Haemodynamic and Recovery Characteristics in Conventional versus Sequential Extubation Using Sugammadex as a Reversal Agent: A Prospective Randomized Comparative Study

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Abstract Running Title: *Sequential versus conventional extubation with sugammadex*

Abstract: ***Background and Aims*****: *Extubation during emergence from general anaesthesia is associated with significant haemodynamic fluctuations and airway-related complications. Sequential extubation using a supraglottic airway device may attenuate these responses. This study compared haemodynamic and recovery characteristics between conventional extubation and sequential extubation using sugammadex for neuromuscular reversal. Methods: This prospective, randomized, comparative study involved 140 adult patients scheduled for elective surgery under general anaesthesia. Participants were randomly assigned to two equal groups: Group C, which received conventional tracheal extubation, and Group S, which underwent sequential extubation utilizing an I-gel supraglottic airway device. Haemodynamic parameters, that include heart rate (HR) and blood pressure (BP), were recorded at baseline and at 0, 5, 10, 15, and 30 minutes post-extubation. Recovery outcomes had been assessed with the help of the Modified Aldrete Score. Results: Sequential extubation was associated with significantly lower HR and mean arterial pressure (MAP) at all post-extubation time-points (P < 0.001). Group S demonstrated faster recovery with a shorter time to train-of-four ratio ≥0.9, shorter time to extubation, higher Modified Aldrete scores at post-anaesthesia care unit arrival, and shorter post-anaesthesia care unit stay duration. No cases of laryngospasm or severe desaturation were observed in the sequential extubation group. Conclusion: Sequential extubation using sugammadex was associated with improved haemodynamic stability, faster recovery, and fewer airway-related complications compared with conventional extubation.***

Keywords: Sugammadex; Airway Management; Tracheal Extubation; Laryngeal Masks; Haemodynamics; Recovery of Function

1. Introduction

Extubation is a crucial stage of general anaesthesia that is frequently accompanied by sympathetic nervous system activation and stimulation of airway reflexes. This process may lead to adverse physiological responses such as tachycardia, hypertension, coughing, bronchospasm, laryngospasm, and oxygen desaturation, especially in high-risk patients.[1-4] While considerable emphasis is placed on airway management during induction of anaesthesia, complications occurring during extubation continue to be a significant source of perioperative morbidity. [2,4]

Sequential extubation is a method wherein the endotracheal tube is replaced with a supraglottic airway device prior to the patient achieving complete recovery from anaesthesia. By reducing direct stimulation of the trachea, this method has the potential to attenuate airway reflex responses and promote greater haemodynamic stability during recovery.[5,8] Sugammadex enables rapid, reliable reversal of aminosteroid-induced neuromuscular blockade without the muscarinic side effects associated with traditional reversal agents, making it well suited for evaluating different extubation strategies.[6,7,9] The objective of the present study was to assess and compare haemodynamic responses and recovery outcomes following conventional extubation and sequential extubation using an I-gel airway device after reversal of neuromuscular blockade with sugammadex.

2. Methods

In this prospective, randomized, comparative study, adult patients between 18 and 65 who were scheduled for elective surgery under general anesthesia after Institutional Ethics

Committee approval (approval number withheld for blinded peer review) were studied. Before registration, each subject provided written informed permission. For six months, from November 25 to April 26, the study was carried out at a tertiary care facility.

By employing a computer-generated randomization sequence, 140 patients with "American Society of Anesthesiologists (ASA)" physical status I–II had been divided into two equal groups, Group C (traditional extubation) and Group S (sequential extubation), each consisting of 70 patients. Sequentially numbered, opaque envelopes were used to preserve allocation concealment.

Patients with significant cardiovascular, respiratory, renal, or neurological problems, a "body mass index (BMI)" of more than 30kg/m², a history of confirmed sugammadex hypersensitivity, or a predicted difficult airway were excluded.

General anaesthesia had been induced with intravenous propofol (2mg/kg) and fentanyl (2μg/kg). Neuromuscular blockade was attained using either rocuronium or vecuronium according to clinical requirements. Anaesthesia was maintained with volatile anaesthetic agents delivered in an oxygen–air mixture. Based on quantitative neuromuscular monitoring results, sugammadex (2–4 mg/kg) was given at the end of the procedure to reverse neuromuscular blockade.

