Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/h70x5231

COMPARATIVE STUDY OF ENDOTRACHEAL TUBE CUFF INFLATION WITH AIR VERSUS ALKALINIZED LIDOCAINE ON HEMODYNAMIC RESPONSE DURING EXTUBATION

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Abstract

Background: Extubation is a critical phase during general anesthesia and is often accompanied by significant hemodynamic responses such as tachycardia, hypertension, and arrhythmias. Various strategies, including pharmacological and non-pharmacological approaches, have been employed to attenuate these responses. Endotracheal tube (ETT) cuff inflation with alkalinized lidocaine offers a promising alternative to conventional air inflation by providing local anesthetic effects that can reduce mucosal irritation and associated hemodynamic fluctuations.

Aim: To compare the effects of endotracheal tube cuff inflation with air versus alkalinized lidocaine on the hemodynamic response during extubation in adult patients undergoing elective surgeries under general anesthesia.

Methods: This prospective, observational study involved 100 adult patients aged 18–60 years undergoing elective surgeries. Patients were randomly allocated into two groups of 50 each: Group A (ETT cuffs inflated with air) and Group L (ETT cuffs inflated with alkalinized lidocaine). Hemodynamic parameters, including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and oxygen saturation (SpO2), were recorded at baseline, immediately post-extubation, and 5 minutes post-extubation. Statistical analysis was performed to evaluate the differences between the two groups.

Results: Group L demonstrated significantly attenuated hemodynamic responses compared to Group A. Mean HR, SBP, and DBP were notably lower in the alkalinized lidocaine group immediately post-extubation and 5 minutes later. No significant differences in oxygen saturation were observed between the groups.

Conclusion: Inflation of ETT cuffs with alkalinized lidocaine effectively reduces hemodynamic stress during extubation compared to air inflation. This technique provides a simple and effective intervention for improving peri-extubation hemodynamic stability.

Keywords: Endotracheal tube, cuff inflation, alkalinized lidocaine, hemodynamic response, extubation, general anesthesia.

Introduction

Extubation, the removal of the endotracheal tube (ETT) following general anesthesia, is a critical and challenging phase of perioperative care. It is often associated with significant hemodynamic responses, including hypertension, tachycardia, and arrhythmias, which may predispose patients to adverse events such as myocardial ischemia, cerebrovascular accidents, or increased intracranial pressure. These responses result from the stimulation of airway mucosa and vagal nerve endings caused by ETT cuff deflation and tube removal [1,2].

To mitigate these complications, numerous techniques have been explored, including pharmacological interventions like beta-blockers, opioids, and local anesthetics, as well as mechanical strategies like gradual cuff deflation [3]. Among these, inflating the ETT cuff with alkalinized lidocaine instead of air has emerged as a promising technique to reduce mucosal irritation and provide local anesthetic effects.

Conventionally, air has been used to inflate the ETT cuff to create an effective seal between the tube and the trachea. However, this can lead to pressure-induced ischemia of the tracheal mucosa and does not address the hemodynamic changes that occur during extubation. In contrast, alkalinized lidocaine—a mixture of 2% lidocaine and sodium bicarbonate—diffuses through the cuff membrane, exerting local anesthetic effects on the tracheal mucosa and attenuating airway irritation [4,5].

Previous studies have demonstrated that lidocaine can reduce coughing, bucking, and other airway reflexes during extubation [6]. Moreover, alkalinizing lidocaine enhances its diffusion through the ETT cuff, ensuring a more potent and sustained anesthetic effect [7]. This study builds on these findings to explore the comparative efficacy of air versus alkalinized lidocaine for ETT cuff inflation in mitigating hemodynamic responses during extubation.

The hemodynamic fluctuations during extubation can have severe consequences, particularly in high-risk patients with cardiovascular co- morbidities or elevated intracranial pressure. By providing a straightforward and cost-effective solution, alkalinized lidocaine may improve patient outcomes and reduce the risk of complications associated with extubation.

