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ORIGINAL

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The use of the laryngeal mask airway as an alternative to the endotracheal tube during percutaneous dilatational tracheostomy

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Abstract *Objective*: To evaluate the safety and efficiency of the use of the laryngeal mask airway (LMA) during percutaneous dilatational tracheostomy under bronchoscopic guidance comparing with the ventilation via endotracheal tube (ET). *Design and setting*: Prospective, randomized clinical trial in the eight-bed general intensive care unit of a university hospital. *Patients*: 60 consecutive adult critically ill patients who required elective tracheostomy for a period of 12 months. *Interventions*: Patients were randomly assigned to ventilated via LMA (*n*=30 patients), and to ventilated via ET (*n*=30). *Measurements and results*: Blood samples for arterial blood gas analyses were taken before the procedure (first value) and just before the insertion of tracheostomy tube (second value). There was no significant difference in pH, PaO_2, or $PaCO_2$ between groups before the procedure. The operating time was significantly shorter in LMA group (4.5±0.8 min versus 5.9±1.4 min). Although the second $PaCO_2$ values were higher than the first in both groups, the rise in was significantly higher in ET group (6.8±3.5 mmHg vs. 4.5±2.4 mmHg). Hypercarbia was noted in 10 patients (38.5%) in the LMA group and 17 (56.7%) in the ET group. The decrease in pH related to hypercarbia was noted in both groups, but it was more significant in the ET group ($p<0.05$). *Conclusion*: LMA is an effective and successful ventilatory device during percutaneous dilatational tracheostomy. It improves visualization of the trachea and larynx during fiberoptic-assisted percutaneous dilatational tracheostomy and prevents the difficulties associated with the use of ET such as cuff puncture, tube transection by the needle, and accidental extubation. The use of a bronchoscope and the puncture of the ET cuff cause major increases in $PaCO_2$.

Keywords Laryngeal mask airway · Percutaneous tracheostomy · Hypercarbia · Bronchoscope

Introduction

Percutaneous dilatational tracheostomy (PDT) is considered a superior alternative to the traditional open approach because of the low complication rate, ease of bedside insertion, and cost-effectiveness [1, 2]. PDT has become a common procedure for insertion of tracheostomy tube in the intensive care unit (ICU). Almost all patients who require tracheostomy are intubated and ventilated mechanically via an endotracheal tube during PDT. This procedure involves insertion of a needle and guide wire into the trachea followed by progressive or one-step dilatation of the resultant tract and placement of a tracheostomy tube [3]. Before insertion of the needle into the trachea the endotracheal tube cuff is deflated and withdrawn so that the cuff is just seen at the vocal cords. Failure to place the endotracheal tube correctly may result in cuff puncture, tube transection by the needle, or

Table 1 Clinical and respiratory characteristics of the patients before the procedure (*ARF* acute respiratory failure, *COPD* chronic obstructive pulmonary disease, *BGA* arterial blood gas analysis, *PaO_2* arterial oxygen tension, *FIO_2* fractional inspired oxygen concentration, *PEEP* positive end-expiratory pressure, *ET* endotracheal tube)

	LMA group (*n*=26)	ET group (*n*=30)	*P*
Age (years)	42.1±22.4 (17–84)	47.1±15.0 (18–74)	0.30[a]
Male/female	2.7/1.0	2.0/1.0	0.60[b]
Diagnosis			
Head injury	8 (30.8%)	7 (23.3%)	
Neurological disease	6 (23.1%)	9 (30.0%)	
Multitrauma	5 (19.2%)	3 (10.0%)	0.76[b]
Sepsis and ARF	4 (15.4%)	7 (23.3%)	
COPD	3 (11.5%)	4 (13.3%)	
BGA and ventilation parameters			
pH	7.45±0.05	7.43±0.06	0.10[c]
$PaCO_2$	35.3±6.5	35.9±4.2	0.70[c]
PaO_2/FIO_2	324.5±105.5	348.5±96.5	0.37[c]
Tidal volume (ml/kg)	8.6±1.5	8.9±1.8	0.18[c]
PEEP (cmH_2O)	6.6±0.8	6.9±1.3	0.29[c]
Plateau pressure (cmH_2O)	22.9±2.5	23.2±2.7	0.62[c]
Length of ET (days)	7.1±3.2 (2–13)	6.0±2.4 (1–11)	0.10[c]

[a] Mann-Whitney *U* test
[b] χ^2 test
[c] Student's *t* test with analysis of variance

accidental extubation, causing loss of the airway [4]. We hypothesized that the use of the laryngeal mask airway (LMA), which has become popular in anesthetic practice, could avoid some of difficulties associated with the use of endotracheal tube and improve visualization of the trachea and larynx during fiberoptic-assisted PDT. There are few studies on the use of LMA during PDT. However, in these studies blood gas analyses (BGA) were not performed to evaluate the safety and effectiveness of this method [4, 5]. The aim of this study was to assess whether the LMA is a suitable alternative method for airway management during PDT compared to ventilation via an endotracheal tube (ET).