In Group C, tracheal extubation was carried out conventionally once patients had regained adequate spontaneous ventilation and protective airway reflexes. In Group S, the endotracheal tube was replaced with an appropriately sized I-gel supraglottic airway device before emergence from anaesthesia. The I-gel was subsequently removed after full recovery of consciousness and airway protective reflexes.

Haemodynamic variables, that involve HR, systolic blood pressure (SBP), diastolic blood pressure (DBP), MAP, and peripheral oxygen saturation (SpO_2), had been recorded at baseline and at 0, 5, 10, 15, and 30 minutes following extubation. Recovery outcomes assessed included the Modified Aldrete Score upon arrival in the "post-anaesthesia care unit (PACU)", time required to achieve a Modified Aldrete Score of ≥9, duration of PACU stay, and the occurrence of peri-extubation adverse events.

The Shapiro-Wilk test for normality had been employed to evaluate the data distribution. The mean ± standard deviation (SD) had employed used to display continuous variables. Comparing groups with the help of independent-samples t-test and serial hemodynamic assessments with ANOVA were done where necessary. The Chi-square test analyzed categorical data. IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY, USA) was employed for statistical analyses. Statistical significance was a two-tailed P value below 0.05.

The sample size had been estimated using an expected 10% difference in mean arterial pressure between research groups with 80% statistical power and 95% confidence. According to the computation, each group needed at least 63 patients. Each group had 70 patients to account for attrition and procedure violations.

3. Results

Age, sex distribution, body mass index, ASA classification, and duration of surgery were among the baseline demographic traits that were similar amongst the groups.

Sequential extubation demonstrated significantly faster neuromuscular recovery. Time to achieve train-of-four ratio ≥0.9 and time to extubation were significantly shorter in Group S compared with Group C.

HR and MAP had been significantly lower in the sequential extubation group at all post-extubation time points. [Table 1, 2] Peak haemodynamic variability was attenuated in Group S, indicating smoother emergence from anaesthesia.

Recovery characteristics were significantly improved in Group S. Modified Aldrete score at post-anaesthesia care unit arrival was significantly higher, while time to achieve Modified Aldrete score ≥9 and post-anaesthesia care unit stay duration were significantly reduced. [Table3]

No cases of laryngospasm or severe desaturation were observed in Group S during the study period. Airway-related complications, including severe coughing and bronchospasm, were more frequent in Group C. [Table 4,5]

4. Discussion

The results of this study show that, in comparison to conventional tracheal extubation, sequential extubation employing an I-gel supraglottic airway device after restoration of neuromuscular blockade with sugammadex offers better recovery outcomes and increased hemodynamic stability.

Reduced activation of the tracheal and laryngeal reflexes during emergence from anaesthesia may be the cause of the sequential extubation group's lower hemodynamic fluctuations. By replacing the endotracheal tube with an I-gel before complete awakening, direct airway irritation is minimized, thereby attenuating sympathetic responses such as tachycardia and hypertension. Previous research on supraglottic airway exchange procedures has shown similar results, including smoother emergence, less coughing, and better patient comfort throughout recuperation.[5,14,16,17]

The favourable recovery characteristics observed in the sequential extubation group are clinically significant. Earlier achievement of satisfactory recovery scores and reduced post-anaesthesia care unit stay may enhance patient throughput and optimize resource utilization, particularly in high-volume surgical settings. In patients with cardiovascular disease, cerebrovascular pathology, or conditions where sudden blood pressure and heart rate rises may harm clinical results, reducing haemodynamic surges during emergence may be beneficial. [15, 20]

Sugammadex played an significant role in the study by providing rapid and reliable reversal of aminosteroid neuromuscular blockade. Unlike traditional reversal agents, sugammadex does not rely on anticholinesterase mechanisms and is not associated with cholinergic adverse effects, thereby allowing a more consistent assessment of extubation-related haemodynamic responses and recovery profiles. [6, 7, 9, 11, 18, 19]

Several limitations should be acknowledged. The study only included ASA physical status I–II patients, which may limit its applicability to higher-risk populations. Furthermore, the investigation had been performed at a single tertiary care institution and involved a heterogeneous range of surgical procedures, which may have introduced variability in perioperative responses. The success and safety of I-gel exchange are also influenced by operator experience; therefore, a learning-curve effect cannot be completely excluded. Additionally, the study focused on immediate postoperative outcomes, and longer-term clinical endpoints were not assessed.

