Tracheal Tube Cuff Pressure

– Study on Tube Size and Inflating Gases –

Masanobu MANABE, Iwao OOKAWA,
Yukio TANAKA and Teruo KUMAZAWA

The effect of nitrous oxide on the cuff pressure was studied from the following points of view. One was the size of tubes and the type of cuff. The other was the effects of different gas mixture in the cuff. The changes of the cuff pressure were investigated using four types of tubes such as the largest standard cuffed tube which could be passed through the glottis, the 1.0 mm less in I.D. standard cuffed tube, the largest profile cuffed tube, and the 1.0mm less in I.D. profile cffed tube. There was no difference between the profile cuffed tube goups but in the standard cuffed tube groups, the cuff pressure increased from the beginning in 1.0mm less I.D. tube group.

Air, inhalation anesthetic gas (nitrous oxide : oxygen = 3 : 2) and mixtured gas (inhalation anesthetic gas and air = 4:3) were used to inflate the cuff. The cuff pressure was measured at the same patients. In the group of anesthetic gas, the cuff pressure decreased and in some cases, there occured a leakage of gas. In the group of air, the cuff pressure increased as well as experiment I. However in the group of mixtured gas, there were almost no changes in the cuff pressure. This means that if the cuff is inflated with a mixtured gas in which nitrous oxide is under the equivalent condition, the cuff pressure would not change. (Key words: nitrous oxide, mixtured gas, cuff pressure, size of tubes, type of cuff)

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When choosing tracheal tubes for adult, it is said that the largest tube which can be passed through the glottis is best. One of the reasons is as follows. The less the volume of air in the cuff, the lower the intracuff pressure[1–3]. And there is less increase of nitrous oxide in the cuff[4]. And also a simple and safe way to prevent the increase of cuff pressure is to inflate the cuff with a mixture of nitrous oxide and oxygen. However, in this case, in the beginning, there is a lowering of the pressure and during mechanical ventilation, there is a risk of leakage[5].

This study was conducted to determine the influence of the size of tubes and the effect of different gas mixtures on the pressure of endotracheal tube cuffs in intubated patients.

Method

Experiment I: Experiments on the tube size and the type of cuff.

Five adult patients undergoing operations for legs or arms or lower abdomen, were selected for the study. The Portex tube was used, and cuff was filled with air. Cuff pressure was measured by the West German V.B.M. Cuff Pressure Measure. All patients were premedicated with diazepam 10 mg and atropine 0.5 mg 30 min before anesthesia. The patients underwent rapid induction using thiamylal (4–6 mg/kg) and S.C.C. (1 mg/kg) and were intubated.

Department of Anesthesia, Yamanashi Medical College, Yamanashi, Japan

Address reprint requests to Dr. Manabe: Department of Anesthesia, Yamanashi Medical College, 1110 Shimokato, Tamaho-cho, Nakakoma-gun, Yamanashi-ken 409-38, Japan

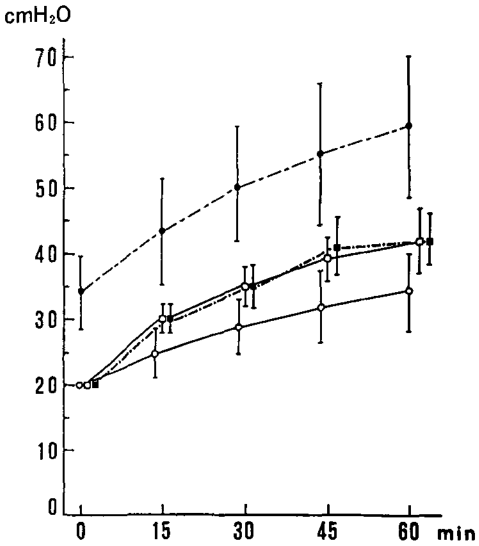

Fig. 1. The change of cuff pressure when the cuff was inflated with air
o : standard and the largest tube which can be passed through a glottis
• : standard and 1.0mm less in I.D.
□ : profile and the largest
■ : profile and 1.0mm less in I.D.
Intracuff pressure with standard cuff was changed greatly by the size of the tubes, but with profile cuff, there was no significant difference even by the size of the tubes.

In stage I, a standard cuffed tube of the largest diameter was used to pass through the glottis. In stage II, the inner diameter (I.D.) of the standard cuffed tube was 1.0mm less than in stage I. In stage III, profile cuffed tube with the same diameter as stage I was used. In stage IV, I.D. of the profile cuffed tube was 1.0mm less than in stage III.