Materials and Methods

Patients

We prospectively studied 60 consecutive critically ill adults who required elective tracheostomy during a 12-month period in our ICU. The study was approved by the ethics committee of the Akdeniz University of Antalya, and informed written assent was obtained from relatives of all patients. The two main indications for tracheostomy were prolonged endotracheal intubation and inability to protect the airway in neurologically impaired patients. All patients were initially intubated and mechanically ventilated. The patients were randomly allocated to two groups: the LMA group (*n*=30) and the ET group (*n*=30). Exclusion criteria for using a LMA included: difficult tracheal intubation, suspected pathology of the pharynx, recent local radiation of the upper airway, and significant infection of the upper airway (e.g., epiglottitis) [6]. Table 1 presents the demographic data for both groups. There were no significant differences between the two groups in terms of age, sex, or length of the endotracheal intubation before PDT. There were also no significant differences in respiratory status, pH, PaO_2/FIO_2, or $PaCO_2$ between the groups before the procedure.

Preparation and technique

Before the procedure the oropharynx was disinfected by 0.9% NaCl containing solution of povidone-iodine 10%. The nasogastric tubes of the patients were suctioned and left in place during the procedure. The inspired oxygen concentration was increased to 100%. All procedures were carried out at the bedside on the ICU under bronchoscopic guidance (a 5-mm-diameter flexible fiberoptic bronchoscope). Oxygen saturation was monitored by pulse oximetry. BGA were collected just before the incision of the skin (first value) and the insertion of the tracheostomy tube (second value).

The LMA was inserted successfully in 26 of the patients in the LMA group after their endotracheal tubes were removed. If ventilation was satisfactory, as judged by adequate chest movement and exhaled tidal volume, minimal air leak and stable vital signs, PDT was performed with the LMA alone. Thirty patients were ventilated via ET during the procedure. In this group the cuff of the ET was deflated and was withdrawn slowly to lie just below the level of the vocal cords while ventilation was discontinued. Then the cuff was reinflated enough to achieve the original tidal volume.

All patients were positioned with the neck extended over a pillow. The neck and upper shoulders were cleaned with the solution of povidone-iodine 10%, and the operation area was draped. The sternal notch, thyroid, and cricoid cartilages were identified. Anesthesia was provided by injection of 5 ml lignocaine 1% containing 1:10,000 adrenaline. All of the patients were sedated with midazolam and paralyzed with a nondepolarizing neuromuscular blocking agent. A 1- to 2-cm incision was made over the estimated level of the first and second or second and third tracheal ring, and the insertion of the needle and guide wire was visualized by the bronchoscope. PDT was performed by the means of the Portex percutaneous tracheostomy kit, which allows a one-step dilatation of the anterior tracheal wall using a set of forceps. The position of the tracheostomy tube was confirmed by physical and bronchoscopic examination, end-tidal CO_2, chest radiography, and arterial blood gas measurement.

Statistics

Statistical analysis used Student's *t* test, paired *t* test, χ^2 test, and repeated-measures analysis of variance. All data are presented as mean ±SD, and statistical significance was considered at $p<0.05$.

Table 2 The changes in pH, PaO_2, and $PaCO_2$ during the procedure and the rates of complications (*PDT* percutaneous dilatational tracheostomy)

	LMA group (*n*=26)	ET group (*n*=30)	*P*
PDT time (min)	4.5±0.8	5.9±1.4	0.001[a]
Decrease in pH	0.04	0.06	0.04[b]
Rise in $PaCO_2$ (mmHg)	4.5±2.4	6.8±3.9	0.01[b]
Patients with hypercarbia ($PaCO_2$>40 mmHg)	10 (38.5%)	17 (56.7%)	0.28[c]
Decrease in PaO_2 (mmHg)	18.6±24.4	24.2±20.8	0.42[b]
Patients desaturated (SaO_2<96%)	–	–	
Complications			
ET cuff puncture	–	3 (10.0%)	
Difficult insertion of tracheostomy tube	–	2 (6.7%)	
Accidental extubation	–	1 (3.3%)	
Tracheal stenosis	1 (3.8%)	1 (3.3%)	
Bleeding	1 (3.8%)	1 (3.3%)	
Total complication rate	2 (7.7%)	8 (26.7%)	0.09[c]

