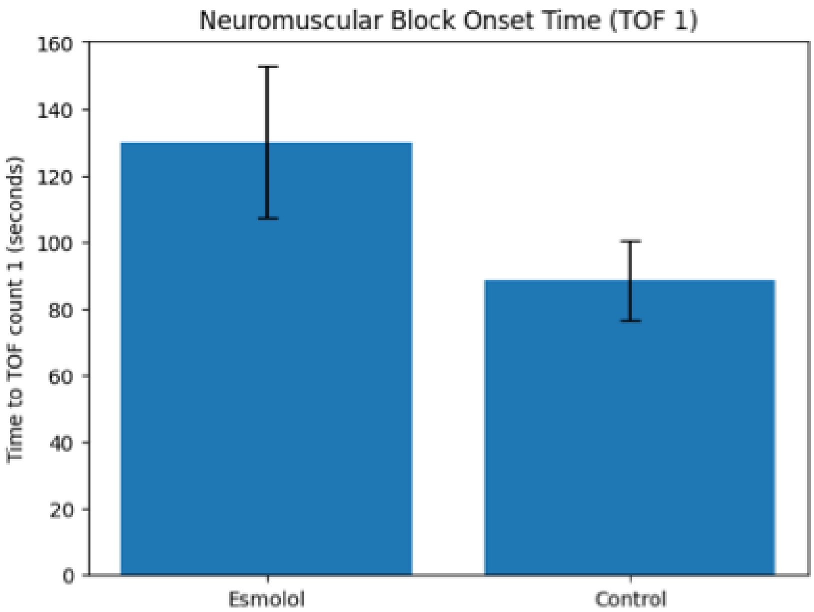

Fig. 1. Neuromuscular block onset time (TOF count 1) in the esmolol and control groups (bars represent mean values, and error bars indicate standard deviation).

Table 2. Hemodynamic parameters at predefined time points.

Time point	SAP (mmHg) esmolol	SAP control	p value	DAP (mmHg) esmolol	DAP control	p value
Baseline	126 ± 11	127 ± 12	0.737	78.8 ± 11.0	76.7 ± 10.0	0.442
Post-induction	112 ± 10	106 ± 11	0.031	75.3 ± 12.2	70.2 ± 13.4	0.128
Post-rocuronium	105 ± 11	116 ± 12	<0.001	69.3 ± 11.5	75.7 ± 10.8	0.030
Post-intubation	132 ± 13	138 ± 14	0.090	92.5 ± 14.1	85.3 ± 15.9	0.068
1 min	126 ± 12	112 ± 11	<0.001	92.7 ± 12.8	85.1 ± 12.1	0.021
3 min	130 ± 13	121 ± 12	0.007	78.0 ± 12.3	76.0 ± 16.5	0.596
5 min	112 ± 11	117 ± 12	0.097	75.4 ± 12.2	74.6 ± 13.2	0.808

Note: Values are presented as mean ± SD.

p-values represent between-group comparisons (Esmolol vs Control) at each predefined time point (two-sided independent-samples t-test).

4. Discussion

In this retrospective study, peri-induction administration of intravenous esmolol was associated with selective changes in early peri-intubation hemodynamics and neuromuscular block onset. Between-group differences in systolic and diastolic arterial pressure were confined to specific early time points around intubation and were not sustained later. Importantly, the time to Train-of-Four (TOF) count 1 after rocuronium administration was significantly longer in the esmolol group, indicating a delayed onset of neuromuscular blockade. While a 41-second delay in neuromuscular block onset is unlikely to be clinically relevant in elective cases, it may become more meaningful in rapid sequence induction scenarios, where rapid airway control is prioritized; nevertheless, this consideration remains theoretical, as our study was conducted under elective conditions. In addition, intubation conditions assessed by the Cooper scale were more favorable in patients receiving esmolol. A plausible explanation is that intubation conditions (e.g., coughing and laryngeal movement) may be influenced not only by the degree of neuromuscular block but also by the intensity of the sympathetic response to laryngoscopy; thus, β1-mediated attenuation of sympathetic activation and stress-related airway reactivity with esmolol might improve Cooper scores even when the onset of rocuronium is slower. However, because we did not measure anesthetic depth, airway reflex markers, or catecholamine levels, this mechanistic interpretation remains speculative. Together, these findings suggest that esmolol influences both early cardiovascular responses to intubation and the onset characteristics of rocuronium-induced neuromuscular blockade.

