Inflation of tapered cuff with 10 mL air for tracheal intubation : An *in vitro* study

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[Abstract] Optimal cuff pressure is essential to avoid aspiration after tracheal intubation. In rapid sequence induction, one cuff filling method is to inject a fixed volume of 10 mL air and adjust immediately afterwards. However, this does not always ensure adequate initial cuff pressure. The aim of this study was to evaluate the initial cuff pressure of tapered-cuff tracheal tubes after injection of 10 mL air *in vitro*. For tracheal models with internal diameters (i.d.) of 18 mm, 19 mm, and 20 mm, the initial cuff pressure of the tapered-cuff tracheal tubes (i.d. 7.0 mm and 8.0 mm) exceeded 99 cmH₂O after injection of 10 mL air. For the tracheal model with i.d. of 22 mm, cuff pressures were 57±7.8 cmH₂O (i.d. 7.0 mm) and, 69.7±5.1 cmH₂O (i.d. 8.0 mm). All studied combinations showed considerably higher pressure than the ideal value of 25 cmH₂O. For tapered cuff, 10 mL air might be excessive.

Key Words : Cuff pressure, Tracheal tube, Tapered-cuff, Rapid sequence induction

Introduction

To avoid the risk of aspiration during rapid sequence induction, the use of a tracheal tube cuff with an optimal cuff pressure is essential. Some cuff filling methods have been described in textbooks and the research literature. In a Japanese textbook for perioperative management, the instruction is given : “inflate with more air than usual ; approximately 10 mL¹⁾.” Rahmani et al. compared the fixed volume and palpation techniques ; injection of a fixed volume of 10 mL air failed to achieve sufficient cuff pressure in 9.3 % of intubated patients²⁾, although the types of tubes used were not mentioned in their study. For a tapered

cuff, a cuff pressure of 25 cmH₂O is sufficient to seal the airway³⁾ because the cuff fits well to the trachea without folds. Shin et al. mentioned that a tapered cuff requires less air to achieve adequate cuff pressure compared with a high-volume, low-pressure cuff⁴⁾. Sakuraba et al. measured human tracheal diameter on CT images at a Japanese hospital (men : n=55, age 58±13 years ; women : n=91, age 59±15 years). Their study showed that the transverse width of the trachea was 17.4±1.7 (range 13.1–20.6) mm for men and 14.8±1.8 (range 10.5–20.9) mm for women⁵⁾. In our *in vitro* study, we used tracheal models of several sizes to investigate the initial cuff pressure of tapered cuff tracheal tubes

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after injection of 10 mL air.

Material and methods

Measurements were conducted in Ueda city Nagano prefecture, 450 m above sea level. The temperature was 27.1°C and atmospheric pressure was 952 hPa. We used tracheal models that were created using commercially available water hoses (soft polyvinyl chloride, internal diameter [i.d.] 18 mm, 19 mm, and 22 mm) and a water supply pipe (polyvinyl chloride, i.d. 20 mm), as well as tapered cuff (Taper) tracheal tubes (ShileyTM Endotracheal Tube with TaperGuardTM Cuff, Medtronic, Boulder, CO, USA) with i.d. 7.0 mm (lot No. 18E0447JZX) and 8.0 mm (lot No. 18E0082JZX). For reference, we used high-volume, low-pressure cuff (HVLP) tracheal tubes (PortexTM Cuffed Clear PVC Endotracheal Tube, Smiths Medical, Hythe, Kent, UK) with i.d. 7.0 mm (lot No. 3550279) and 8.0 mm (lot No. 3561584). The cuff pressure was measured with AG Cuffill (Medtronic, lot No. 100418). We inserted the tracheal tube in the tracheal model and injected 10 mL air into the tracheal cuff. We measured the initial pressure with AG Cuffill and then gradually drew air until the observed cuff pressure was 25 cmH₂O; the volume of air drawn was recorded. We repeated the measurement 3 times for each combination of the tracheal models with different internal diameters and tracheal tubes. Data were analyzed using Excel (Microsoft, Redmond, WA, USA). Comparisons of Taper and HVLP were performed using one-sided Welch's t-tests. A *P* value of < 0.05 was regarded as statistically significant.

