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Retraction

Retracted: The Relationship between Cuff Pressure and Air Injection Volume of Endotracheal Tube: A Study with Sheep Trachea Ex Vivo

Applied Bionics and Biomechanics

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] R. Wang, X. Qin, W. Zhou et al., "The Relationship between Cuff Pressure and Air Injection Volume of Endotracheal Tube: A Study with Sheep Trachea Ex Vivo," *Applied Bionics and Biomechanics*, vol. 2022, Article ID 1748233, 10 pages, 2022.

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Research Article

The Relationship between Cuff Pressure and Air Injection Volume of Endotracheal Tube: A Study with Sheep Trachea Ex Vivo

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Background. Endotracheal intubation is a widely used treatment. Excessive pressure of the endotracheal tube cuff leads to a series of complications. Here, we used tracheae of sheep to analyze the relationship between the air injection volume and endotracheal tube cuff pressure so as to guide the doctors and nurses in controlling the pressure of the endotracheal tube cuff during clinical work and minimise the risk of complications. *Materials and Methods*. Forty sheep tracheae were utilised and were divided into five groups according to their diameters. Different sizes of endotracheal tubes were inserted into each trachea, and the cuff pressure with the increase of air injection volume was recorded. The formulas that reflect the relationship between air injection volume and cuff pressure were obtained. Then, sheep tracheae were randomly selected; different types of tubes were inserted, and the stipulated volume of air was injected. The actual pressure was measured and compared with the pressure predicted from the formulas. Statistical analysis was conducted to verify whether the formulas obtained from the first part of the experiment were in accordance with the expert evaluation table, which consists of opinions of several experts. *Results*. After obtaining 15 formulas, we collected the differences between the theoretical cuff pressure and the actual cuff pressure that satisfied the expert evaluation. Relying on the formulas, the medical turntable was obtained, which is a tool that consists of two round cards with data on them. The top card has a notch. The two cards are stacked together, and as the top card rotates, the data on the bottom card can be easily seen in a one-to-one relationship. *Conclusion*. The formulas are capable of showing the relationship between the cuff air injection volume and pressure of endotracheal tube cuff. The medical turntable can estimate the air injection volume to ensure that the pressure stays in an acceptable range.

1. Introduction

Endotracheal intubation is an important procedure to ensure the airway management patency of surgical and critical patients. Expert guidelines have clearly pointed out that endotracheal tube cuff pressure has a great impact on the tracheal mucosa. According to the guidelines, the ideal pressure of endotracheal tube cuff (20–30 cm H_2O) should not interfere with the blood circulation of the tracheal mucosa, and it should prevent the leakage between the endotracheal tube and the trachea. When the pressure of the endotracheal tube cuff is maintained within the safe range, there are few obvious tracheal ischemic and other complications in clinical work. However, when the pressure of the endotracheal tube cuff is not appropriate, a series of complications can occur. When the pressure of the endotracheal tube cuff is extremely high, the blood vessels of the tracheal mucosa are compressed [1]. With time, ischemia of the tracheal mucosa leads to necrosis, peeling, and eventually forms scarring contracture, which results in tracheal stenosis [2, 3]. Moreover, inflammation of the tracheal mucosa, ulcers, tracheoesophageal fistula, and other serious complications can occur [4, 5]. Overinflation of the cuff can cause certain adverse reactions like irritation of tracheal mucosa and even rupture as reported in cats, dogs, and horses [6–8].

On the other hand, endotracheal intubation may be too deep or too shallow when the endotracheal cuff is underinflated, which can increase the risk of unilateral lung ventilation or endotracheal tube come off [9]. Moreover, low tidal volume, aspiration, and other complications can occur [10, 11]. Thus, as per abovementioned studies and their observations, measuring endotracheal tube cuff pressure is deeply imperative to reduce the risk of complications. Hence, it can be hypothesised that maintaining appropriate endotracheal tube cuff pressure is important; otherwise, the risk of complications can be higher [12].

The gold standard for measuring the pressure of endotracheal tube cuff involves a pressure measuring device. Unfortunately, endotracheal cuff pressure monitoring is not widely used in clinical work. According to a survey among 305 anesthesiologists in Australia and New Zealand hospitals, only 40.0% of anesthesiologists perform endotracheal cuff pressure monitoring during surgery in their daily work. A similar situation was also reported in the ICU, by Saad; namely, cuff was underinflated in 24% of patients, overinflated in 53% of patients, and underinflated or overinflated for more than 30 min in 33% patients [13]. The main reasons for such observations are as follows: (1) there are not enough pressure measuring devices, and only a few pressure measuring devices are used in hospitals [14]. For the emergency conditions, there are no cuff pressure devices in most ambulances, which is why the pressure of the endotracheal tube cuff is often too high [15]. (2) Due to the lack of pressure measuring devices, doctors and nurses often estimate the pressure of the endotracheal tube cuff by palpation [16, 17]. (3) It has been pointed out that some anesthesiologists are not comfortable in using pressure measuring devices because using them can lead to air leakage of the cuff [18, 19]. Harm et al. pointed out that the average cuff pressure in a single hospital was 63.17 ± 32.79 cm H_2O [20]. These findings are consistent with the results of our previous investigation in several Class-III/Grade-A hospitals of Xinjiang, China. Our previous investigation has shown that the average pressure of endotracheal tube cuff in almost all emergency patients reached 68.4 ± 22.6 cm H_2O. By estimating the pressure through palpation in a study by Michlig, it was shown that only 9% of the respondents correctly detected the pressure within the recommended range (20–30 cm H_2O) by palpation, while even 91% of the respondents underestimated the cuff pressure [21]. Therefore, there is an urgent need to create a simple method so that medical personnel can easily and rapidly control the pressure of endotracheal tube cuff in a reasonable range, which can effectively prevent complications without delaying endotracheal intubation. If such a procedure is established, it can remove the chances of complications as well as hesitation and lack of practice of anaesthetists to measure cuff pressure prior to endotracheal intubation.

