

A Simple Method To Repair A Supraglottic Airway Device

Tingting Wang

The First Affiliated Hospital of Anhui Medical University

Jiang Wang

The First Affiliated Hospital of Anhui Medical University

Yao Lu

The First Affiliated Hospital of Anhui Medical University

Shangui Chen (✉ chenshanguimz@163.com)

The First Affiliated Hospital of Anhui Medical University

Research Article

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Abstract

Background: During the perioperative period or while in the intensive care unit, the inflation line is often cut accidentally during medical procedures or is damaged. As a result, it is not uncommon for a cuff leak to result in inadequate ventilation for the patient. The risk of using endotracheal tubes (ETTs) for secondary intubation is great, increasing the probability of respiratory tract infection and injury and even causing death in severe cases. The best method is to repair the damaged ETT to avoid secondary intubation and to ensure the safety of patients. Therefore, we recommend a practical and straightforward method to repair damage to the line or valve assembly of an endotracheal tube(ETT) and laryngeal mask airway (LMA).

Methods: The distal end of a 22G vein (IV) catheter was inserted into the broken end of the inflation line. After insertion, the internal tube was withdrawn 1 mm to restore the inflation line. After 15 hours, the repaired ETT/LMA devices were tested for air leakage by measuring the pressure and load-bearing tension of the inflation line.

Results: There was no difference in ETTs pressure between five intact ETTs and five repaired ETTs (Group A, ETT, mean difference = 0.2 cmH₂O; 95% confidence interval 1.78 to 2.12 cmH₂O; P = 0.82). When the cuff expanded to 120 cm H₂O, there was no air leakage in the five ETTs after repair, and the tensile strength of the inflation line of the repaired ETTs in the experimental group was lower than that in the control group (each n = 5; mean difference = 33.3N; 95% confidence interval, 27.5 to 39.1N; P <0.001). There was no difference in LMAs pressure (Group B, LMAs, mean difference = 0.4 cmH₂O; 95% confidence interval: -1.8 to -2.6 cmH₂O; P = 0.67). When the cuff was expanded to 120 cmH₂O, there was no air leakage from the five repaired LMAs. The tensile strength of the inflation line of the repaired LMAs in the experimental group was lower than that in the control group (n = 5; mean difference = -10; 95% confidence interval: -14 to -5.8 N; P = 0.001).

Conclusion: When the ETT, LMA inflation line, or valve assembly is damaged or accidentally broken, an IV catheter can be directly inserted into the inflation line to quickly and effectively repair it. It is a safe and effective emergency remedial measure, which can be widely used in the clinic.

Introduction

During the perioperative period, life-threatening emergencies can occur during anaesthetisation affecting the safety of the patient. Cuff leakage is not uncommon[1–2], and the level of pressure directly affects the prognosis and safety of patients [3–4]. Recently, a patient tore the inflation line of an ETT during resuscitation after an operation. Because the patient was not awake, there was a risk of extubating; therefore, we chose to repair it using an intravenous catheter. This method could be utilised to repair malfunctioning ETT or LMA inflation lines or incompetent valves(Fig. 1). Herein, we conducted a study to evaluate the reliability and effectiveness of this repair method in both ETTs and LMAs.

Material And Methods

Experimental group and control group

The ETT group (group A) used 10 sets of ETTs with good performance and no air leakage of the same model and size. Five ETT sets were assigned to the experimental group and five sets were assigned to the control group. LMA group (group B) used 10 sets of laryngeal masks with good performance and no air leakage of the same model and size. Five LMA sets were assigned to the experimental group and five LMA sets were assigned to the control group.

In group A, a 20-ml syringe was used to stimulate the trachea. In group B, it was directly used on the LMA mold when the LMA itself was not in use. The American Kehui combined inflation/pressure gauge device was used for inflation and pressure measurements. In the experimental group, the inflation line was deliberately cut off and then the IV catheter was used to repair it. The inflation line in the control group remained intact.

Integrity test of ETT / LMA inflation pipeline

We used sensors to monitor. In group A/B, the balloon pressure of five repaired endotracheal tubes/laryngeal masks was adjusted to 120 cmH₂O. The test was conducted in a quiet room and the detector was zeroed before the measurements were made. The laryngeal mask was immersed in water and leaks were visually observed if bubbles were dispersed from the repaired end.