The selections of the tubes were made by the same anesthesiologist. Each stage took one hour, and at starting time, the cuff pressure was set to 20 cmH_2O. If there was gas leakage, then air was infused until no leakage occurred. For each stage, the cuff pressure was measured at the start, 15, 30, 45, and 60 min. The anesthesia was maintained with 60 percent nitrous oxide, 37–40 percent oxygen and 0–3 percent enflurane or halothane. Ventilaltion was performed by anesthetic ventilator, and minute volume was determined by the author according to the table already published[6]. During each stage, sufficient intratracheal and oral suction were done. Each patient was intubated four times.

Experiment II: Experiment on gas mixture to inflate the cuff.

Portex profile cuffed tube was used. In stage I, air was used. In stage II, inhalated anesthetic gas was used. In stage III, mixtured gas (inhalation anesthetic gas: air = 4:3) was used to inflate the cuff. Stages I and III, each took 2 hours, stage II, one hour and between each stage, cuff and measuring circuit were washed 5–6 times by new gas. Aside from this, the method was the same as the experiment I.

Results

Experiment I: In stage II, when using the narrower tube for the standard cuff, to prevent the leakage of gas from between the cuff and tracheal wall, it was necessary to infuse an average of 3.9 ml of air, and also from the beginning, the cuff pressure of an average of 34 cmH_2O was necessary. In the other stages, if we have a cuff pressure of 20 cmH_2O, there was no gas leakage from between the tubes and the tracheal wall for all cases. In stages I and II where the I.D. of the standard cuff was 1.0mm different, there was a clearly significant difference in the cuff pressure. But in stage III and IV where the I.D. of the profile cuff was 1.0 mm different, there was no significant difference in the cuff pressure.

Experiment II: The volume of gas necessary to maintain the cuff pressure of 20 cmH_2O was 4.1 ± 1.0 ml. In stage I, using air as an experiment I, the cuff pressure increased time dependently. In stage II, using anesthetic gas which was the same as inhalation gas, when the cuff was inflated, gradually the cuff pressure decreased and in some cases, there was a leakage of gas from between the cuff and tracheal wall. Only in this stage, experiment terminated at 60 min. In stage III where the cuff was inflated by the mixtured gas (inhalation gas: air = 4:3), there was almost no change in the cuff pressure even after two hours.

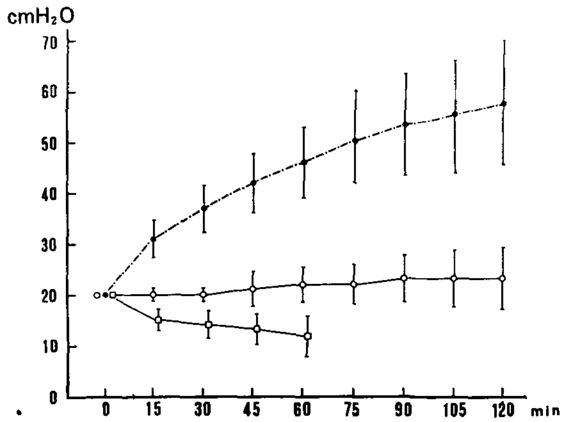

Fig. 2. Pressure change caused by various kinds of gases
● : air
□ : inhalation gas
○ : inhalation gas: air = 4:3
In air groups, the cuff pressure increased. In inhalation gas group, the cuff pressure decreased and in some cases there was a leakage of gas. In mixtured gas group, there was almost no changes in the cuff pressure.

Discussion

Reports of damage to the tracheal wall during general anesthesia are not uncommon[7,8]. It is mandatory to measure the intracuff pressure, which is recommended to be between 20 and 30 cmH_2O to provide a safe two-way seal against both air leakage and aspiration[9]. If the cuff is inflated with air and the patient is ventilated with a nitrous oxide and oxygen mixture, nitrous oxide will diffuse into the cuff and increase both cuff volume and intracuff pressure continuously for the first few hours[5].

Almost all papers which have discussed the effect of nitrous oxide on cuff pressure, have used a tube of same diameter which was intubated into each patient[5,10]. In such cases, the volume of gas within the cuff varied greatly. The authors used the Portex standard cuffed and the profile cuffed tubes. In our experiment, we compared tubes with the greatest diameter to pass through the glottis and those with I.D. 1.0mm less for a total of four times per patient. Using this method, we could see the effect of the large cuff versus small cuff and the effects of the diameters of the tubes.

