Effect of Cuff Pressure Elevation on Internal Diameter of Tracheal Tube in Simulated Trachea

Yukiko Matsuki1, Nobuyuki Matsuura1 and Tatsuya Ichinohe1,2

1) Department of Dental Anesthesiology, Chiba Hospital of Tokyo Dental College, 1-2-2 Masago, Mihama-ku, Chiba 261-8502, Japan
2) Department of Dental Anesthesiology, Tokyo Dental College, 2-9-18 Misaki-cho, Chiyoda-ku, Tokyo 101-0061, Japan

Received 25 June, 2015/Accepted for publication 25 August, 2015

Abstract

Application of nitrous oxide during anesthesia causes an increase in tracheal tube cuff pressure over time. The purpose of this study was to investigate the effect of an increase in cuff pressure on 3 types of tube (the Portex, Mallinckrodt, and Parker) commonly used for nasotracheal intubation. A cylindrical vessel was used to simulate a trachea. Cuff pressure was set at 0 cmH2O (R0) or 20 cmH2O (R20) at room temperature, or at 20 cmH2O (H20), 40 cmH2O (H40), 60 cmH2O (H60), or 80 cmH2O (H80) in 38°C hot water and pressure applied for 30 min. The value obtained at R0 was used as a reference (100%) and the rate of change under each condition determined.

No change was observed at R20 in any of the 3 groups. In 38°C hot water, internal diameter in the Portex group decreased by 5.4% at H20 and 7.3% at H40, while that in the Mallinckrodt group decreased by 6% at H40. No significant change was observed in internal diameter in the Parker group, even when cuff pressure was increased.

The internal diameter in the Portex group was the smallest at all cuff pressures in hot water. When the nasotracheal intubation tubes selected were placed in a simulated trachea and cuff pressure increased, internal diameter in the Portex and Mallinckrodt groups decreased.

Key words: Tracheal tube — Cuff pressure — Diameter

Introduction

Use of nitrous oxide during anesthesia leads to an increase in tracheal tube cuff pressure over time. This can impair mucosal blood flow, which has been reported to cause post-anesthesia sore throat and tracheal mucosal damage.

Nasal is often chosen over oral intubation during oral surgery to prevent bleeding, as the tube used in the former is more flexible. This flexibility, however, means that any increase in cuff pressure might not only damage the tracheal mucosa, but also result in deformation or constriction of the tube itself, although this remains to be demonstrated.

The purpose of this study was to investigate change in the internal diameter of 3 types
of tracheal tube used for nasotracheal intubation by increasing cuff pressure within a cylindrical vessel designed to simulate a trachea.

Methods

Ten of each of the following 3 types of tracheal tube were used, all with an internal diameter of 7.5 mm: the Portex™ Tracheal Tube with Profile Soft Seal® Cuff Ivory PVC Nasal (Portex group); the Mallinckrodt™ Nasal RAE™ Tracheal Tube with TaperGuard™ Cuff (Mallinckrodt group); and the Parker Flex-Tip® Tracheal Tube PFNC (Preformed Nasal Cuffed) (Parker group). A Terumo 20-ml syringe with an internal diameter of 20 mm was severed at the needle end to produce a simple cylinder for simulation of a trachea. The tracheal tube was inserted so that the tip of the cuff was located at a point 6 mm from the severed end (Fig. 1). Cuff pressure was measured by using a VBM® cuff pressure gauge (Smiths Medical, United States). The tracheal tube was warmed in a water bath (YM-1200-NB yogurt maker: Tanica Electric Company, Japan) with the water temperature set at 38°C.

Cuff pressure was set at 0 cmH2O (R0) or 20 cmH2O (R20) at room temperature, or at 20 cmH2O (H20), 40 cmH2O (H40), 60 cmH2O (H60), or 80 cmH2O (H80) in 38°C hot water and pressure applied for 30 min. After pressurization for 30 min, a camera set up at a distance of 10 cm from the tube tip was used to photograph the tracheal tube lumen, and the minimum internal diameters of the tube were measured. The value at R0 was used as the reference value (100%) and the rate of change under each condition determined.

A repeated-measures ANOVA was used for intragroup comparisons, and the Dunnett test for multiple comparisons. A non-repeated measures ANOVA was used for intergroup comparisons, and the SNK test for multiple comparisons. The level of significance was set at p<0.05.