[a] Student's *t* test with analysis of variance
[b] Repeated measures analysis of variance
[c] χ^2 test

Results

The mean operation time for PDT (from incision of the skin to insertion of tracheostomy tube) was significantly shorter in the LMA group (4.5±0.8 vs. 5.9±1.4 min, $p<0.001$; Table 2). The mean values of the second PaO_2 were not significantly different from the mean values of the first in either groups. Figure 1 demonstrates that the second $PaCO_2$ values were significantly higher than the first in both groups ($p<0.001$), and that the rise in $PaCO_2$ was significantly higher in the ET group (6.8±3.9 mmHg vs. 4.5±2.4 mmHg, $p<0.01$). The decrease in pH related to hypercarbia was noted in both group, but it was more significant in the ET group (Fig. 2; $p<0.05$). Hypercarbia was noted in 10 patients (38.5%) in the LMA group and 17 (56.7%) in the ET group (n.s.). None of the patients became desaturated in either group.

Tracheostomy tube placement was successful in all patients, and none of the patients in the PDT needed conversion to surgical tracheostomy. The LMA were not able to be inserted in two patients (6.7%), and these were excluded from the study. The other complications seen in the LMA group were tracheal stenosis in one patient (3.8%) and bleeding in another. Aspiration of gastric contents was not observed in this group. The complications in the ET group were puncture of the ET cuff in three patients (10.0%), difficulty at the insertion of tracheostomy tube in two (6.7%), and accidental extubation (3.3%), tracheal stenosis, and bleeding in one patient each (Table 2). Tracheal stenosis was diagnosed by endoscopic examination in two patients who demonstrated significant clinical symptoms of airway obstruction after a few weeks of decannulation. Severe partial narrowing of the subglottic area (<8 mm in diameter) was shown in these cases and required surgical correction including insertion of costa-cartilage graft or intraluminal stent after the failure of multiple endoscopic repairs. Clinically significant bleeding was managed successfully with digital compression. During two procedures in the ET group the fiberoptic bronchoscope was damaged by the needle because of the failure adequately to withdraw the bronchoscope. There was no guide malposition, pneumothorax, or death related to either technique.

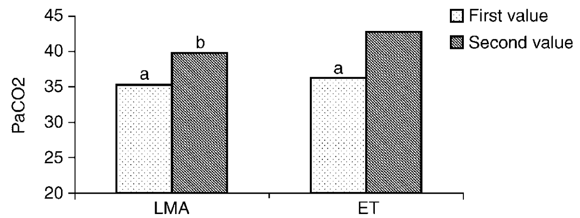

Fig. 1 The $PaCO_2$ values before the procedure (*first value*) and before the insertion of tracheostomy tube (*second value*). [a]$p<0.001$ (paired *t* test, first value vs. second value), [b]$p=0.015$ (repeated measure analysis of variance, in the rise in $PaCO_2$ LMA group vs. ET group)

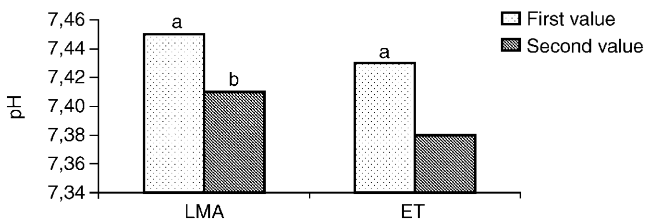

Fig. 2 The pH values before the procedure (*first value*) and before the insertion of tracheostomy tube (*second value*). [a]$p<0.01$ (paired *t* test, first value vs. second value), [b]$p<0.05$ (repeated measure analysis of variance, in the decrease in pH LMA group vs. ET group)

Discussion

Over the past 10 years an increasing number of centers have adopted PDT as a new approach for tracheostomy in the ICU because of its practicality and safety [7]. Various methods of airway control during PDT have been practiced, including withdrawal of the tracheal tube until the cuff lies at the level of the vocal cords, but this technique may cause problems such as cuff puncture, tube transection by the needle and accidental extubation, leading the loss of the airway [4]. The LMA has been used to overcome some of the problems associated with the ET. In addition, it does not require head and neck manipulation for insertion and facilitates the fiberoptic bronchoscopic guidance, which confirms accurate positioning of the needle in to the trachea [5, 8]. We think also that we can better assess the anatomy when we use the fiberoptic bronchoscope through the LMA.