In order to control the endotracheal tube cuff pressure more conveniently, we used the sheep tracheae to simulate the human tracheae. Sheep tracheae ex vivo were chosen as they serve as a realistic in expensive and safe model to mimic the human tracheae for variety of surgical procedures related to laryngotracheal emergency situations specifically due to their surgical simulation with human organs [22].

Different types of the endotracheal tubes were then used with a series of air injections and changes in pressure were measured. After analyzing the data, a simple and effective method to control pressure in a reasonable range was designed.

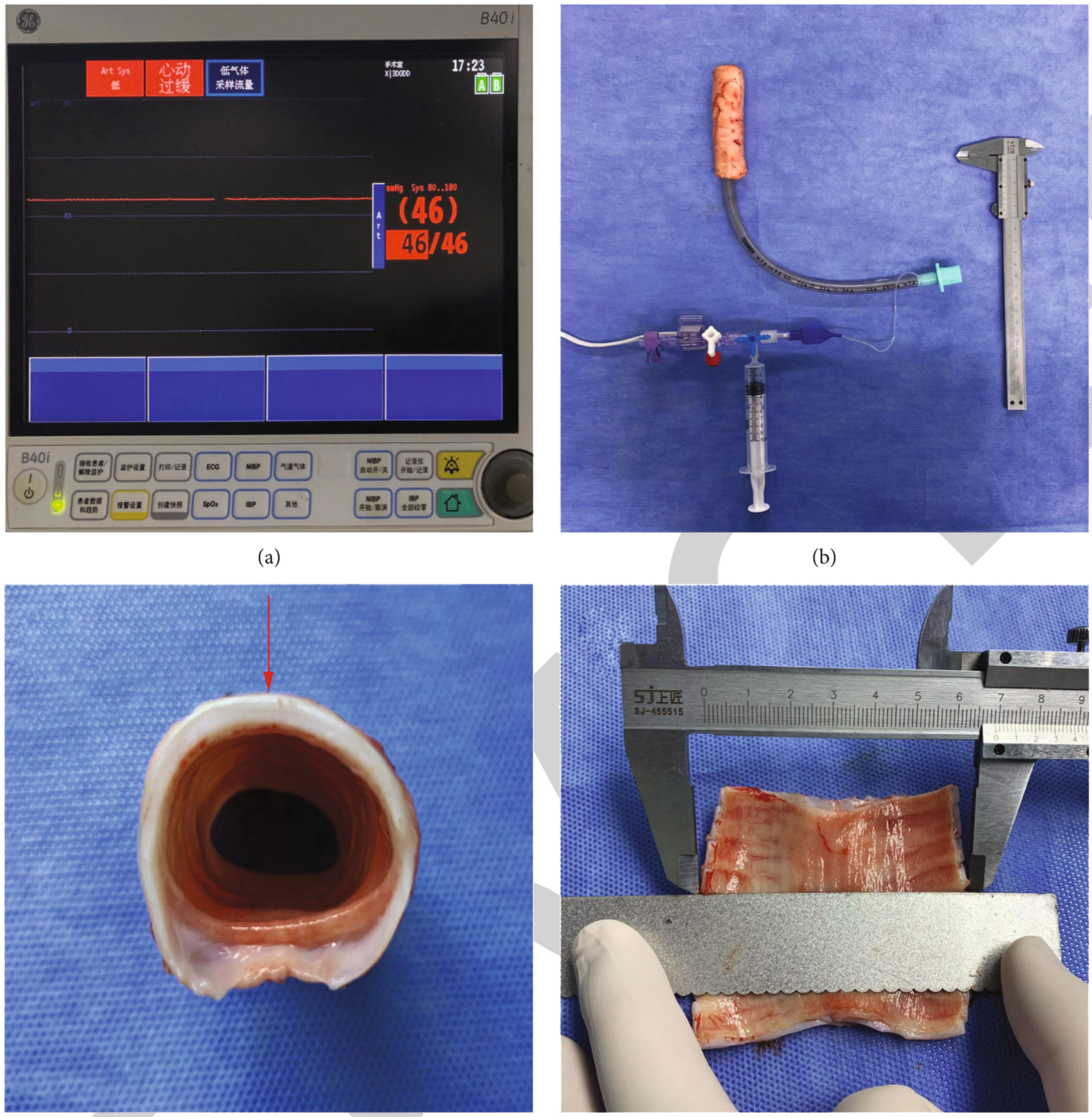
2. Methods

All animal procedures were approved by the Animal Care and Use Committee of the First Affiliated Hospital of the Medical College, Shihezi University, and were in accordance with the Guidance Suggestions for the Care and Use of Laboratory Animals, formulated by the Ministry of Science and Technology of China, and the Guide for the Care and Use of Laboratory Animals by the National Institutes of Health (NIH Publication No. 85-23, revised in 2006). The experiment was approved by the Medical Ethics Committee of First Affiliated Hospital, Shihezi University School of Medicine (A2019-095-01).

