A randomised controlled study comparing the effects of laryngeal mask airway and endotracheal tube on early postoperative pulmonary functions

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ABSTRACT

Introduction: Classic laryngeal mask airway (LMA) has long been used for airway management. General anaesthesia has been associated with a significant decrease in pulmonary functions during the postoperative period. The decrease in pulmonary functions has been found to be greater with the use of a tracheal tube (TT). In this study, we compared the effects on pulmonary functions during the early postoperative period when the airway was managed using an LMA versus a TT.

Methods: A total of 20 patients in each group received either LMA or TT for airway management. Postoperative pulmonary functions were recorded at 30 and 60 minutes after removal of the airway device in patients undergoing peripheral limb surgeries. Forced vital capacity (FVC), forced expiratory volume during the first second (FEV_1), vital capacity, FEV_1/FVC, peak expiratory flow rate and percentage saturation of oxygenated haemoglobin were compared. Postoperative coughing and hoarseness were also recorded.

Results: Pulmonary functions were significantly decreased in both groups at 30 and 60 minutes postoperatively. The decrease in the TT group was significantly greater than that in the LMA group at both 30 and 60 minutes. The FEV_1/FVC was not significantly changed, indicating a restrictive pattern. Patients in the TT group had a significantly higher incidence of coughing at both 30 and 60 minutes.

Conclusion: The use of LMA instead of TT for airway management during peripheral limb surgeries causes less depression of pulmonary functions during the early postoperative period. The incidence of coughing is also significantly lower.

Keywords: classic laryngeal mask airway, early postoperative period, pulmonary functions, tracheal tube

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INTRODUCTION

The postoperative period is frequently associated with clinically important abnormalities of pulmonary function. Pasteur described lobar collapse of the lung after abdominal operations in his study.[1] The role of shallow breathing without periodic 'sighs' in producing hypoxaemia was identified by Haldane et al.[2] Beecher's report of reduced lung volumes after laparotomy stated attempts to quantitate changes in mechanical lung function following surgery.[3] Laryngeal mask airway (LMA) triggers lesser bronchoconstriction than the tracheal tube (TT) in paralysed anaesthetised patients.[4] Tracheal intubation causes a doubling of airway resistance in awake, healthy patients with topically anaesthetised airways.[5] Pulmonary airway resistance increases regardless of whether LMA or TT is used; however, the increase in resistance is lower with LMA. The early postoperative phase (within the first two hours), characterised by arterial hypoxaemia with or without alveolar hypoventilation, is followed by a second delayed phase in which mechanical abnormalities dominate, with accompanying arterial hypoxaemia.[3] During both phases, respiratory control may be impaired such that normal respiratory response to arterial hypoxaemia, hypercarbia or acidaemia is blunted or absent.[4] Pulmonary airway resistance for LMA includes glottic resistance (considered to be 33% of upper airway resistance in awake patients[6]), suggesting that the difference in the subglottic component of pulmonary resistance is even greater between LMA and TT.[3] A reversible component of respiratory system resistance is seen after TT placement, but not after LMA placement.[7] Furthermore, respiratory system resistance

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after TT placement is substantially higher than that after LMA placement. In this study, we compared the effect on pulmonary functions during the early postoperative period when the airway was being managed using an LMA versus a TT.

METHODS

Institutional review board approval was obtained for this study. This is a prospective, randomised study conducted on 40 male American Society of Anesthesiologists (ASA) physical status 1 patients aged 18–60 years, who were scheduled to undergo minor lower limb surgeries. Patients with a body mass index < 20 kg/m^2 or > 30 kg/m^2 as well as those whose surgeries were done in non-supine positions were excluded from the study. All patients had a normal airway.

A routine preoperative check-up, including physical examination, haematological and biochemical testings, chest radiograph and electrocardiogram, was performed in all the patients. Written, informed consent was obtained from all the patients, and they were randomly allocated to one of the two study groups by means of a computer-generated randomisation list (Microsoft Excel™ 7.0, Microsoft, Gurgaon, India). Power analysis was not performed due to inadequate published literature on this subject; however, the sample size was based on our pilot study. Allocation concealment was done using sealed envelopes. The groups were as follows: (1) LMA group (n = 20): appropriate size classic LMA was inserted using conventional technique; and (2) TT group (n = 20): appropriate size cuffed TT was inserted after laryngoscopy. All patients as well as the anaesthesiologist who recorded the pulmonary functions were blinded to the study groups.