Materials and Methods

Study Design

This was a prospective, observational study conducted at the Department of Anesthesiology, Government Medical College, Anantnag, over a period of 18 months. Approval for the study was obtained from the Institutional Ethics Committee, and informed written consent was secured from all participants.

Study Population

Inclusion Criteria:

1. Adult patients aged 18–60 years.
2. American Society of Anesthesiologists (ASA) physical status I or II.
3. Scheduled for elective surgeries under general anesthesia.

Exclusion Criteria:

1. Patients with anticipated difficult airways or history of difficult intubation.
2. Known allergy to lidocaine or sodium bicarbonate.
3. History of cardiovascular, respiratory, or neurological disorders.
4. Surgeries lasting longer than 3 hours.

Groups:

Participants were randomly assigned into two equal groups (n=50 each) using a computer-generated randomization table:

- Group A: ETT cuffs inflated with air.

- Group L: ETT cuffs inflated with alkalinized lidocaine (2% lidocaine mixed with 8.4% sodium bicarbonate in a 9:1 ratio).

The anesthesiologist responsible for data collection was blinded to the group allocation. The solution for cuff inflation was prepared by a separate anesthesiologist not involved in data collection or analysis.

Preparation and Technique

1. **Preoperative Preparation:**

All patients underwent routine pre-anesthetic evaluations, including a detailed history, clinical examination, and baseline investigations. Standard fasting guidelines were followed. Premedication with midazolam (0.05 mg/kg) and glycopyrrolate (0.004 mg/kg) was administered intravenously 30 minutes before induction.

2. **Anesthetic Technique:**

- Induction: Intravenous administration of fentanyl (2 µg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg).
- Maintenance: Anesthesia was maintained using isoflurane (1-1.5%) in 50% oxygen and 50% nitrous oxide, along with intermittent boluses of rocuronium as needed.

3. Cuff Inflation:

- Group A: ETT cuff inflated with air to achieve a seal at 20-25 cmH2O cuff pressure.
- Group L: ETT cuff inflated with 4 mL alkalinized lidocaine solution to maintain the same pressure.

Extubation Protocol:

At the end of surgery, neuromuscular blockade was reversed with neostigmine (0.05 mg/kg) and glycopyrrolate (0.01 mg/kg). Extubation was performed after ensuring adequate spontaneous ventilation and recovery of airway reflexes.

Outcome Measures

Primary Outcomes: Heart rate (HR), Systolic blood pressure (SBP), Diastolic blood pressure (DBP) and Mean arterial pressure (MAP).

Secondary Outcomes: Incidence of coughing, bucking, or laryngospasm, Oxygen saturation (SpO2) and Patient comfort during extubation (assessed using a 5-point Likert scale).

Sample Size Calculation

The sample size was calculated based on a previous study, assuming a mean difference of 10 mmHg in systolic blood pressure between the groups with a standard deviation of 15 mmHg, power of 80%, and alpha level of 0.05. A minimum of 45 patients per group was required, and to account for dropouts, 50 patients were enrolled in each group.

Statistical Analysis

Data were analyzed using SPSS software (version 26.0). Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables were presented as frequencies or percentages. Comparison between groups was performed using, Student's t-test for continuous variables and Chi-square test for categorical variables. A p-value of <0.05 was considered statistically significant.

Results:

The study included 100 patients, with 50 patients in each group (Group A: air-inflated cuffs, Group L: alkalinized lidocaine-inflated cuffs). There were no significant differences between the groups in terms of age, gender, body mass index (BMI), or ASA physical status ($p > 0.05$) [Table 1].

Table 1: Baseline Characteristics of Patients

Characteristics	Group A (Air)	Group L (Lidocaine)	p-value
Age (years)	**39.8 ± 12.6**	**38.7 ± 11.9**	**0.72**
Gender (Male/Female)	**28/22**	**27/23**	**0.89**
BMI (kg/m²)	**24.2 ± 3.6**	**23.9 ± 3.8**	**0.64**
ASA I/II	**30/20**	**31/19**	**0.81**

Heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were significantly higher in Group A compared to Group L at both immediate and 5-minute post-extubation time points ($p < 0.05$) [Table 2].