To validate these results and clarify the function of sequential extubation techniques in modern anaesthetic practice, larger and more varied patient populations-especially those at elevated cardiovascular or neurological risk—should participate in future multicenter randomized controlled trials.

5. Conclusion

Sequential extubation using I-gel following sugammadex reversal was associated with improved haemodynamic stability, smoother recovery, and fewer airway-related complications compared with conventional extubation. The technique may represent a useful airway management strategy during emergence from general anaesthesia

Table 1: Comparison of Baseline Hemodynamic Parameters Between Conventional and Sequential Extubation Groups (n = 140).

Parameter	Conventional Extubation (n = 70)	Sequential Extubation (n = 70)	t-value	df	p-value
Heart Rate (bpm)	73.8 ± 3.255	71.6 ± 2.275	4.755	138	**<0.001**
SBP (mmHg)	124.7 ± 6.814	120.2 ± 4.198	4.660	138	**<0.001**
DBP (mmHg)	79.1 ± 4.679	76.7 ± 3.571	3.432	138	**<0.001**
MAP (mmHg)	94.2 ± 5.387	91.1 ± 3.907	3.916	138	**<0.001**
SpO_2 (%)	98.6 ± 0.490	98.7 ± 0.473	−0.702	138	**0.484**

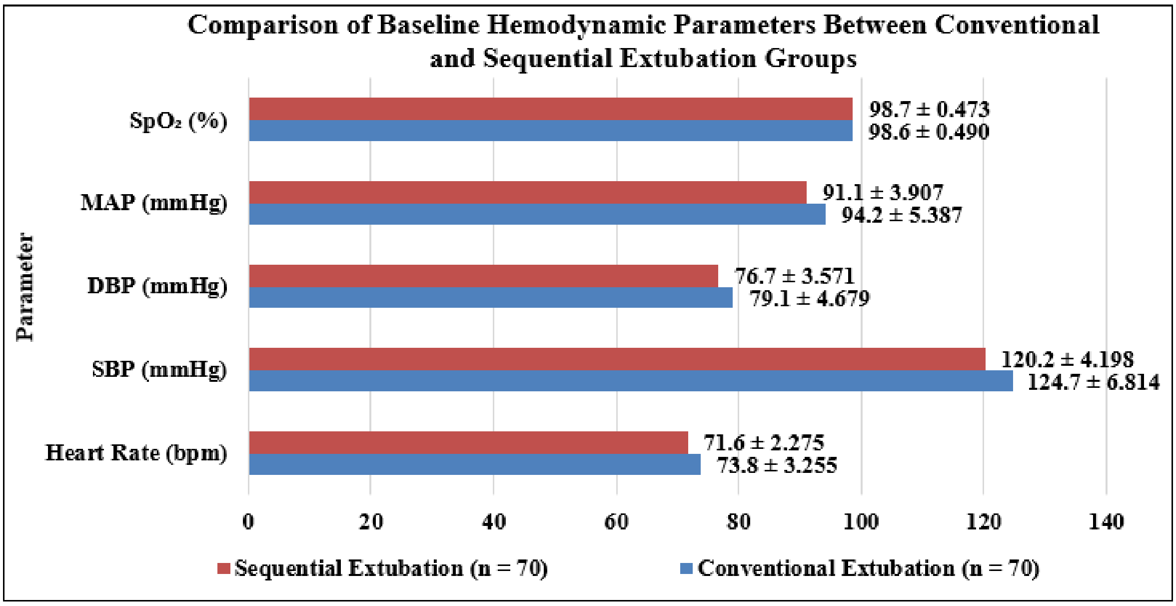


Table 2: Comparison of Hemodynamic Variability and Peak Hemodynamic Parameters Between Conventional and Sequential Extubation Groups (n = 140).