ETT/LMA airbag cuff pressure

Literature suggests that a small amount of gas will be lost during an airbag pressure measurement. We conducted an airbag pressure test and found that the pressure loss is caused by the leakage of a small amount of air when the pressure gauge is directly connected to the pilot ball valve and a small amount of air enters into the pressure gauge. In order to avoid a small amount of air leakage when the pressure gauge is connected with the balloon for pressure measurements, we clamped the endotracheal tube/laryngeal mask inflation lines with the vascular forceps. The experimental group used the venous indwelling needle to carry the stop clamp. The stop clamp was closed during the pressure measurements, and then connected to the balloon pressure gauge. The stop clamp was open during pressure measurements to prevent air leakage during pressure measurement. In this test, we found that the amount of air loss positively correlated with the pressure of LMA. The greater the pressure, the more air that escaped. There is no difference in pressure measured between the experimental and control groups. Therefore, we adjusted the pressure of group A and group B to 30 cmH₂O. After 15 hours, we reassessed the pressure of each laryngeal mask and endotracheal tube with a pressure gauge and compared the pressure changes between the experimental and control groups.

Tensile strength test of ETT/LMA inflation pipe

Tensile strength test of the inflatable tube of the experimental and control groups was conducted to assess the bearing strength of the repaired end. An electronic scale was hung on a wall and, the proximal

end of the inflation line of the experimental and control groups was fixed with cotton thread, and the scale was rotated. At the other end, the distal end of the whole endotracheal tube/laryngeal mask inflation bag and the distal end of the repaired venous indwelling needle was held. With the increase of pressure, the weight on the electronic scale continues to increase until the inflation tube is broken or separated (Fig. 2). The weight on the electronic scale was recorded and converted to Newtons. The force required for the fracture or separation of the inflation line between the experimental and control groups was assessed by comparing the weights.

Statistical analysis

The SPSS 22 software was used for statistical analysis. The measurement data are expressed by $\bar{X} \pm s$. The mean of two groups was compared using a t-test. $P < 0.05$ was considered statistically significant.

Results

Group A consisted of five intact and five repaired endotracheal tubes and pressure measurements were conducted. After 15 hours, there were no significant difference between the pressure of the repaired endotracheal tubes and that of the intact endotracheal tubes. The air leakage experimental group was less than the control group (mean difference = 0.2 cmH₂O; 95% confidence interval 1.8-2.1 cmH₂O; $P = 0.82$; Fig. 3A). When the pressure was adjusted to 120 cmH₂O, there was no visible air leakage using the water test for the five repaired lines. The tensile strength of the repaired laryngeal mask inflation line in the experimental group was lower than that in the control group (each $n = 5$; mean value difference = 33.3N; 95% confidence interval, 27.5–39.1 N; $P < 0.001$; Fig. 3B).

Group B consisted of five intact and five repaired LMAs and pressure measurements were conducted. After 15 hours, there was no significant difference between the pressure of an intact and repaired LMA. Further, the experimental group also had less air leakage (mean difference = 0.4 cmH₂O; 95% confidence interval -1.8 ~ -2.6 cmH₂O; $P = 0.67$; Fig. 4A). When the pressure was adjusted to 120 cmH₂O, the five repaired inflation lines had no visible signs of air leakage when submerged underwater. The tensile strength of the repaired laryngeal mask inflation line in the experimental group was lower than that in the control group (each $n = 5$; mean difference = -10; 95% confidence interval, -14.2 ~ -5.8 N; $P = 0.001$; Fig. 4B). This method has been successfully used to repair inflation lines of ETTs and LMAs from various manufacturers (Table 1).

Table 1
Catheter Size Required for Repair of a Transected Inflation Line

Endotracheal tube / laryngeal mask manufacturer	Model of endotracheal tube / laryngeal mask	Internal Diameter (mm)	Venous indwelling needle repair model
LMA supreme	3, 4	2	All models
Intersurgical	2.0, 2.5	1	22
COVIDIEN Curity	4.5,5.5-8.0	1	22
COVIDIEN Shiley	3.5,4.0,5.0-7.5	1	22

Discussion

The artificial airway is instrumental for proper mechanical ventilation and is essential for airway patency of patients during operation. During the while in intensive care unit or the perioperative period, it is necessary to manage the airways and airbags to ensure the safety. The common causes of airbag leaks includes airbag and tube rupture. The common causes of airbag tube rupture in perioperative anaesthesia or during ICU care are bites, tears, or accidental severing of the tube while providing medical care when the patient is unconscious during resuscitation. [5–12]

