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Use of a processed endotracheal tube in general anesthesia for palatoplasty in a patient with subglottic stenosis

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Introduction

In patients with subglottic stenosis who undergo surgery not directly related to the stenotic region, it is important to prevent subglottic edema [1]. Especially during anesthetic management for palatoplasty, the endotracheal tube can frequently move because of the change of head and jaw position [2] and adjustment of the mouth opener with a tongue depressor. These motions increase the possibility of subglottic edema by mechanical stimulation [3–5]. Therefore, the part of the endotracheal tube located in the trachea should be thin and soft. However, an excessively thin and soft tube is easily kinked and obstructed at the excluded part of the tube, and an excessively thin preformed tube is short from the bending site to the tip. Therefore, the endotracheal tube to be used should be thinner than the stenotic region while maintaining the largest possible lumen, moderately soft, and long enough not to fall out.

In this case, we performed general anesthesia for palatoplasty in a child with subglottic stenosis using a processed endotracheal tube, the tip of which was made elliptical to resemble the stenotic lumen by pressure and heating to satisfy the conditions mentioned above.

Case report

A girl aged 5 years and 11 months, 16 kg in weight, and 101 cm in height, was scheduled to have palatoplasty under general anesthesia. She was diagnosed as having a cleft palate immediately after birth, velo-cardiac-facial syndrome at 2 years, and mild mental retardation at 3 years. Tracheal intubation failed, first for palatoplasty in a general hospital at 1 year and 6 months, and second for intensive dental treatment in our hospital at 3 years and 4 months. As for the former, after close examination, the patient was diagnosed as having tracheostenosis caused by pressure of the brachiocephalic trunk. Computed tomography (CT) revealed disappearance of the stenosis at 3 years and 1 month. In the latter trial, a nasal endotracheal tube with an inner diameter of 4.0 mm could not be inserted, and swelling of the glottic region was significant, despite gentle operation for intubation. Therefore, we decided that the time for the surgeries should depend on the growth of her trachea. The patient was hospitalized again at 5 years and 11 months. Stenosis in the tracheal lumen at 3–12 mm below the glottis was found in the CT images of the airway sliced at intervals of 3 mm. The most severe stenosis was located 6 mm below the glottis. It was elliptical due to the pressure from both sides, with a minor axis of 5 mm and a major axis of 9 mm (Fig. 1). No abnormalities were detected by chest radiography, electrocardiography, and other examinations.

We chose an oral tube with an inner diameter of 4.0 mm (outer diameter, 5.4 mm; distance between the tube tip and the bending site, 12 cm; Polar Preformed Tracheal Tube, Portex, Hythe, UK), and processed its end 4 cm in length from the tip by pressure and heating to make the cross section elliptical (Fig. 2). A diagram of the pressure on the tube is shown in Fig. 3. Heating of the tube was performed in a drying oven at 85°C for 5 min, after which the tube was cooled in a refrigerator for 10 min and then kept at room temperature. The processed tubes had an outer minor diameter of 4.6 mm, an outer major diameter of 6.6 mm, an inner minor diameter of 3.2 mm, and an inner major diameter of 5.2 mm. The part of the tube around the bending site

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that comes in direct contact with a tongue depressor during surgery was covered with a metal protector that we made by cutting out an angled connector to an endotracheal tube with an inner diameter of 6.0 mm (Aika, Matsudo, Japan). The parents of the patient gave their consent for the use of the processed tube.

Prior to the clinical use of the processed tube, the properties of a tube of the same type that had been heated by the above procedures were evaluated. Three-point bending tests [6] of the tubes (supporting point distance, 14 mm) were performed using a universal test machine (Model 4204, Instron, Boston, MA, USA). The relationship between load and displacement at displacement levels of 0–2 mm was determined and was regarded as representing the elasticity (Fig. 4). The elasticity of a tube of the same type that had not been heated and that of a nasal tube (Portex) were also examined for comparison. The elasticity of the heated tube was about 60% of that of the nonheated one and 75%–89% of that of the nasal tube, indicating that the heated tube was moderately soft. The tube processed by pressure and heating was further tested by immersion in water at 37°C for 15 h. There was neither reversal of the diameter to the original one nor a change in the diameter after larger pressures were applied.