Parameter	Conventional Extubation (n = 70)	Sequential Extubation (n = 70)	t-value	df	p-value
ΔHR (Peak – Baseline) (bpm)	18.6 ± 3.36	11.69 ± 1.30	16.1	138	<0.001
Peak HR (within 30 min) (bpm)	101.9 ± 4.16	92.26 ± 2.59	16.4	138	<0.001
Peak MAP (within 30 min) (mmHg)	114.1 ± 4.17	103.80 ± 2.37	17.9	138	<0.001
ΔMAP (Peak – Baseline) (mmHg)	16.3 ± 3.01	9.67 ± 1.30	16.9	138	<0.001
SBP Variability (SD) (mmHg)	16.0 ± 1.74	11.54 ± 1.09	18.1	138	<0.001

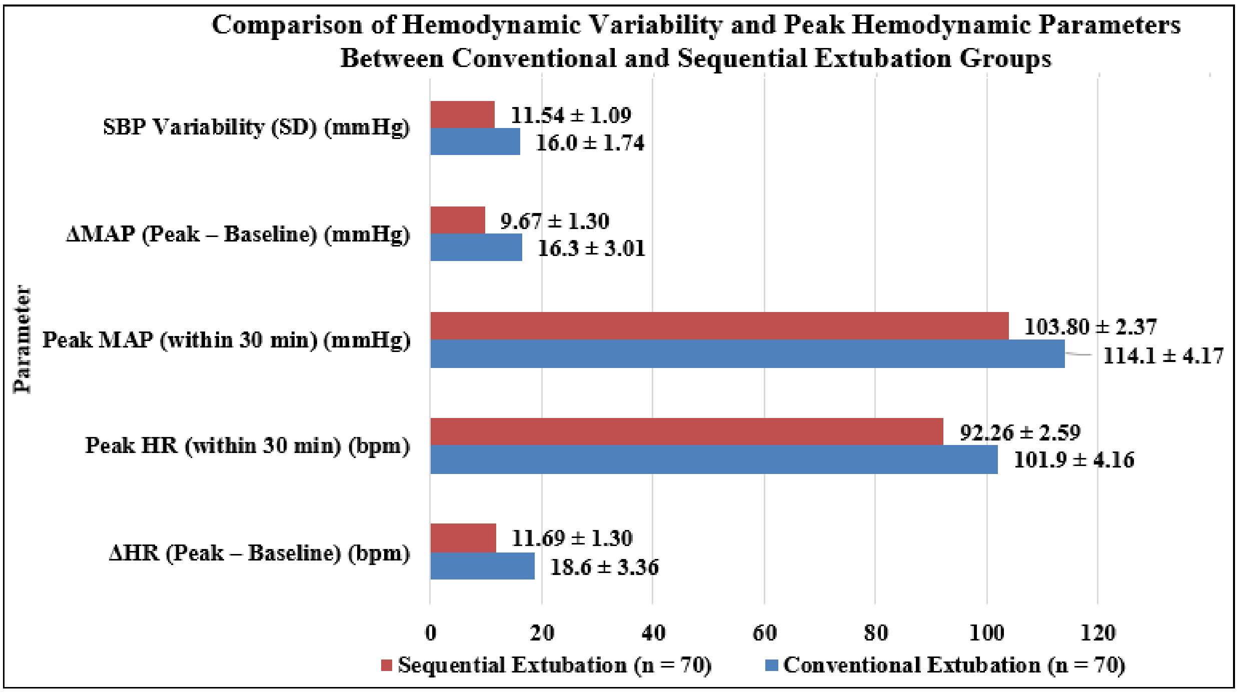


Table 3: Comparison of Recovery Characteristics Between Conventional and Sequential Extubation Groups (n = 140)

Parameter	Conventional Extubation (n = 70)	Sequential Extubation (n = 70)	t-value	df	p-value
Aldrete Score at PACU Arrival	8.49 ± 0.503	9.30 ± 0.462	−9.98	138	<0.001
Time to Achieve Aldrete Score ≥9 (minutes)	13.41 ± 1.592	7.64 ± 0.703	27.74	138	<0.001
PACU Stay Duration (minutes)	72.84 ± 7.099	53.51 ± 3.904	19.96	138	<0.001