If the treatment is not timely, oral secretions and gastric contents can enter the airway leading to aspiration pneumonia, which in severe cases can result in death. [13] It is reported that a broken inflation line can be clamped with a syringe air supply vessel clamp to provide adequate airbag pressure, [5] however, this prevents the airbag pressure for being measured. For instance, excessive inflation of the endotracheal tube may cause the airbag pressure to increase to a great extent leading to increased risk of serious injury, including tracheal mucosal ischaemia, ulcer, necrosis, tracheoesophageal fistula and even tracheal rupture. Excessive injection of the laryngeal mask will also make the cuff pressure too high, resulting in pharyngeal mucosal compression and even ischaemic necrosis. Postoperative complications such as severe pharyngeal pain, eating difficulty and hoarseness may occur [14–16].

Several previous studies have described six catheter balloon repair methods. **Whiteside** et al. [5] a syringe and directly clamping the blood vessel clamp after gas injection in the inflation line to restore the pressure of the airbag. **Barrios et al.** [6] also proposed that a closing cap be used after clamping the blood vessel clamp to maintain pressure of the airbag. However, these methods do not allow one to monitor the cuff pressure and it can lead to tracheal mucosal damage or even severe complications. **Yoon K** et al. [17] used a metal puncture needle, intercepted the middle needle stem and inserted both ends of the needle stem into the two sides of the inflation line to maintain the pressure in the airbag. There are several disadvantages to this method. First, improper cutting of the needle can cause complete blockage of the needle tip or narrow lumen, which can prevent air from entering the airbag. Secondly, if the cutting end is sharp, it is easy to puncture the connecting pipe when joining the connecting lines. When attaching the needle stem to the stump, the operation is complex because the material is small. This leads to more

potential safety hazards for patients. Additionally, the device cannot be used during magnetic resonance examinations. Emergency repair of endotracheal tube balloons takes a long time and increases the workload of medical care workers. **Dayan** et al. [18] used a puncture needle to repair the line by connecting both ends to maintain the pressure in the airbag, which has numerous limitations. Due to the lack of tube core support, it is difficult to connect the two ends during operation. Further, the material is small and improper usage can be dangerous to patients. **Owusu** et al. [19] directly connected the residual end of the airbag inflation line of the endotracheal tube with an epidural puncture needle, and then connected it to a three-way valve to fill the airbag. Although effective, the materials needed for this repair are not readily available in an ICU setting. During pressure measurements, it is also necessary to operate the three-way valve to measure the airbag pressure. Lastly, **Singh** et al. [20] described a method of reconstructing an inflation line. In this method, the LMA device was repaired using a connector, but the process of material acquisition and production takes some time.

Existing methods are limited as they involve complex operations and materials and increase medical workload. In contrast, our method is convenient as only one intravenous indwelling needle is needed. Further, the operation is simple and shortens the recovery time for patients. In addition, the liquid injection end of the intravenous indwelling needle provides a valve plug, which is safe and sealed (Fig. 5). There is no need to connect the three-way valve, and it will not cause air leakage of the airbag. It can be used to measure the airbag pressure accurately, even when in an intense magnetic field [18]. Current literature suggests that the breakage of the endotracheal tube and laryngeal mask inflation line is common. Therefore, our repair method is an easy way to repair a broken inflation tube or valve to avoid compromising the airway and prevent secondary intubation and shorten the rescue time of patients in distress due to ETT or LMA failure.

This method still has several shortcomings to consider. When repairing the connecting line of an endotracheal tube, the position can be too deep and difficult to operate. Secondly, the types of adult and child endotracheal tubes and laryngeal masks in our department are limited. Products from other manufacturers may function differently after utilising this repair method. Second, our cuff pressure test was completed through an *in vitro* model. Although our experimental conditions are similar to what is used clinically, the pressure measurement may differ from the pressure in the human body. According to the statistical analyses, there is no difference in the pressure between intact and repaired tubes. Finally, as we hypothesised, the strength of the restored ETT or LMA inflation lines was much lower than the control, intact ETT or LMA lines.

Conclusion

This straightforward method is the most effective process to date and shortens the rescue time of patients to ensure their safety. The method is safe and reliable and can be effectively used to temporarily repair damaged inflation tubes, inflation bags, or inflation valves. This method prevents reintubation and secondary intubation and reduces the workload of medical staff. Furthermore, this convenient and rapid method will reduce physical and mental harm of patients and the occurrence of legal disputes.