2.1. Animal Preparation. All animals were clinically healthy Alertai sheep, weighing **22 ± 2 kg**. Tracheae were collected 10 minutes after premeditating them with sedatives by removing once animal stopped responding.

2.2. Device for Measuring the Pressure of Endotracheal Tube Cuff. Radial artery pulse pressure sensor (Tuoren, China) which is a mechanical device that does not require a power supply was used. When it is connected with a monitor (Dash 4000, GE company, USA), during the observation, the data are observed in real time (Figure 1(a)). By using an invasive pressure transducer, we used a three-way valve (Sujia, China) that included a valve connected with the tracheal tube (Tuoren, China), a valve connected with radial artery pulse pressure sensor, and a valve connected with a 10 mL syringe. In order to avoid air leakage during pressure measurement, the air injection valve was closed before each air injection. Radial artery pulse pressure sensor was not linked with the syringe when air was injected into the tracheal cuff so as to avoid inaccurate gas injection (Figure 1(b)).

2.3. Study Protocol. The diameter of the human trachea is 1.5-2.5 cm. After the tracheal diameter was measured at the end of the experiment, we collected data from the tracheae of sheep. Standards for the collected data were from tracheae of sheep with diameter between 1.5 cm and 2.5 cm. There were five groups, each group containing eight tracheae (group A: 15.01-17.00 mm; group B: 17.01-19.00 mm; group C: 19.01-21.00 mm; group D: 21.01-23.00 mm; group E: 23.01-25.00 mm) [23]. Each trachea was longer than 8 cm, so that endotracheal tube cuff could be fully inserted into it. To ensure that the conditions of sheep tracheae resemble those of human tracheae as much as possible, the



(a) (b) (c) (d)

Figure 1: (a) The waveform and value of endotracheal tube cuff pressure displayed on the monitor. (b) Pressure monitoring device for endotracheal tube cuff pressure, including endotracheal tube cuff guide balloon, a 10 ml syringe and pressure monitoring sensor. (c) The point where to cut trachea (red arrow). (d) Measurement of tracheal diameter.

experiment was conducted 2 hours after isolating the tracheae from the body. Before the experiment, we put the tracheae into specimen bags and soaked them in water at 37°C to simulate the body temperature. Sizes 6.5#, 7.0#, 7.5#, and 8.0# of endotracheal tubes were selected for adult patients. In this experiment, endotracheal tubes with sizes 6.5#, 7#, and 7.5# were implanted to group A, group B, and group C, while endotracheal tubes with sizes 7#, 7.5#, and 8# were implanted to groups D and E.

The experiment was divided into two parts.

2.3.1. Part I. First, 8 mL of air was injected with a syringe to fill the cuff; then, the three-way valve was twisted to connect the tracheal cuff with the atmosphere. After waiting for 5 seconds, the pressure in the tube cuff was restored to 0 cm H_2O. Next, air was injected into endotracheal tube cuff, starting with 0.2 mL, and then with each time of new injection, the amount of injection increased by 0.2 mL (0.2 mL, 0.4 mL, and 0.6 mL). After the injection, the numerical value of the actual pressure on the monitor was recorded. We kept on testing until the pressure was measured to be 80 cm H_2O. In order to eliminate air compression and air leakage caused by screwing the three-way valve, before each injection, we turned the three-way valve to connect the endotracheal tube cuff with the atmosphere and restored the pressure to 0 cm H_2O. After the data for each tracheal tube had been collected completely, the sheep tracheae were cut longitudinally in the middle of the C-type cartilage ring to avoid the retraction of connective tissue attached to the side of the esophagus, which would cause errors (Figure 1(c)). The inner diameter was measured with a Vernier caliper (Figure 1(d)). We assumed that the tracheal cross-section was circular, so the