Table 1. The change of intracuff pressure with various size of tubes and type of cuff

Stage	Air (ml)	Time (min)				
		start	15	30	45	60
I	2.1	20	25	28	32	34
II	3.9	34	43	50	55	59
III	3.8	20	30	35	39	42
IV	4.7	20	30	35	41	42

Table 2. The change of intracuff presure when the profile cuff was inflated with air or inhalation as (N_2O/O_2 = 60/40 %) or inhalation gas and air (4/3)

	Time (min)								
	start	15	30	45	60	75	90	105	120
(stage I)	20	31	37	42	46	50	53	55	57
(stage II)	20	15	14	13	12	—	—	—	—
(stage III)	20	20	20	21	22	22	23	23	23

We believe that this is the first report on this method. As shown in figure 1, when the cuff was inflated by air, in all four stages, the cuff pressure increased. In stage II using a narrow standard cuff, the usage of 20 cmH_2O was insufficient to prevent gas leakage.

And an average of 34 cmH_2O cuff pressure was necessary. In stage II, the increase in cuff pressure according to nitrous oxide was larger than in stage I using large tubes. And as a result, it was unfavorable for the patients. In the case of the profile cuff, I.D. 1.0mm less, there was no significant increase in cuff pressure. This is in accordance with Crowley et al.[11], who said that the advantages of a large volume low pressure cuff lies in sealing by low pressure along the trachea due to deform. However, the result of our experiment shows that this occurs due to setting the cuff pressure in the beginning at 20 cmH_2O. Kim et al.[12], warns as follows. Pressure injury caused by overinflating a large volume cuff will damage to the wide ranges of tracheal mucosa. If the cuff is inflated with air and the patient is ventilated with nitrous oxide and oxygen mixture,

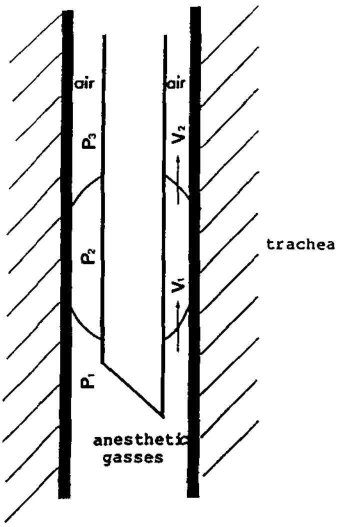

Fig. 3. Schematic illustration of the cuff pressure

P_1, P_2, and P_3 mean the partial pressure of the gas when the volume of the system is equivalent. P_1 is pulmonary side and P_2 intracuff and P_3 oral side respectively.

nitrous oxide will diffuse into the cuff and intracuff pressure will increase continuously. To prevent these effects, inflation of the cuff with saline or the mixtured gas which is the same as inhalation anesthetic gas should be used. According to Revenas et al.[5], if the cuff was inflated with nitrous oxide and oxygen, no pressure increase occurred. However, when their data were studied in detail, starting cuff pressure (70 mmHg) in small cuff group decreased to 62 mmHg after an average of 110 min. In large cuff group, although there was very little change, there was decrease 120 min after the start. Stage II of experiment showed this in our experiments. However, our results show the pressure decreased from 20 cmH_2O at the start and in some cases, there occured leakage.

Figure 3 shows $V_1 = K(P_1-P_2)S_1$, $V_2 = K(P_2-P_3)S_2$. K is a constant of specific membrane. S_1 is the cuff area of the pulmonary side. S_2 is the cuff area of the oral side. P_1, P_2, P_3 is the partial pressure of the gas when the volume of the system is equivalent. V_1, V_2 are the moved gas volume in unit time. At this point, the equivalent condition means that $V_1 = V_2$. Therefore $(P_1-P_2)S_1 = (P_2-P_3)S_2$. If we concentrate on the partial pressure of nitrous oxide, P_3 goes through the trachea to come in contact with the air. At this point, the partial pressure of nitrous oxide is always viewed as zero. Then $P_2 = \frac{S_1}{S_1+S_2}P_1$. Again, no matter what mixture of gas is infused, when an equivalent condition reached, $P_1>P_2$ and P_2 is not P_1 as long as S_2 is not zero. And the same can be said for oxygen and nitrogen, however diffusion of nitrous oxide is faster and so it is natural that in clinical anesthesia, we would concentrate only nitrous oxide. The authors proposed that the partial pressure of nitrous oxide in the cuff should be maintained from the beginning with the same as the pressure under an equivalent condition. And so, in the operating room, we used the two most available gases, inhalation anesthetic gas and air which were appropriately mixed. According to our preparatory test, the ratio was 4 to 3, inhalation gas to air and we conducted experiment II using that ratio. The results were obtained using the Portex tube which has the profile cuff, however if the difference between S_1 and S_2 mentioned before was not great, then the results of another tubes would be the same. When artificial ventilation was begun by inflating the cuff with air in the I.C.U., it is understandable from the above explanation that although there was no leakage in the beginning, after a period of time leakage would occur.

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