List Of Abbreviations

ICU— Intensive Care Unit; ETT—Endotracheal tubes; LMA—Laryngeal mask

N—Newton

Declarations

Ethics approval and consent to participate

No written informed consent was obtained from participants, because it was a In vitro abiotic experimental study and did not utilize any individual person's data.

Consent for publication:

Not applicable.

Availability of data and materials

The datasets analysed during the current study are available from the corresponding author upon reasonable request.

Competing interests:

The authors declare that they have no competing interests.

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Authors' contributions:

TW and SC designed this study and wrote the manuscript. TW and JW performed the experiments. TW, SC and JW assisted with data analysis. SC and YL revised the final manuscript. All the authors contributed to the final version of the manuscript.

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Figures

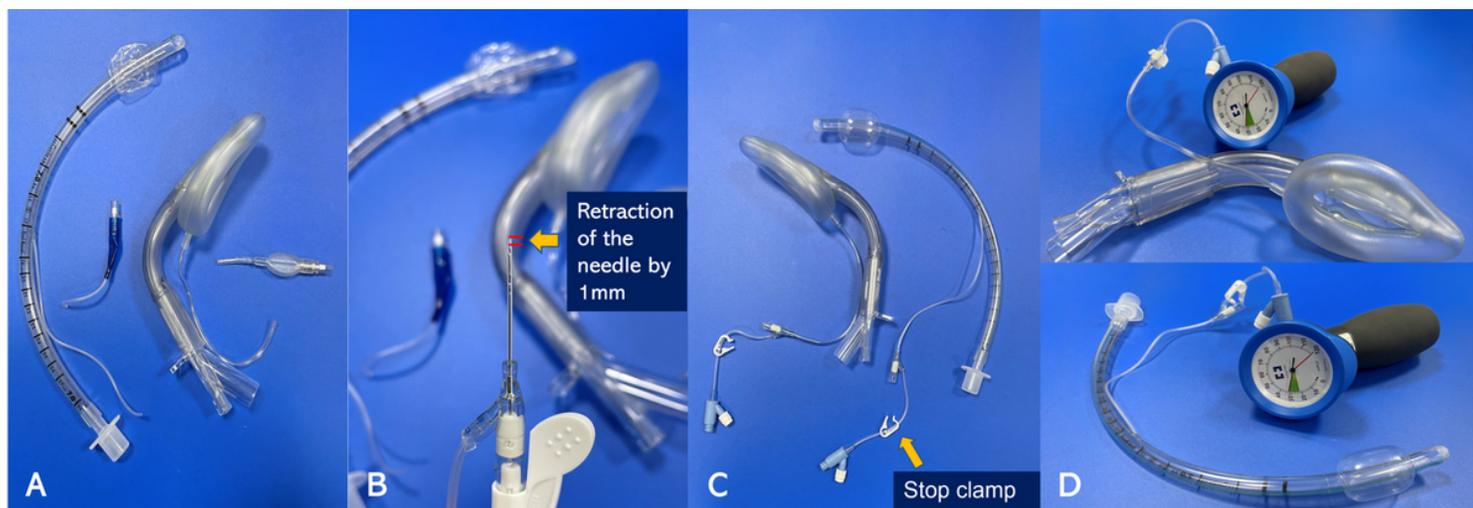


Figure 1

Steps for Repairing ETT/LMA inflation lines. First, cut off the remaining end of the ETT/LMA inflation pipeline (A). Retraction of the needle by 1mm prior to its insertion.(B).and connect it with the remaining end of the airbag inflation pipeline (C). The pressure at the ETT/LMA cuff is measured using a pressure gauge.(D)



Figure 2

Tensile strength test of ETT/LMA inflation pipe.

The cotton thread on the ETT/LMA inflation line is fixed with an electronic scale and the distal pressure is maintained.

Figure 3

A Cuff pressures of ETTs group over 15 hours. Cuffs from five intact (blue blocks) and five repaired (brown blocks) were inflated to 30 cmH₂O, and tensions were remeasured 15 hours later. There was no significant difference in the pressure drop from baseline between the two groups (9.60 ± 1.14 to 9.4 ± 1.52 cmH₂O, $t = 2.36$, $p = 0.82$). **B** Force required to break intact versus repaired inflation lines. Segments

from entire (blue blocks) and revised (brown blocks) inflation lines were attached to an electronic scale and pulled down until the tubes were disrupted. Repaired inflation lines were weaker than entire inflation lines ($7.88 \pm 1.73\text{N}$ to $36.62 \pm 5.62\text{ N}$, $t = 10.93$, $P < 0.05$).