Results

For the tracheal models with i.d. of 18 mm, the initial cuff pressure exceeded 99 cmH₂O using both

Taper and HVLP tubes. AG Cuffill showed “OP; out of range” when pressure exceeded 99 cmH₂O; therefore specific values of initial cuff pressures are unknown. For the tracheal models with i.d. of 19 mm, 20 mm, and 22 mm, the cuff pressures when using Taper tracheal tubes were higher than those when using HVLP tracheal tubes. The individual values are shown in Table 1. Data regarding air volume drawn to achieve 25 cmH₂O cuff pressure are presented in Table 2. The optimal cuff air volume is 10 mL minus the drawn air volume.

Discussion

Our *in vitro* study showed that 10 mL air is excessive for inflation of a Taper tracheal tube. For rapid sequence inductions with Taper tracheal tubes, “inflate with a sufficient volume of air” might be a better expression than “inflate with approximately 10 mL air.” If a manometer is available, inflation by manometer could be a viable alternative method, because the human tracheal diameter is distributed over a wide range⁵⁾. Limitations of this study were that the maximum diameter of our tracheal model was 22 mm, and the compliance of the tracheal models in this study might differ from that of a human trachea in a clinical setting. Further studies are needed to establish an ideal cuff inflation method for rapid sequence induction.

These results were presented in the second Airway Management Conference (2018, Tokyo).

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Table 1 Cuff pressure after injection of 10 mL air

Tracheal model i.d. (mm)	18	19	20	22
Cuff pressure (cmH ₂ O)				
Tracheal tube i.d. 7.0 mm				
Taper	>99	>99 *	>99 *	57.0 ± 7.8 *
HVLP	>99	83.0 ± 6.7	61.0 ± 3.5	32.0 ± 2.5
Tracheal tube i.d. 8.0 mm				
Taper	>99	>99	>99	69.7 ± 5.1 *
HVLP	>99	>99	>99	49.5 ± 3.5

Values are presented as mean±SD

* $P < 0.05$

Taper : tapered cuff, HVLP : high-volume, low-pressure cuff

Table 2 Drawn air volume needed to achieve 25 cmH₂O

Tracheal model i.d. (mm)	18	19	20	22
Drawn air volume (mL)				
Tracheal tube i.d. 7.0 mm				
Taper	3.4 ± 0.3	2.1 ± 0.4 *	1.6 ± 0.2 *	0.5 ± 0.1 *
HVLP	3.1 ± 0.2	1.4 ± 0.2	1.0 ± 0.2	0.3 ± 0.1
Tracheal tube i.d. 8.0 mm				
Taper	4.1 ± 0.2	2.5 ± 0.2	1.9 ± 0.1	0.7 ± 0.1
HVLP	3.6 ± 0.4	2.3 ± 0.1	1.9 ± 0.1	0.6 ± 0.1

Values are presented as mean±SD

* $P < 0.05$ (Taper vs HVLP)

Taper : tapered cuff, HVLP : high-volume, low-pressure cuff

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気管挿管時に10mLの空気をテーパーカフに注入したカフ圧 —模擬気道を用いた検討—

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気管挿管後の誤嚥を防ぐためには適切なカフ圧が必要である。迅速導入時に10mLの空気を注入してから調整するという手法があるがそのカフ圧は不明である。本研究では模擬気道を用いてテーパーカフに10mLの空気を注入した時のカフ圧を測定した。内径18mm, 19mm, 20mmの模擬気道で、気管チューブ内径7.0mm, 8.0mmともにカフ圧は99cmH₂Oを越えた。内径22mmの模擬気道では57±7.8cmH₂O(気管チューブ内径7.0mm), 69.7±5.1cmH₂O(気管チューブ内径8.0mm)のカフ圧であった。すべての組み合わせで適正圧の25cmH₂Oを大幅に上回った。

キーワード: カフ圧, 気管チューブ, テーパーカフ, 迅速導入

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