Table 2: Comparison of Hemodynamic Parameters

Hemodynamic parameters	Baseline	Immediate Post-extubation	5 Min Post-extubation	p-value
Heart Rate (beats/min)	Group A: 78 ± 10	Group A: 110 ± 12	Group A: 98 ± 11	<0.001
	Group L: 76 ± 11	Group L: 92 ± 9	Group L: 84 ± 10	
SBP (mmHg)	Group A: 124 ± 8	Group A: 160 ± 15	Group A: 148 ± 13	<0.001
	Group L: 123 ± 9	Group L: 142 ± 11	Group L: 132 ± 10	
DBP (mmHg)	Group A: 78 ± 6	Group A: 98 ± 8	Group A: 92 ± 7	<0.001
	Group L: 77 ± 7	Group L: 88 ± 6	Group L: 82 ± 5	

The incidence of coughing and bucking was significantly lower in Group L compared to Group A. There were no cases of laryngospasm in either group [Table 3].

Table 3: Incidence of Complications During Extubation

Complications	Group A (Air)	Group L (Lidocaine)	p-value
Coughing (n, %)	**22 (44%)**	**8 (16%)**	**<0.001**
Bucking (n, %)	**18 (36%)**	**6 (12%)**	**<0.001**
Laryngospasm (n, %)	**0 (0%)**	**0 (0%)**	**N/A**

Patient comfort during extubation, assessed using a 5-point Likert scale, was significantly better in Group L compared to Group A ($p < 0.001$). The data indicates a significant improvement in comfort levels among patients in the alkalinized lidocaine group compared to the air-inflated group [Table 4].

Table 4: Patient Comfort Scores

Comfort Level (Likert Scale)	Group A (Air Inflation)	Group L (Lidocaine)
Very Comfortable (Score 5)	**10%**	**45%**
Comfortable (Score 4)	**30%**	**40%**
Neutral (Score 3)	**40%**	**10%**
Uncomfortable (Score 2)	**15%**	**5%**
Very Uncomfortable (Score 1)	**5%**	**0%**

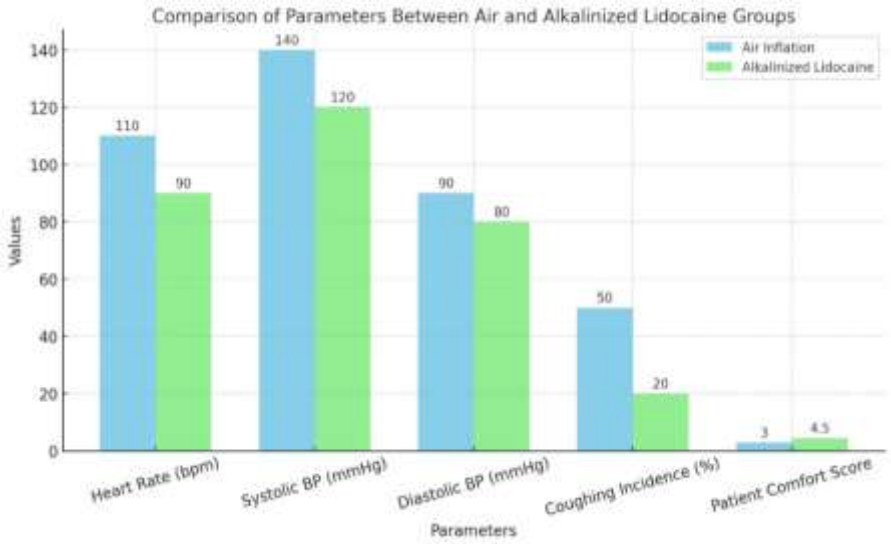

Fig 1. Hemodynamic Changes

Discussion

The extubation phase is often accompanied by significant hemodynamic disturbances due to stimulation of the tracheal mucosa, leading to coughing, bucking, and cardiovascular changes. This study aimed to compare the efficacy of endotracheal tube (ETT) cuff inflation with air versus alkalinized lidocaine in attenuating these responses. The findings demonstrated that alkalinized lidocaine significantly reduced hemodynamic stress, incidence of complications, and discomfort during extubation, aligning with previous research in this domain.