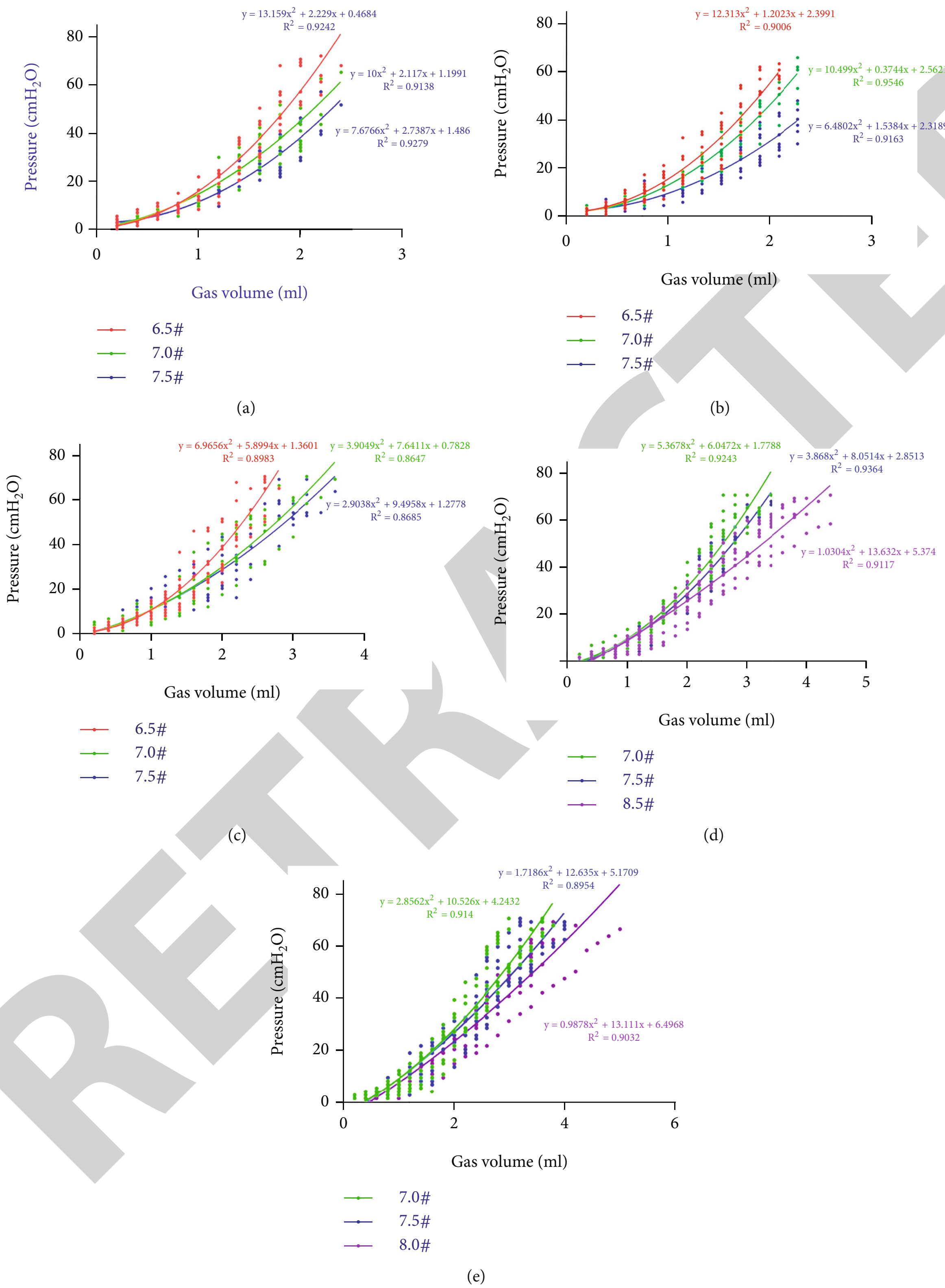


FIGURE 2: Relationship between endotracheal tube cuff pressure and air injection volume in groups (a)–(e).

diameter of the trachea was calculated from the formula of circumference length. We analyzed the relationship between the air injection volume of the endotracheal tube and pressure of the endotracheal tube cuff.

2.3.2. Part II. Based on the first part of the experiment, we obtained the formulas relating the endotracheal tube cuff volume and the pressure of endotracheal tube cuff in each group. Through the formulas, we calculated the theoretical

Table 1: The pressure corresponding to the different air injection volume (1 ml, 1.4 ml, 1.8 ml, 2.2 ml, 2.6 ml, and 3 ml) which calculated according to the first part formulas.

Tracheal group	Tracheal tube size	Theoretical pressure (1.0 ml)	Theoretical pressure (1.4 ml)	Theoretical pressure (1.8 ml)	Theoretical pressure (2.2 ml)	Theoretical pressure (2.6 ml)	Theoretical pressure (3.0 ml)
	6.5	15.9	29.4	47.1	69.1	95.2	125.6
A	7	13.4	23.8	37.5	54.4	74.5	97.7
	7.5	11.9	20.4	31.3	44.7	60.5	78.8
	6.5	15.9	28.2	44.5	64.6	88.8	116.8
B	7	13.4	23.7	37.3	54.2	74.5	98.2
	7.5	10.3	17.2	26.1	37.1	50.1	65.3
	6.5	11.5	20.6	31.8	45.3	61.1	79.0
C	7	10.8	17.6	25.6	34.9	45.5	57.3
	7.5	11.1	17.7	25.2	33.7	43.0	53.3
	7	7.3	13.1	20.6	30.0	41.3	54.3
D	7.5	9.1	16.0	24.2	33.6	44.2	56.1
	8	9.3	15.7	22.5	29.6	37.0	44.8
	7	9.1	16.1	24.0	32.7	42.4	53.0
E	7.5	9.2	15.9	23.1	30.9	39.3	48.2
	8	7.6	13.8	20.3	27.1	34.3	41.7

Table 2: The difference between the actual cuff pressure and theoretical cuff pressure inferred by the formula.