Oral diazepam 5 mg was administered to all patients on the night before surgery. Baseline pulmonary functions were recorded in all patients preoperatively. The patients performed three manoeuvres of expiratory forced vital capacity (FVC) in the preoperative room in supine position. The manoeuvre with the best forced expiratory volume in the first second of expiration (FEV_1) was selected. Vital capacity (VC), FVC, FEV_1 and peak expiratory flow rate (PEFR) were recorded. The percentage saturation of oxygenated haemoglobin (SPO_2) was also recorded. Routine monitoring (SPO_2, electrocardiogram and non-invasive blood pressure) was instituted and each patient was given intravenous fentanyl 2 µg/kg. Anaesthesia was induced using intravenous propofol 2.5 mg/kg and oxygen, nitrous oxide, isoflurane with FiO_2 0.33. Intravenous rocuronium bromide 0.6 mg/kg was administered to facilitate muscle relaxation, and the neuromuscular blockade was monitored at the right ulnar nerve using a train-of-four (TOF) watch. Manual ventilation by appropriate size mask was performed until the TOF value became 0. Patients then received LMA/TT for airway management as per the random group allocated. After intubation or placement of the laryngeal mask, volume-controlled ventilation was provided and adjusted to maintain an end-tidal CO_2 pressure of approximately 4–4.7 kPa. A maximum peak pressure of 30 cmH_2O (25 cmH_2O LMA) was set. The cuff pressure was continuously adjusted to 30 cmH_2O (LMA 50 cmH_2O). Anaesthesia was maintained using oxygen, nitrous oxide, isoflurane 0.8% with FiO_2 0.33.

Top-up doses of intravenous rocuronium bromide 0.1 mg/kg were administered when the TOF watch showed more than two responses in the TOF. Intramuscular diclofenac sodium 1.5 mg/kg was administered deep in the gluteal region, and intravenous metoclopramide 0.1 mg/kg was given slowly 30 minutes before the anticipated completion of surgery. Isoflurane was discontinued ten minutes before the anticipated completion of surgical procedure. Atropine 0.02 mg/kg and neostigmine 0.05 mg/kg were given to reverse the neuromuscular block, and LMA or TT was removed at TOF > 0.90. The patients were then transferred to the postoperative unit while breathing room air during transport.

All patients received oxygen at FiO_2 0.3 in the post-anaesthesia care unit, and all measurements of pulmonary function test (PFT) and SPO_2 were conducted, with the patients breathing no supplemental oxygen for five minutes. 30 minutes and 60 minutes after extubation, the patients were required to repeat three expiratory FVC manoeuvres in the supine position and the parameters were recorded. In each patient, pre- and postoperative spirometry were performed by the same investigator, who was not involved in the anaesthetic procedure and was blinded regarding the randomisation group. Postoperative analgesia was provided using intramuscular ketorolac 30 mg/kg at Visual Analogue Score > 4. Patients who complained of pain or breathlessness during spirometry were excluded. Any change in the voice quality of the patients was noted as hoarseness, and any incidence of coughing was also noted. These secondary outcomes were assessed at 30 and 60 minutes postoperatively.

Data was expressed as mean ± standard deviation. Analysis was performed by unpaired *t*-test for parametric data, differences between the values before and after intervention (T0 & T1) in each group were tested by paired *t*-test. Differences in frequency were assessed

Table I. Patient data, comparison of preoperative pulmonary functions and duration of surgery.