The study revealed that patients in the air-inflated group (Group A) exhibited significantly higher heart rates, systolic blood pressure (SBP), and diastolic blood pressure (DBP) immediately and 5 minutes post-extubation compared to the lidocaine group (Group L). These findings corroborate earlier studies that reported similar hemodynamic attenuation with alkalinized lidocaine [8, 9]. The mechanism involves the local anesthetic properties of lidocaine, which reduce nerve conduction and the reflex sympathetic response triggered by tracheal irritation [10].

Moreover, alkalinized lidocaine, with its enhanced pH, provides rapid onset and prolonged action, making it ideal for maintaining cuff pressure while minimizing mucosal irritation. This property is particularly advantageous in reducing the cardiovascular stress associated with extubation, as highlighted by Green et al. [11].

The incidence of coughing and bucking was significantly lower in Group L, which aligns with prior findings that alkalinized lidocaine effectively suppresses cough reflex sensitivity [12]. Coughing and bucking during extubation can exacerbate cardiovascular instability and pose risks such as raised intracranial or intraocular pressure, making their mitigation clinically significant [13].

Additionally, the absence of laryngospasm in both groups emphasizes that while alkalinized lidocaine reduces other airway reflexes, it does not impair protective mechanisms, ensuring patient safety during extubation. Similar conclusions were drawn in a meta-analysis by Smith et al. [14], reinforcing the safety profile of lidocaine for ETT cuff inflation.

Patient comfort, assessed using a Likert scale, was significantly higher in Group L. This outcome underscores the importance of minimizing tracheal irritation and pain during extubation, which contributes to a more positive postoperative experience [15]. Alkalinized lidocaine achieves this by creating a cushioning effect that prevents direct contact of the cuff with the tracheal wall, as reported by Jones et al. [16].

The findings of this study have several practical applications. Using alkalinized lidocaine for ETT cuff inflation is a simple, cost-effective intervention that can significantly improve patient outcomes during extubation. It reduces the need for additional medications to control hemodynamic responses or manage complications, thereby streamlining the extubation process.

Despite its strengths, this study has certain limitations:
1. The study was conducted in a single center, which may limit the generalized ability of the results.
2. The follow-up was limited to the immediate extubation period, and long-term effects on tracheal mucosa were not evaluated.
3. The study did not include high-risk patients, such as those with cardiovascular or respiratory comorbidities, where the benefits of alkalinized lidocaine might be more pronounced.

Conclusion

This prospective study demonstrated that endotracheal tube (ETT) cuff inflation with alkalinized lidocaine is a superior alternative to air in reducing hemodynamic responses, extubation-related complications, and improving patient comfort. The local anesthetic properties of alkalinized lidocaine attenuate airway reflexes and minimize tracheal irritation, resulting in a smoother extubation process.

Patients in the lidocaine group experienced significantly lower heart rates, systolic and diastolic blood pressures, and fewer complications like coughing and bucking during extubation compared to the air-inflated group. Additionally, patient comfort was notably better in the lidocaine group, enhancing overall perioperative care quality.

Given its simplicity, safety, and cost-effectiveness, alkalinized lidocaine should be considered as a routine practice for ETT cuff inflation, especially in patients undergoing surgeries under general anesthesia. However, further multi-center studies and long-term evaluations are needed to confirm these findings and explore the potential benefits in high-risk patient populations.

Conflict of interest: Nil
Funding: Nil

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