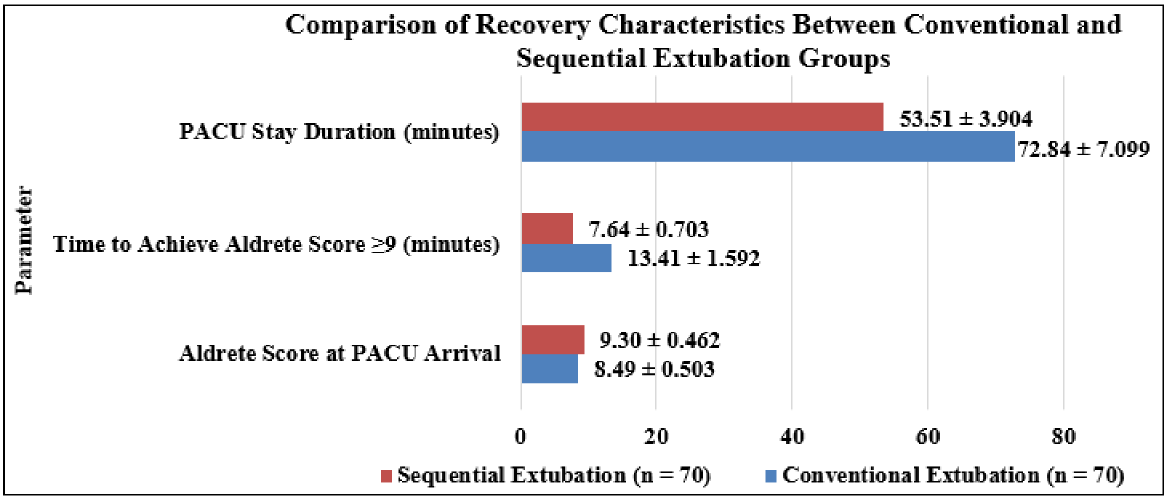


Table 4: Comparison of Airway-Related Postoperative Complications Between Conventional and Sequential Extubation Groups (n = 140)

Complication	Category	Conventional Extubation (n = 70)	Sequential Extubation (n = 70)	Total (n)	p-value
Coughing/Bucking	Mild	21 (30.0%)	45 (64.3%)	66	<0.001
	Moderate	28 (40.0%)	25 (35.7%)	53	
	Severe	21 (30.0%)	0 (0.0%)	21	
Laryngospasm	No	63 (90.0%)	70 (100%)	133	0.007
	Yes	7 (10.0%)	0 (0.0%)	7	
Desaturation (SpO_2 <90%)	No	42 (60.0%)	70 (100%)	112	<0.001
	Yes	28 (40.0%)	0 (0.0%)	28	