Demographic	LMA	TT	p-value
Age ± SD (yrs)	29.75 ± 9.13	29.75 ± 7.39	1.00
Male gender (No.)	20	20	1.00
ASA I physical status (No.)	20	20	1.00
Weight ± SD (kg)	60.85 ± 6.71	59.55 ± 6.77	0.54
Height ± SD (cm)	165.05 ± 7.50	163.1 ± 7.08	0.40
BMI ± SD (kg/m^2)	22.30 ± 1.71	22.47 ± 1.76	0.76
VC ± SD (L)	2.99 ± 0.30	3.01 ± 0.32	0.82
FVC ± SD (L)	3.22 ± 0.13	3.29 ± 0.21	0.24
FEV_1 ± SD (L)	2.84 ± 0.15	2.81 ± 0.26	0.71
FEV_1/FVC ± SD (%)	0.86 ± 0.03	0.84 ± 0.03	0.13
PEFR ± SD (L/min)	360.0 ± 46.0	346.1 ± 32.77	0.27
SPO_2 ± SD (%)	98.85 ± 0.36	98.80 ± 0.41	0.68
Mean duration of surgery ± SD (min)	89.25 ± 11.38	90.50 ± 11.22	0.98

LMA: laryngeal mask airway; TT: tracheal tube; SD: standard deviation; BMI: body mass index; ASA: American Society of Anesthesiologists; VC: vital capacity; FVC: forced vital capacity; FEV_1: forced expiratory volume in 1st second of expiration; PEFR: peak expiratory flow rate; SPO_2: oxygen saturation

Table II. Comparison of mean depression of pulmonary functions after the removal of airway device.

Test (postop)	LMA	p-value	TT	p-value
VC ± SD (L)				
30 min	0.58 ± 0.22	0.00	0.96 ± 0.15	0.00
60 min	0.37 ± 0.11	0.00	0.66 ± 0.1	0.00
FVC ± SD (L)				
30 min	0.60 ± 0.12	0.00	0.91 ± 0.25	0.00
60 min	0.45 ± 0.11	0.00	0.66 ± 0.18	0.00
FEV_1 ± SD (L)				
30 min	0.76 ± 0.28	0.00	0.94 ± 0.23	0.00
60 min	0.55 ± 0.29	0.00	0.67 ± 0.21	0.00
FEV_1/FVC ± SD (%)				
30 min	0.03 ± 0.04	0.07	0.09 ± 0.02	0.08
60 min	0.07 ± 0.028	0.07	0.02 ± 0.03	0.08
PEFR ± SD (L/min)				
30 min	75.9 ± 24.0	0.00	113.7 ± 30.1	0.00
60 min	54.1 ± 17.23	0.00	81.7 ± 23.4	0.00
SPO_2 ± SD (%)				
30 min	0.50 ± 0.6	0.00	2.00 ± 0.97	0.00
60 min	0.40 ± 0.59	0.00	2.05 ± 2.21	0.00

LMA: laryngeal mask airway; TT: tracheal tube; SD: standard deviation; VC: vital capacity; FVC: forced vital capacity; FEV_1: forced expiratory volume in 1st second of expiration; PEFR: peak expiratory flow rate; SPO_2: oxygen saturation

using Chi-square comparison of means. Values were considered statistically significant at $p < 0.05$ and highly significant at $p < 0.01$.

RESULTS

The two study groups were comparable with regard to their demographic profiles and ASA physical statuses. All patients underwent varicose vein stripping. The mean duration of surgery was 89.25 ± 11.38 min in the LMA group and 90.50 ± 11.22 min in the TT group (Table I). Airway device was placed in a single attempt in all patients, and no laryngospasm was noted in any patient. Repositioning of the LMA was not required in any patient. No patient required supplemental analgesic and all patients were included in the statistical analysis.

The preoperative pulmonary functions were comparable in both groups (Table I). Comparison of the mean depression of PFTs 30 minutes after the removal of device showed significant decreases in both groups (Table II), except for FEV_1/FVC. The relative decrease was significantly lower in the LMA group (Table III). Comparison of the mean depression of PFTs 60 minutes after the removal of device showed significant decreases in both groups (Table II), except for FEV_1/FVC. The

relative decrease was significantly lower in the LMA group (Table III) at 60 minutes. The comparison of coughing and hoarseness showed a significantly lower incidence of coughing in LMA group (Table IV).

Table III. Comparison of relative depression of pulmonary functions between the groups.