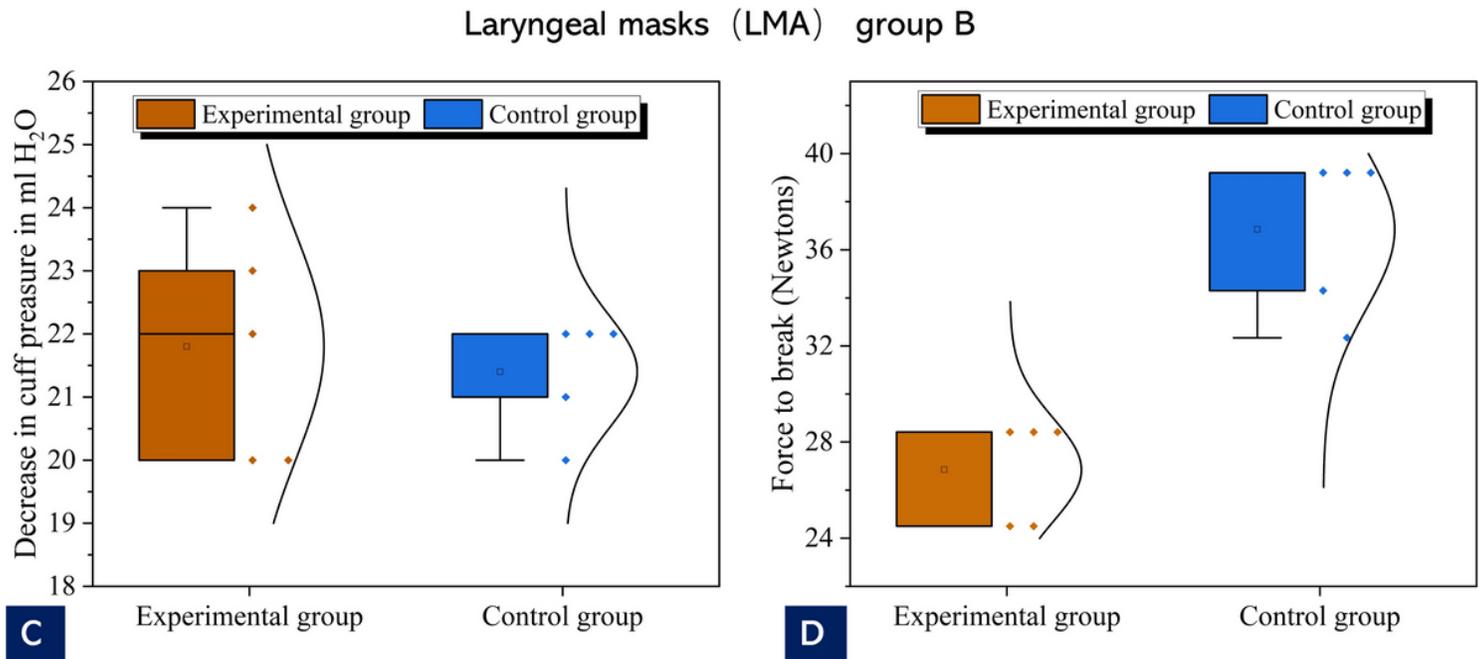


Figure 4

C Cuff pressures of LMA group over 15 hours. Cuffs from five intact (blue blocks) and five repaired (brown blocks) LMAs were inflated to 30 cmH₂O, and tensions were remeasured 15 hours later. There was no significant difference in the pressure drop from baseline between the two groups (21.80 ± 1.79 to 21.40 ± 0.89 cmH₂O, $t = 0.45$, $p = 0.67$). **D** Force required to break intact versus repaired inflation lines. Segments from entire (blue blocks) and revised (brown blocks) inflation lines were attached to an electronic scale and pulled down until the tubes were disrupted. Repaired inflation lines were weaker than entire inflation lines ($26.85 \pm 2.15\text{ N}$ to $36.85 \pm 3.29\text{ N}$, $t = 5.68$, $P < 0.05$).

Figure 5

Sealing the injection end of the needle with a valve plug.