Tracheal group	Tracheal tube size	The mean difference between the theoretical data and actual data of endotracheal tube cuff injection (cmH_20)					
		1.0 ml	1.4 ml	1.8 ml	2.2 ml	2.6 ml	3.0 ml
	6.5	3.76 ± 1.69	9.79 ± 2.44	6.72 ± 1.7	8.89 ± 4.4	9.45 ± 2.6	13.2 ± 4.32
A	7	3.35 ± 0.42	5.86 ± 1.85	6.53 ± 3.68	5.76 ± 5.47	7.96 ± 2.72	9.32 ± 4.67
	7.5	3.81 ± 2.21	6.18 ± 2.97	6.54 ± 3.77	7.44 ± 3.06	9.02 ± 1.47	13.73 ± 5.55
	6.5	4.69 ± 1.24	6.83 ± 3.10	7.32 ± 4.91	8.32 ± 5.64	11.72 ± 3.64	14.49 ± 6.82
B	7	3.24 ± 2.32	6.18 ± 1.88	8.31 ± 4.96	6.73 ± 5.74	9.84 ± 5.58	18.32 ± 6.54
	7.5	4.16 ± 2.24	3.74 ± 3.61	9.74 ± 2.79	9.72 ± 1.94	11.10 ± 6.58	16.32 ± 5.37
	6.5	5.74 ± 2.22	6.92 ± 4.43	7.83 ± 4.65	8.21 ± 5.61	11.60 ± 6.35	14.73 ± 5.68
C	7	5.56 ± 1.48	5.39 ± 3.79	7.21 ± 3.69	9.54 ± 6.12	8.78 ± 5.46	11.58 ± 8.26
	7.5	5.43 ± 0.92	8.06 ± 1.71	9.14 ± 4.45	10.57 ± 5.01	9.87 ± 3.77	12.02 ± 8.66
	7	3.98 ± 1.91	6.19 ± 2.71	6.32 ± 2.15	10.73 ± 3.66	11.35 ± 5.26	13.56 ± 8.78
D	7.5	4.30 ± 1.72	5.43 ± 2.13	7.84 ± 5.96	10.02 ± 5.96	13.01 ± 7.92	14.78 ± 5.17
	8	1.59 ± 1.51	2.66 ± 2.01	5.22 ± 2.69	8.09 ± 2.33	11.31 ± 2.29	15.46 ± 7.56
	7	5.42 ± 1.11	7.26 ± 2.51	8.41 ± 4.75	6.20 ± 3.81	11.34 ± 6.48	16.36 ± 4.54
E	7.5	3.68 ± 2.23	6.39 ± 2.38	8.21 ± 2.14	10.13 ± 2.96	9.69 ± 3.86	14.38 ± 3.45
	8	2.45 ± 2.05	5.17 ± 1.79	7.98 ± 3.35	9.45 ± 5.06	10.68 ± 5.04	10.19 ± 5.15

cuff pressure with the different injection volumes. In the next step, we collected data of 40 sheep tracheae with diameter between 1.5 and 2.5 cm. There were five groups, each group containing eight tracheae (group A: 15.01-17.00 mm; group B: 17.01-19.00 mm; group C: 19.01-21.00 mm; group D: 21.01-23.00 mm; group E: 23.01-25.00 mm). We inserted the tracheal tubes of 6.5#, 7.0#, 7.5#, and 8.0#. We kept the experimental method from the first part, and the pressure of the endotracheal tube cuff was reset to 0 cm H_2O. We injected air volume into endotracheal tube cuff (1 mL, 1.4 mL,1.8 mL, 2.2 mL, 2.6 mL, and 3.0 mL) and recorded the pressure. After this, the trachea was cut, and measuring of inner diameter was done to obtain the tracheal diameter. We contrasted the real data of the experiment with the theoretical data from the formula and verified the rationality and representation of the first part's formulas. Although the guidelines recommend that the endotracheal tube cuff pressure should be less than 30 cm H2O, the range of endotracheal tube cuff pressure is wider in clinical work. Thus, we determined whether the differences between the actual data