Test (postop)	LMA	TT	p-value
VC ± SD (%)			
30 min	19.47 ± 6.43	32.37 ± 5.77	0.000
60 min	12.53 ± 3.20	22.40 ± 7.50	0.000
FVC ± SD (%)			
30 min	18.76 ± 3.60	27.59 ± 7.31	0.000
60 min	14.01 ± 3.36	19.60 ± 6.27	0.001
FEV_1 ± SD (%)			
30 min	26.66 ± 8.36	33.42 ± 6.80	0.008
60 min	19.00 ± 9.15	24.05 ± 7.07	0.048
FEV_1/FVC ± SD (%)			
30 min	8.37 ± 6.04	6.93 ± 5.74	0.442
60 min	4.15 ± 6.85	4.57 ± 4.85	0.827
PEFR ± SD (%)			
30 min	21.06 ± 6.28	32.68 ± 7.37	0.000
60 min	14.91 ± 4.10	23.47 ± 5.72	0.000
SPO_2 ± SD (%)			
30 min	0.50 ± 0.69	2.02 ± 0.98	0.000
60 min	0.40 ± 0.60	2.07 ± 2.25	0.003

LMA: laryngeal mask airway; TT: tracheal tube; SD: standard deviation; VC: vital capacity; FVC: forced vital capacity; FEV_1: forced expiratory volume in 1st second of expiration; PEFR: peak expiratory flow rate; SPO_2: oxygen saturation

Table IV. Comparison of postoperative coughing and hoarseness in patients after the removal of airway devices at 30 and 60 minutes.

	No. of patients		p-value
	LMA	TT	
Coughing			
30 min	0	5	0.047
60 min	0	5	0.047
Hoarseness			
30 min	3	7	0.273
60 min	3	7	0.273

DISCUSSION

It has been reported that LMA triggers less bronchoconstriction in paralysed anaesthetised patients than TT.[3] Tracheal intubation has been found to cause a doubling of airway resistance in awake healthy patients with topically anaesthetised airways.[5] Pulmonary airway resistance increased regardless of whether LMA or TT was used; however, the increase in resistance was lower with LMA. Sackner et al found a 37% decrease in mucociliary clearance after one hour with cuffed TT, but no change was seen with an uncuffed TT.[8] These findings also correspond well to those of Trawöger et al,[9] who showed that a new TT with a no-pressure seal positioned at the level of the glottis did not impede mucociliary clearance after three hours of intubation, but it declined by 67% with the standard TT. The above studies, which indicate that LMA impedes mucociliary clearance less than TT in anaesthetised patients, may have implications for reducing the risk of retention of secretions, atelectasis and pulmonary infections, ultimately leading to impairment of pulmonary functions in the postoperative period.

Our results show that while the PFTs were decreased significantly at both 30 and 60 minutes following removal of the airway device, the decrease was significantly lower in the LMA group. However, FEV_1/FVC remained unaltered at both 30 and 60 minutes after the removal of both the LMA and TT, indicating a restrictive pattern of pulmonary dysfunction. The restrictive pattern is consistent with the finding of other studies.[10-12] This occurred because FVC and FEV_1 both decreased, thereby causing the ratio to remain relatively unchanged. A recent retrospective analysis reported that both coughing and hoarseness of voice are more common with TT.[13] In our study, there was significantly less coughing in the LMA group; however, the difference in postoperative hoarseness was insignificant at the end of the 60-minute study period. Our study evaluated the pulmonary functions in ASA physical status 1 patients only, and the sample size for hoarseness may have been inadequate. In addition, as we compared the pulmonary functions for up to 60 minutes after the removal of airway devices, patient-centric parameters, such as length of hospital stay, need for supplemental oxygen, postoperative pulmonary complications and time till normalising of pulmonary functions, were not studied.

In conclusion, the use of LMA for peripheral limb surgeries is associated with significantly less depression of pulmonary functions when compared to the use of TT. Moreover, the incidence of coughing is also significantly lower with LMA. Therefore, LMA is a better alternative for airway management for peripheral limb surgeries, as there is less depression of pulmonary functions during the early postoperative period. This study was conducted only in ASA physical status 1 patients with normal pulmonary functions; thus, further studies are required to establish its usefulness in patients with co-existing pulmonary dysfunctions.

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