Although placement of the LMA is relatively easy, failure to obtain adequate ventilation occurs in a small percentage of cases [9]. When the placement of the LMA is assessed solely by its ability to maintain effective gas exchange, positive pressure ventilation, or both, it is successful in 94–98% of first attempts [10, 11, 12]. Studies using fiberoptic examination, computed tomography, or magnetic resonance imaging show that the airway can be functionally patent and clinically acceptable even though the LMA is not in an anatomically ideal position [13, 14, 15]. Although the LMA offers no protection against the aspiration of gastric contents, this complication was not a substantial problem in several studies in which the LMA was used in resuscitation, obstetrics (i.e., “full stomach”), or by prehospital emergency personnel [16, 17]. In our study, although none of the patients had a high risk of aspiration at the time of the procedure, their nasogastric tubes were suctioned and left in place during the procedure. Contraindications to use of the LMA include the risk of aspiration, foreign body in the upper airway or trachea, suspected pathology of the pharynx or upper esophagus, traumatic tracheal disruption, recent local radiation of the upper airway, significant infection of the upper airway, and difficult tracheal intubation [6].

Transient hypercarbia leading to resultant acidosis and elevated intracranial pressure have been reported during the performance of PDT [18]. Case reports of hypercarbia associated with hypoventilation have raised concerns about the utility of this procedure in patients in whom hypercarbia is a serious problem (e.g., patients with closed head injury) [19]. The hypoventilation seen during this procedure may be associated with the air-leak due to cuff puncture or with the bronchoscopy used to assist proper placement of the tracheostomy tube. One study reported that $PaCO_2$ increased 8 mmHg during PDT under bronchoscopic guidance of patients ventilated via endotracheal tube [20]. Similarly, our study showed that $PaCO_2$ rose in both groups during the procedure. However, the rise in $PaCO_2$ was more significant in the ET group. We think that the increase in $PaCO_2$ seen in the ET group could be due to the increased operative duration and cuff puncture since the increased operative duration is associated with prolonged use of the bronchoscope and increased air leak. Crockett and colleagues [19] reported that hypoventilation could be prevented using a pediatric bronchoscope and minimizing bronchoscopy time.

The overall complication rate associated with the PDT ranges from 3.9% to 31% [21, 22, 23, 24, 25, 26]. Hill and colleagues [27] reported an operative mortality rate of 0.3%, an overall complication rate of 19%, and a symptomatic tracheal stenosis rate of 3.7% in a large series of 356 PDT cases. Various studies on PDT have been reported rates of tracheal stenosis ranging from 1% to 18% [27, 28, 29]. It is difficult to attribute tracheal stenosis solely to the tracheostomy itself because the preceding endotracheal intubation may also have caused mucosal ulceration, necrosis, and cartilage damage before the tracheostomy. In addition, the lack of proper management of the tracheostomy tube following placement, which includes regular cuff pressure monitoring and the use of a double-swivel connector between the tube and the ventilator tubing, may contribute to the development of tracheal stenosis. In our study the overall complication rate was 7.7% in the LMA group and 26.7% in the ET group. Cuff puncture and accidental extubation, which accounted for 13.3% of the complications seen in the ET group, are preventable by the use of LMA during PDT. Moreover, these complications might have been prevented if a different technique had been performed, including appropriate fixation of the ET and fiberoptic guidance of the tracheal puncture site by transillumination. However, there is a learning curve in the skillful execution of PDT, which may alter the potential for direct PDT complications. Petros and Engelmann [24] documented an overall complication rate of 11% with PDT, but the rate of acute complications was 18.5% during the first 2 years and dropped to 6% during the last 2 years, which they attributed to the learning curve.

In conclusion, our study showed that LMA is an effective and successful ventilatory device during PDT. We had better anatomical orientation, and the operating time was significantly shorter when we used fiberoptic bronchoscopy through the LMA. The rise in $PaCO_2$ and the decrease in pH was more significant at the end of the procedure when the patients were ventilated via an endotracheal tube. While transient hypercarbia seems well tolerated by most of the patients, its effect on cerebral blood flow should be considered carefully before performing PDT on the critically ill patient with evidence of elevated intracranial pressure.

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