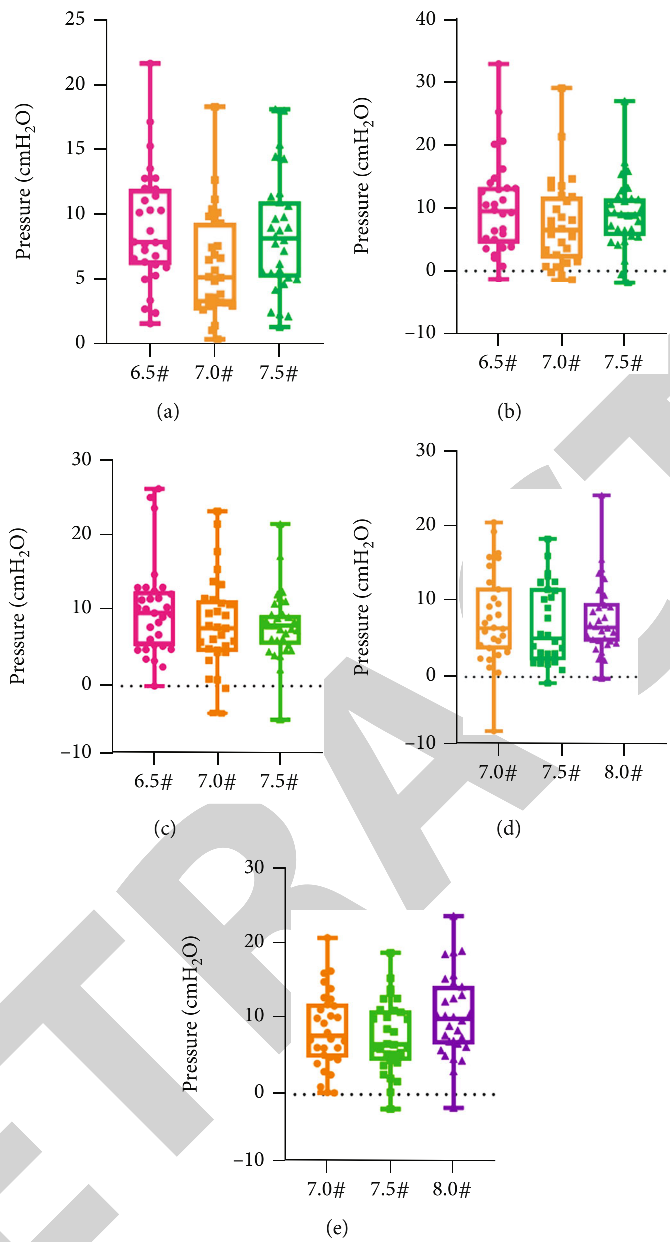


FIGURE 3: The difference between the actual cuff pressure and theoretical cuff pressure inferred by the formula.

and the theoretical data were in the acceptable range to judge whether the first part's formula is reasonable. We collected evaluation forms from 10 experts, according to their opinions on the specific range of endotracheal tube cuff pressure. Since the medical personnel's working time, education level, and the number of intubation cases have a certain influence on the accuracy of pressure control of endotracheal tube cuff, the requirements for the experts who filled in the form were as follows: (1) working experience for more than 15 years, (2) senior medical professional titles, (3) education level at least master of medicine or above, and (4) more than 300 cases of endotracheal intubation completed every year. When the difference was in an acceptable range obtained from 10 experts' evaluation sheet, it means that we could rely on the formulas to calculate the recommended endotracheal tube cuff injection volume for different tracheal diameters and different endotracheal tube sizes.

2.4. Statistical Analysis. SPSS 25.0 was used for data analysis. Part I: according to tube diameter and endotracheal tube size, we used linear regression method to measure the data of air injection volume with pressure of the endotracheal tube cuff into a synthesis of binary quadratic equations and analyzed the slope. Part II: we used t test to contrast the actual data of endotracheal tube cuff pressure and the theoretical data of endotracheal tube cuff pressure belonging to the same injection volume. We calculated the value, the average value, and distribution of the differences between them and then compared them with the data from the experts' evaluation table. If the data conformed with the

Table 3: Characteristics and situation of form responding experts.

	Number
Time of service in health structures (years)	
15-25	6
25-35	4
Education background	
Doctor of medicine (M.D.)	6
M.M. (master of medicine)	4
The number of endotracheal intubation	
400-500	4
500-600	4
600-700	2
Types and grades of service hospitals	
General hospital	8
Specialized subject hospital	2
Acceptable pressure of endotracheal tube cuff (cmH_2O)	
30 ± 5	3
30 ± 10	6
30 ± 15	1

expert evaluation table, we considered the formula to be valid.

3. Results

3.1. Part I. In the first part of the experiment, the measured pressure was recorded and fitted as a binary quadratic formula with air injection volume and pressure as variables. The rate ratios of all formulas from different endotracheal tube sizes and different tracheal groups were greater than 0.85, signifying a strong correlation between pressure of the endotracheal tube cuff and air injection volume. Moreover, we found that a larger size of endotracheal tube was associated with a greater slope of the binary quadratic equation (Figure 2).

3.2. Part II. The pressure of the endotracheal tube cuff was obtained from the formulas (Table 1). After t test, the mean difference between the actual endotracheal tube cuff pressure and the theoretical endotracheal tube cuff pressure was less than 10 cm H2O (Table 2). Classified by tracheal diameter and tube size, the difference distribution is shown in Figure 3. Based on these findings and the correlation curve, the acceptable pressure of the endotracheal tube cuff in clinical work was 30 ± 10 cm H2O (Table 3). The difference between the pressure derived from the formulas and the actual pressure measured was within the acceptable range, which means that these formulas can be used to predict the optimal air injection volume of endotracheal tube cuff.

In clinical work, the measurement of tracheal diameter is based on computed tomography and ultrasound (33.34). We can select the size of endotracheal tube according to the tracheal diameter, and relying on the formula, the recommended air injection volume can be calculated to control the pressure of endotracheal tube cuff within the range from the experts' evaluation form. However, in order to reduce the time of calculations from the formulas, we designed a medical turntable (Figure 4). It is a tool that consists of two round cards with data on them. The two cards are stacked together, and the top card has a notch. When the top card rotates, the data on the bottom card can be easily seen in a one-to-one relationship. This method only requires to rotate and match the required variables to directly obtain the recommended air injection volume, which is convenient and simple to operate.