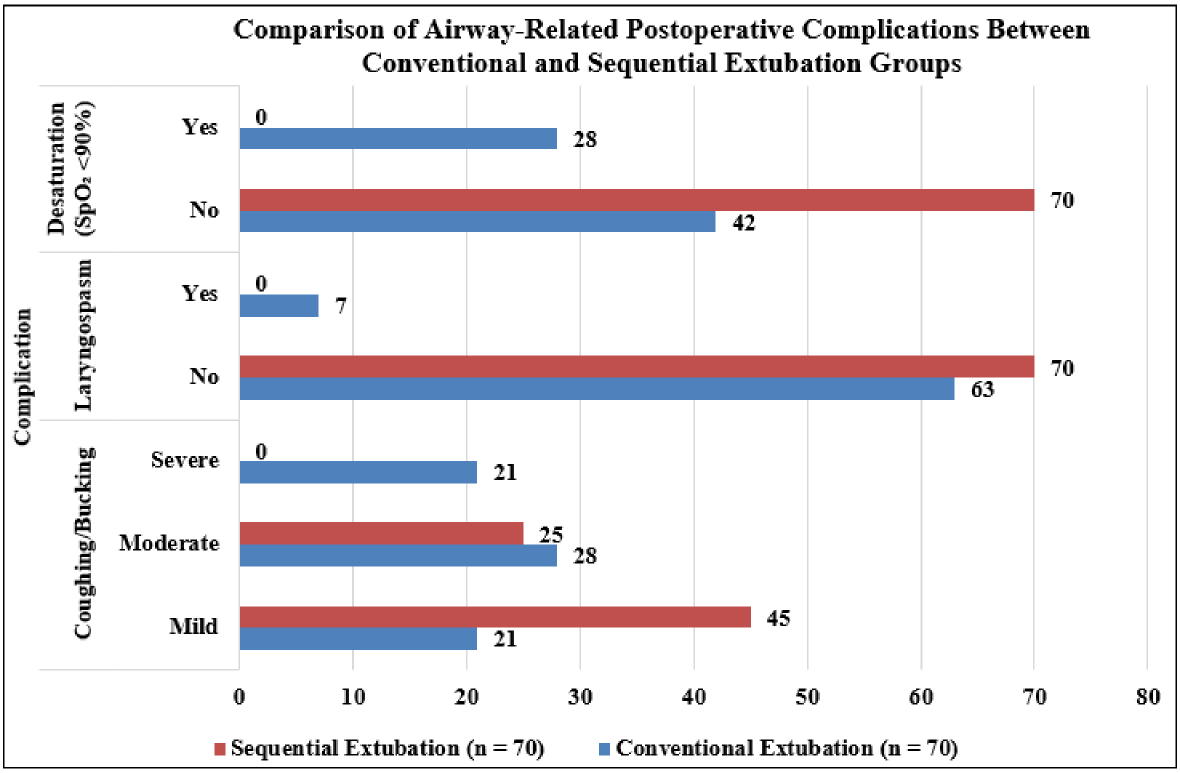
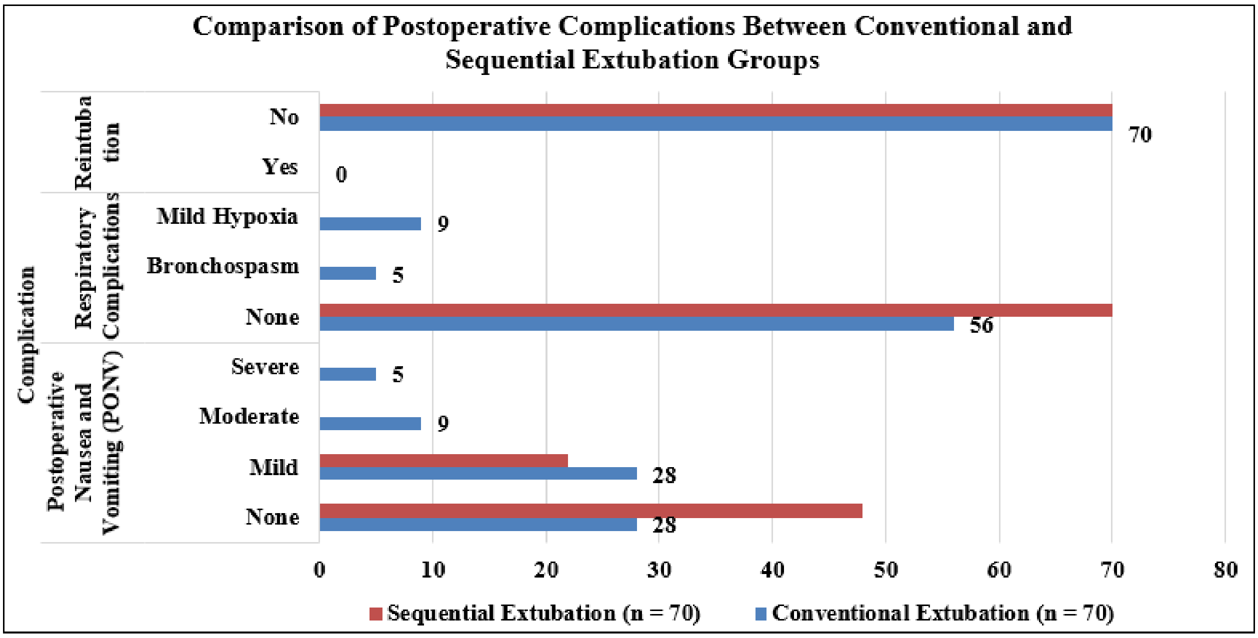


Table 5: Comparison of Postoperative Complications Between Conventional and Sequential Extubation Groups (n = 140)

Complication	Category	Conventional Extubation (n = 70)	Sequential Extubation (n = 70)	Total (n)	χ^2 value	df	p-value
Postoperative Nausea and Vomiting (PONV)	None	28 (40.0%)	48 (68.6%)	76	20.0	3	**<0.001**
	Mild	28 (40.0%)	22 (31.4%)	50			
	Moderate	9 (12.9%)	0 (0.0%)	9			
	Severe	5 (7.1%)	0 (0.0%)	5			
Respiratory Complications	None	56 (80.0%)	70 (100%)	126	15.6	2	**<0.001**
	Bronchospasm	5 (7.1%)	0 (0.0%)	5			
	Mild Hypoxia	9 (12.9%)	0 (0.0%)	9			



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