Several clinical studies have examined peri-induction esmolol in the context of airway instrumentation on the hemodynamic response to laryngoscopy and endotracheal intubation, and most have reported that esmolol effectively and most have reported that esmolol attenuates the magnitude of peri-intubation cardiovascular stimulation, particularly early surges in arterial blood pressure [4,6,7]. This effect is generally attributed to its rapid onset, short duration of action, and β1-selective blockade, making it suitable for use during the induction period. Similar hemodynamic attenuation has also been described with other agents commonly used during induction, such as opioids and intravenous lidocaine; however, these drugs may be associated with limitations related to respiratory depression, delayed recovery, or inconsistent efficacy. In line with the existing literature, our findings demonstrate that peri-induction esmolol administration is associated with modulation of the early hemodynamic response to endotracheal intubation, supporting its role as an effective adjunct for controlling intubation-related sympathetic activation [8,9].

An interesting finding of the present study was the prolongation of the time to TOF count 1 in patients receiving esmolol. To our knowledge, the effect of esmolol on the onset of nondepolarizing neuromuscular blockade has not been specifically investigated in previous studies, and available literature primarily focuses on its cardiovascular effects during induction [10,11]. Esmolol itself does not possess intrinsic muscle-relaxant properties, and the observed delay in neuromuscular block onset cannot be directly attributed to a neuromuscular mechanism. It is possible that alterations in early hemodynamics, such as reduced cardiac output or changes in muscle perfusion, may have influenced the distribution kinetics of rocuronium during the onset phase. Alternatively, a pharmacodynamic interaction cannot be excluded. However, given the retrospective design of this study and the absence of dedicated pharmacological or mechanistic data, these explanations remain speculative. Further prospective and experimental studies are required to clarify the relationship between beta-blockade and neuromuscular block onset [12,13].

This study has several limitations that should be acknowledged. First, its retrospective design limits causal interpretation of the observed associations and may be subject to selection bias. Pre-induction and peri-intubation heart rate measurements were not systematically recorded in this retrospective dataset; therefore, we could not evaluate the effect of esmolol on heart rate control or analyze heart rate variability. Second, the decision to administer esmolol was left to the discretion of the attending anesthesiologist, which may have introduced variability in patient selection and dosing. Third, neuromuscular blockade was evaluated using time to TOF count 1 only; therefore, conclusions regarding block depth, duration, or recovery cannot be drawn. In addition, detailed pharmacokinetic or pharmacodynamic data were not available, precluding mechanistic interpretation of the prolonged onset of neuromuscular blockade. Finally, the study was based on data derived from a single center and a limited sample size, which may restrict the generalizability of the findings.

5. Conclusions

In this retrospective analysis, peri-induction intravenous esmolol was associated with modulation of early hemodynamic responses to endotracheal intubation and a delayed onset of rocuronium-induced neuromuscular blockade. These effects were confined to the early peri-intubation period and were not sustained over time. Further prospective studies are needed to clarify the clinical significance and underlying mechanisms of these findings.

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Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

Data Availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author upon reasonable request.

AI Assistance

No AI-based tools were used in the preparation of this manuscript.

Ethics Approval and Consent to Participate

This study was conducted as a retrospective observational analysis based on data derived from a specialty thesis performed between 01.01.2007, and 01.01.2008. At the time of data collection, formal ethics committee approval was not mandatory under national regulations. The data were obtained during routine clinical practice, with no additional interventions performed. Approval for the retrospective analysis and publication of anonymized patient data was subsequently obtained from the local Ethics Committee (Koşuyolu KAEK Approval Date: 20.05.2025; Decision No: 2025/08/1112).

Author Contributions

Mustafa Simsek: *conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, supervision, writing – original draft, writing – review & editing.*
Elif Bombaci: *data curation, formal analysis, investigation, visualization, writing – original draft.*

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