4. Discussion

The damage to the tracheal mucosa caused by high pressure of endotracheal tube cuff has always been in focus and an area of great concern [23]. Thus, various researchers have proposed certain methods to predict or control endotracheal tube cuff pressure to reduce the risks of complications [24, 25]. Shibasaki et al. pointed out that the optimal endotracheal tube cuff volume could be predicted from the tracheal diameter, patient's height, and age. Unfortunately, the correlation between age, height, and tracheal diameter is so poor that it results in low accuracy of the endotracheal tube cuff injection [26]. Kumar and Hirsch have proposed the usage of the sporadic volume technique (seal pressure) in daily work which specifically involves an approach of injecting air into the cuff until the sound of air leakage disappears [27]. However, as pointed out by Douglas Willian Bolzan, this technique cannot accurately decide the time to stop inflation, and thus, there is always an associated risk of having insufficient pressure in the endotracheal tube cuff [28, 29]. Some researchers have considered that the management of endotracheal cuff pressure can be carried out according to the volume/time curve of respirator [30]. However, in line with our results, the volume/time curve can only help to determine if there is an air leakage after injecting air into the endotracheal cuff, and no specific guidance to help in getting the acceptable pressure. Slocum et al. designed a kind of syringe using the principle of the negative pressure; which may be used to adjust for high pressure but cannot correct the low-pressure situations [31].

In this study, sheep tracheae were included which were divided into different groups according to their diameter to simulate the real patients' trachea. Radial artery pulse pressure sensor was used to show pressure and reduce the air leaking when air was injected into the cuff [32]. According to the formulas, a strong positive correlation was observed between the air injection volume and the endotracheal tube cuff pressure. From the curve and formulas in the same tracheal diameter group, when the same volume was injected into the cuff, the cuff pressure increased faster in the small-sized endotracheal tube than in large-sized one. We consider that it was associated with the volume of the endotracheal tube cuff. With the increase in the tube diameter, injection volume increased significantly to ensure that the pressure reached the appropriate level. During the experiments, it was found that the diameter of trachea reached more than 21.01 mm, for size 6.5# endotracheal tube. Though injected, the cuff was injected fully, the pressure observed was above