Six milligrams of dexamethasone was administered intramuscularly 45 min before induction. Anesthesia was induced with nitrous oxide, oxygen, and sevoflurane, and the processed tube was smoothly intubated orally after injection of 1.5 mg of vecuronium bromide. The tube was fixed to the genial skin with tape, after the marker of the bending site was located in accordance with the anterior teeth of the mandible. After air leakage had been confirmed at an airway pressure below 20 cm H_2O, packing gauze was inserted into the pharynx. Anesthesia was maintained with nitrous oxide and sevoflurane under controlled ventilation. At the end of surgery, 6 mg of dexamethasone was administered intravenously. Immediately after the patient reacted to the sound of her name postoperatively, the tube was removed. Postoperatively, dexamethasone 3 mg was administered intravenously three times every 8 h. Inhalation therapy using 0.2 mg salbutamol sulfate and 0.1 mg dexamethasone was performed 3 times per day for 3 days. Symptoms of subglottic edema, such as stridor or dyspnea, were not observed.

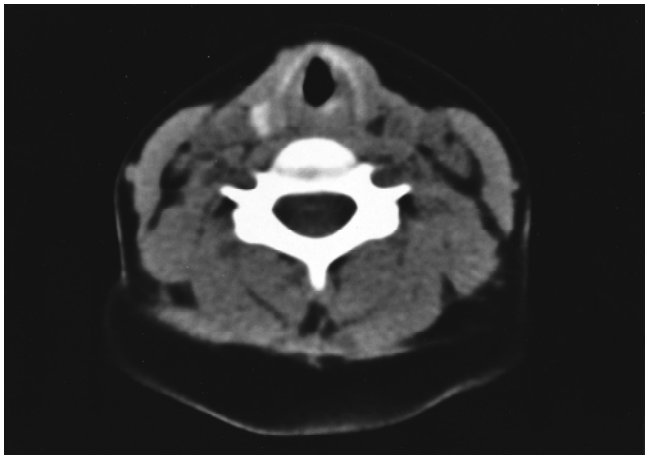


Fig. 1. CT images of the tracheal lumen 6 mm below the glottis. Elliptical stenosis with a minor axis of 5 mm is seen

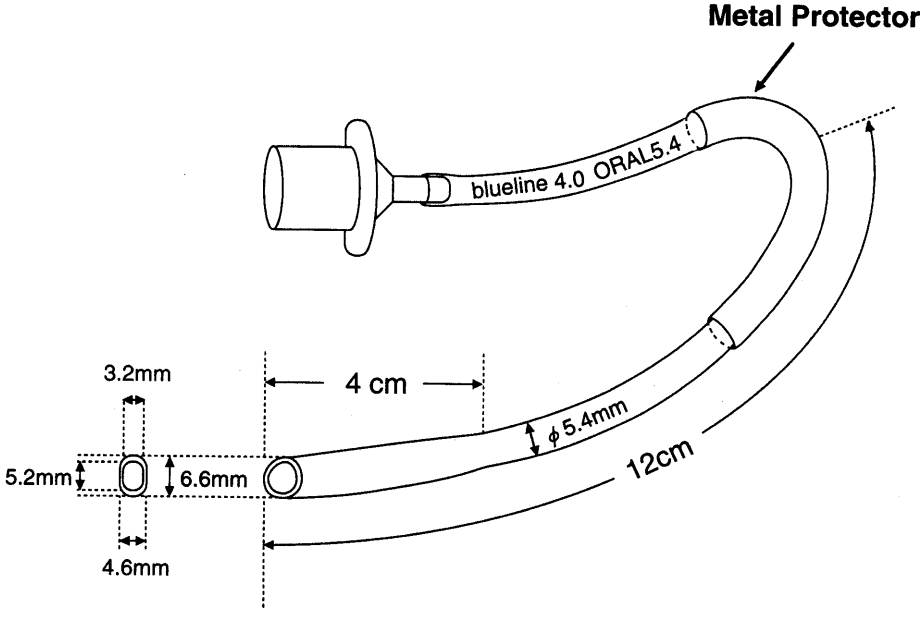


Fig. 2. Processed endotracheal tube. The tube was processed 4 cm in length from the tip by pressure and heating to make the cross section elliptical (outer minor diameter, 4.6 mm). The part of the tube around the bending site is covered with a metal protector