Results

The results are shown in Fig. 2.

1. Intragroup comparison

No change was observed in the internal diameter of the tube at a pressure of 20 cmH2O at room temperature in any of the 3 groups. In 38°C water, the internal diameter in the Portex group decreased by 5.4% (4.0–7.5%) at a pressure of 20 cmH2O, and by 7.3% (5.1–9.6%) at a pressure of 40 cmH2O, showing a maximum decrease of 13.4% (p<0.001). No significant change was observed in internal
diameter in the Mallinckrodt group at a pressure of 20 cmH₂O; at a pressure of 40 cmH₂O, however, it showed a decrease of 6% (0–9.3%, p<0.001). No significant change was observed in internal diameter in the Parker group, even when cuff pressure increased (p=0.75).

2. Intergroup comparison
The internal diameter in the Portex group was smallest at all cuff pressures exposed to heated water (p<0.001).

Discussion
The results of this study showed that the internal diameter in the Portex and Mallinckrodt groups decreased with increase in cuff pressure, with an approximate rate of decrease of 6–7% at a clinical cuff pressure of between 20 cmH₂O and 40 cmH₂O.

According to the information provided, the appropriate cuff pressures for the 3 types of tracheal tube used in this study are between 27 cmH₂O and 34 cmH₂O for the Portex and Parker tubes, and <25 cmH₂O for the Mallinckrodt tube. This suggests that the internal diameter in Portex-type tubes may decrease by approximately 5–7% at cuff pressures commonly seen in clinical practice. The Hagen-Poiseuille law states that the volume of a fluid flowing through a pipe is proportional to the fourth power of the radius, which means that a 7% reduction in the internal diameter will decrease flow to approximately 75% of its original value. Put another way, resistance rises by approximately 35%. In the event of a 13% reduction in internal diameter, the maximum value seen in this study, the flow would drop to around 57% of its original value, and resistance rise by approximately 75%. This would prolong the duration of the expiratory phase, and if sufficient expiration time could not be assured, then intrathoracic pressure might rise, decreasing cardiac output and potentially causing a drop in blood pressure.

The flexibility of tracheal tubes is an important factor in preventing nasal bleeding and other intranasal complications during nasal intubation. Here, however, a decrease of approximately 5% was observed in internal diameter merely as a result of warming, especially in the Portex-type tubes, even at a cuff pressure of only 20 cmH₂O. This decrease would probably be even greater if nitrous oxide were used. When general anesthesia with 50% nitrous oxide was maintained, cuff pressure was found to rise from a reference value of 36 ± 5 cmH₂O to 81 ± 22 cmH₂O after 180 min. Another study found that when 67% nitrous oxide was used, cuff pressure rose from a reference value of 22 cmH₂O to 47.5 cmH₂O after 60 min. These results suggest that attention must be paid not only to damage to the tracheal mucosa, but also to a decrease in the internal diameter of the tube as a result of cuff pressure elevation during general anesthesia with nitrous oxide. While monitoring vital signs, it is important to continually check cuff pressure as well as airway pressure if this is to be avoided, and use of a cuff pressure release valve may also be of value.

All the tracheal tubes used in this study contained polyvinyl chloride resin with bis (2-ethylhexyl) phthalate (DEHP) as a plasticizer. Accordingly, differences in the mechanical properties of the tube materials may have been due to differences in the proportions of other ingredients, although the details are unknown. Tube stenosis may also have been influenced by the shape or compliance of the cuff. The Parker tubes used in this study had a cylindrical cuff, while the other types had a spherical cuff. No detailed information was given by the manufacturer, however, regarding the materials or mechanical properties of the cuffs.

In conclusion, the present results showed that when Portex, Mallinckrodt, or Parker nasotracheal intubation tubes were placed in a model trachea and cuff pressure increased, the internal diameter of the Portex and Mallinckrodt tubes decreased. The rate of decrease was greatest in the Portex tubes.
References


Correspondence:
Dr. Yukiko Matsuki
Department of Dental Anesthesiology,
Tokyo Dental College,
1-2-2 Masago, Mihama-ku,
Chiba 261-8502, Japan
E-mail: ymatsuki@tdc.ac.jp