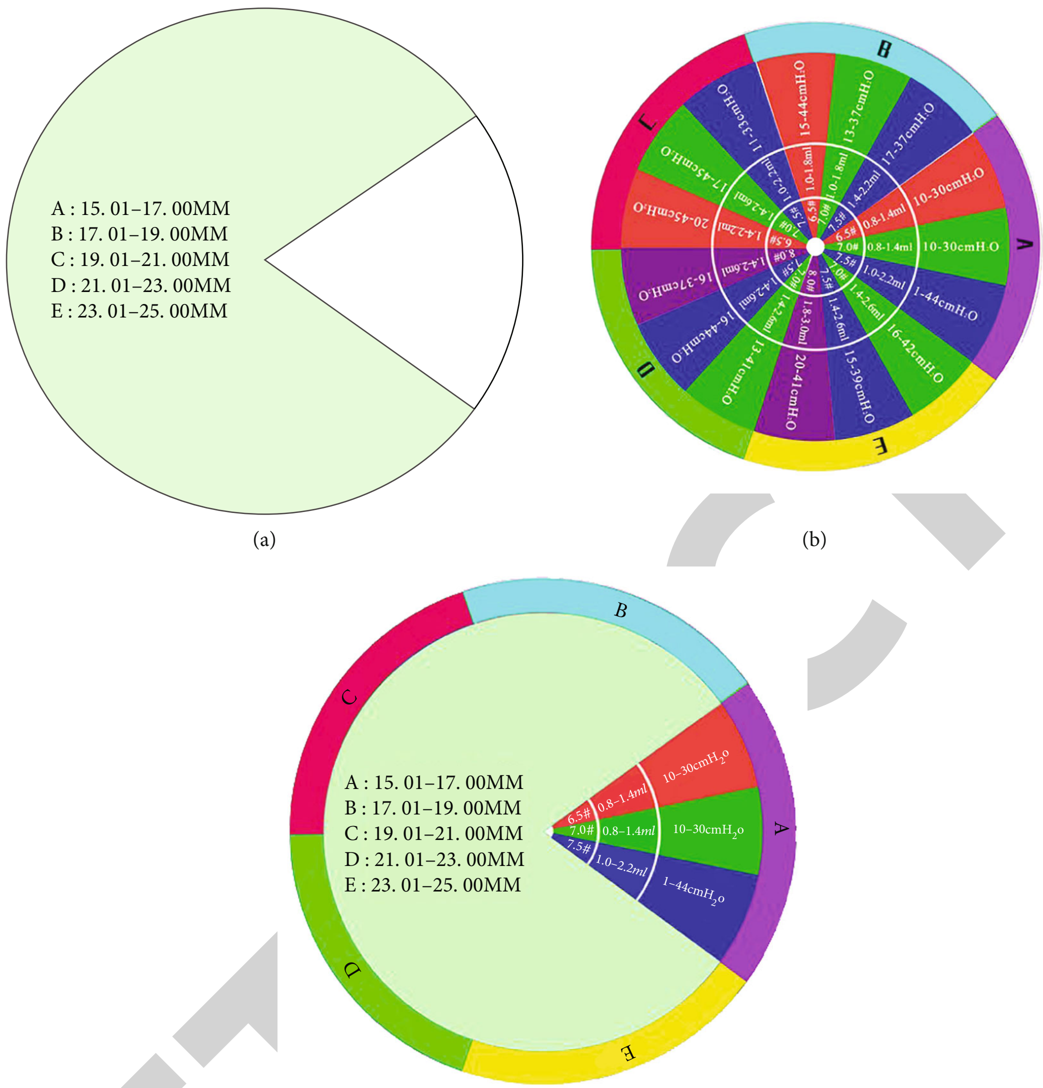


Figure 4: (a) The first page—trachea diameter grouping. (b) The second page—recommended best air injection volume and the pressure range to be achieved. (c) The final form is combined (a) and (b).

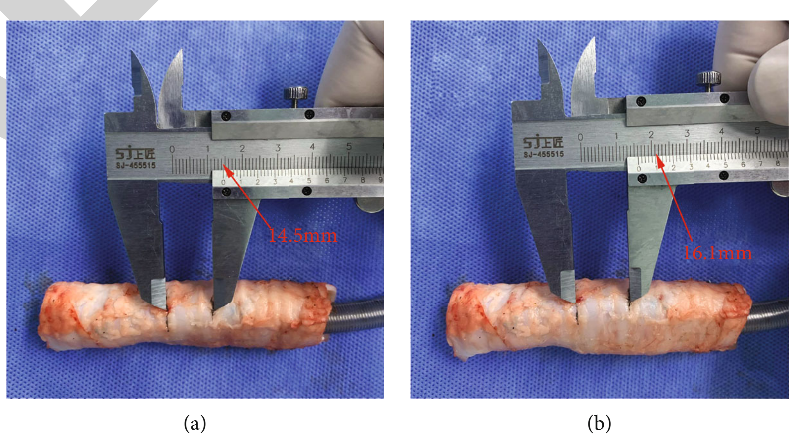


Figure 5: Variation of length of the same tracheal under different pressure of endotracheal tube cuff (red arrow).

100 cm H_2O, the cuff was not entirely in contact with the trachea, the tightness of the air was not satisfactory, and positive pressure ventilation caused air leakage. Considering the differences in the rate of endotracheal tube cuff pressure increase caused by tube size and tightness of air, we suggest that doctors and nurses should select normal or larger size for the tracheal tube when performing endotracheal intubation, but patients with tracheal stenosis have to be excluded. However, some researchers have pointed out that choosing a smaller size of the endotracheal tube may reduce the damage [33, 34]. Therefore, further studies are needed to choose the suitable size of the endotracheal tube.

During the experiment, we found that the increase in endotracheal tube cuff pressure caused tracheal longitudinal extension, and this degree of extension was proportional to the pressure (Figure 5). The surface of airway was formed by the capillaries which have a rich blood capillary network. When the extension of the trachea was too large, the blood capillaries deformed severely. When the pressure was extremely high, the capillaries could even rupture. However, further studies are needed to explore whether this situation would become another factor of iatrogenic injury by leading to ischemia or necrosis of the local mucosa.

4.1. Limitations. This study also had some limitations. The first limitation was the scarcity of data from previous studies. As many studies or research are not done till now to establish such a procedure, many related or similar research publications could not be found in the literature to support discussion. Second, although we completed the experiment 2 hours after procuring sheep trachea in order to simulate surgical conditions, the isolated tracheae may not have simulated the human tracheae completely. Furthermore, there are different brands of endotracheal tubes with different shapes, and this difference of endotracheal tubes may have also affected the accuracy of the obtained data.

5. Conclusion

Through analysis of the data and results of endotracheal tube cuff pressure and cuff air injection volume in this study, we found a strong correlation between them. Relying on the relationship between them, a series of formulas were summed up, which were classified according to tracheal diameter and endotracheal tube size. The medical turntable obtained by formula can serve to be a quick and effective method that can help in recommending the near accurate endotracheal tube cuff air injection volume to maintain the pressure of endotracheal tube cuff in the acceptable range.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The experimental protocol was established in accordance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals (NIH publications number 80–23, revised in 1996). The experiment was approved by the Medical Ethics Committee of First Affiliated Hospital, Shihezi University School of Medicine (A2019-095-01).

Conflicts of Interest

The authors have declared that no competing interests exist.

Authors' Contributions

Sheng Wang conceived and designed the experiments. Ruixue Wang, Xinlei Qin, and Wenyi Zhou performed the experiments. Zhengang Cao and Jingwen Zhai analyzed the data. Jiangwen Yin contributed reagents/materials/analysis tools. Ruixue Wang and Xinlei Qin wrote the paper. All authors reviewed the manuscript. Ruixue Wang and Xinlei Qin contributed equally to this work as co-first authors.

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