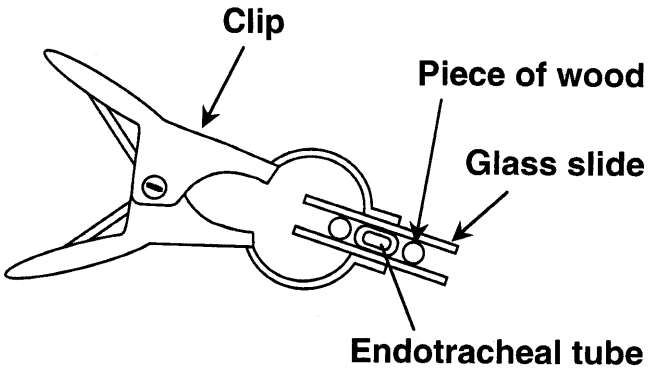
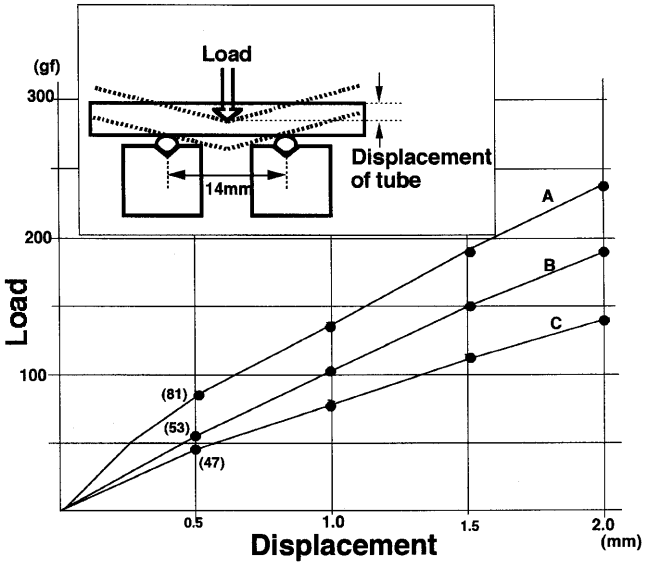


Fig. 3. Diagram of the pressure on the endotracheal tube. The tube was sandwiched by glass slides, then clipped



Ratio of load	C/A	0.58 (47/81)	0.60	0.59	0.59
	C/B	0.89 (47/53)	0.82	0.77	0.75

Fig. 4. Three-point bending test of the endotracheal tubes. *A*, Oral tube not heated; *B*, nasal tube not heated; *C*, oral tube heated. The ratio of load is proportional to that of the modulus of elasticity of the tubes in these conditions. The elasticity of the heated tube (85°C) was about 60% of that of the nonheated one (22°C) and 75%–89% of that of the nonheated nasal tube, indicating that the heated tube was moderately soft

Discussion

The patient had a stenotic region in the trachea lumen 3–12 mm below the glottis. It is unclear whether this stenotic region was congenital or acquired. If it did not exist before anesthesia at 1 year and 6 months, it might have resulted from the injury of the subglottic trachea during the first difficult intubation and deterioration of the injury due to repeated respiratory infections. However, it is clear from the clinical process that the stenotic region already existed before the second difficult intubation at 3 years and 4 months.

The minor diameter of the stenosis in this patient was 5 mm, which was comparable to the outer diameter of an endotracheal tube with an inner diameter of 3.5 mm. Because the diameter of the stenosis was determined from the CT images of the airway sliced at intervals of 3 mm, it could have been even smaller. We used a tube with an inner diameter of 4.0 mm, the tip of which was made elliptical by pressure and heating to resemble the stenotic lumen. The elasticity of the processed tube was 60% of the original one, showing softness. The tube was not thought to be so soft that its lumen would be easily occluded, because its elasticity was 75%–89% of that of a nonprocessed nasal tube. The luminal area of the processed tubes was reduced to 0.92 of the area of a nonprocessed tube, whereas it was 1.2-fold larger than that of a tube with an inner diameter of 3.5 mm. The largest possible luminal area of the tube, even if the difference is small, is considered advantageous for children with tracheostenosis. Because the distance from the vocal cords to the anterior teeth of the mandible calculated from CT in the girl was 85 mm, the vocal cords were thought to be located at the part of the processed tube 35 mm from the tip. Sugiyama et al. [2] studied the relationship between the head or jaw position and movement of the endotracheal tube in adults. If their results can be applied to a 5-year-old child, the moving distance of the processed tube inserted was calculated to be about 16 mm (two-thirds that of adults) when the head was bent 45 degrees backward with her mouth closed. Therefore, the tube was thought not to be pulled out even with maximal movement. Nishijima et al. [7] reported the use of a tube with an inner diameter of 5.5 mm into which an endotracheal tube with an inner diameter of 4 mm had been inserted and adhered for a patient with tracheostenosis. The material of the tube was the same as that used in the present study. Therefore, a heated and pressed tube with an inner diameter of 4 mm inserted into a non-processed tube with an inner diameter of 5.5 mm would be ideal for the present patient, although processing at two sites would be necessary to make it. This is because the use of such processed tubes would prevent bending of the tube by a tongue depressor and falling out of a sufficiently long tube, as well as subglottic edema.

In summary, a moderately soft endotracheal tube, the lumen of the distal region of which had been made elliptical by pressure and heating to resemble the stenotic lumen, was useful for the prevention of subglottic edema.

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