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Short communications

Effect of tube guide assembly of closed suction system on airway pressure gradient

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The removal of secretions from the tracheobronchial tree of a mechanically ventilated patient is indispensable for cleaning the lung and preventing pulmonary complications. The conventional open suction system requires that the patient be disconnected from the ventilator circuit during tracheal suctioning. Many complications can arise during tracheal suctioning using the open suction system. A closed suction system, which was developed in the 1980s to prevent the adverse effects of the open suction system, can maintain the connection between the patient and the ventilator circuit during tracheal suctioning. This closed suction system is placed between the tracheal tube (TT) and the Y-piece of the ventilator circuit during respiratory management.

With careful observation of the closed suction system, it is apparent that the guide assembly of the suction tube protrudes into the L-connector (Fig. 1). We hypothesized that this protruding assembly would narrow the internal diameter (ID) of the L-connector, increasing the resistance and airway pressure gradient of the ventilator circuit during respiratory management. Although there is a report concerning the effect on airway pressure gradient of the insertion of the suction catheter into the TT during tracheal suctioning [1], there is no report on the effect of the tube guide assembly itself on the airway pressure gradient during respiratory management. In this study, we assessed the effect of the tube guide assembly on the airway pressure gradient, using a test lung and the method of Guttmann et al. [2].

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We connected a Dual Adult TTL model 1600 test lung (Michigan Instruments, Grand Rapids, MI, USA), a pressure and flow sensor (OMR; Nihon Kohden, Tokyo, Japan), a TT (Mallinckrodt, St. Louis, MO, USA), another sensor, and an Evita 4 ventilator (Drägerwerk, Lubeck, Germany) in series (Fig. 2). Two kinds of TT (with IDs of 6.5 and 8.5 mm) were used for this experiment. The distal side of each TT was set inside a plastic tube, which was connected to the test lung. The cuff was inflated with air to prevent leakage, and the proximal side of each TT was connected to the respiratory circuit of the Evita 4.

We used the original Ballard Trach Care Directional Tip Closed Suction System for 12-Fr catheter (Ballard Medical Products, Midvale, UT, USA), and a modified closed suction system, in which the tube guide assembly in the L-connector was removed (Fig. 1).

The settings of the Evita 4 ventilator were: tidal volume, 600 ml; respiratory frequency, 12 breaths·min^{-1}, inspiratory time, 1 s (with attenuation wave); $F_{I_{O2}}$, 0.21, inspiratory pause, 0%, and positive end-expiratory pressure (PEEP), 0 cmH_2O. The resistance and compliance of the test lung were set at 20 $cmH_2O \cdot l^{-1} \cdot s^{-1}$ and 0.05 $l \cdot cmH_2O^{-1}$, respectively.

The airway pressures were measured simultaneously at the proximal side of the closed suction system (P_2) and the distal site of the TT (P_1), and the flow was measured at the proximal site. Three signals (two pressures and one flow) were recorded simultaneously with a Power Book G3 (Apple Computer, Cupertino, CA, USA) via a MacLab AD converter (AD Instruments) at a sample rate of 100 Hz. We calculated and analyzed the relationship between the airway pressure and the flow using Chart v3.6.4B5/s (AD Instruments) and Microsoft Excel (Microsoft, Redmond, WA, USA) for every breath.

It has been reported that the pressure gradient across the TT (P_{TT}) has a nonlinear dependence on the flow generated by the ventilator [2]. This relationship is expressed in the quadratic approximating formulas: $P_{TT} = K_1 \times \text{flow} + K_2 \times \text{flow}^2$ (where K_1 and K_2 are coefficients). We calculated the P_{TT} of the inspiratory and expiratory phases from the formula: P_{TT} of the inspiratory phase $= P_2 - P_1$, and the P_{TT} of the expiratory phase $= P_1 - P_2$. The approximating formulas for the relationship between the P_{TT} and the flow of the inspiratory and expiratory phases were calculated by polynomial regression through zero, using StatView-J5.0 (SAS Institute, Cary, NC, USA). Data from six consecutive breaths were analyzed and averaged. Data values were expressed as means ± SDs. Statistical analyses were performed with Student's unpaired *t*-test. A *P* value of less than 0.05 was considered to be significant.

All relationships between P_{TT} and flow could be expressed as a quadratic approximating formula: $P_{TT} = K_1$ flow $+ K_2$ flow^2. The pertinent values of K_1 and K_2 in all conditions are shown in Table 1.

The calculated values of the airway pressure gradient, based on the mean flow rates, are shown in Table 2. When the flow was the same, the calculated airway pressure gradients of the original system were significantly higher than those of the modified system for both sizes of the TT ($P < 0.05$, for both). But, in the inspiratory and expiratory phases, the differences in the calculated airway pressure gradients of the original system and the modified system were negligible from the standpoint of clinical practice.

It has been reported that the closed suction system can avoid decreasing lung volume [3] and hypoxemia [4] during tracheal suctioning and that this system can decrease the rate of nosocomial pneumonia in mechani-

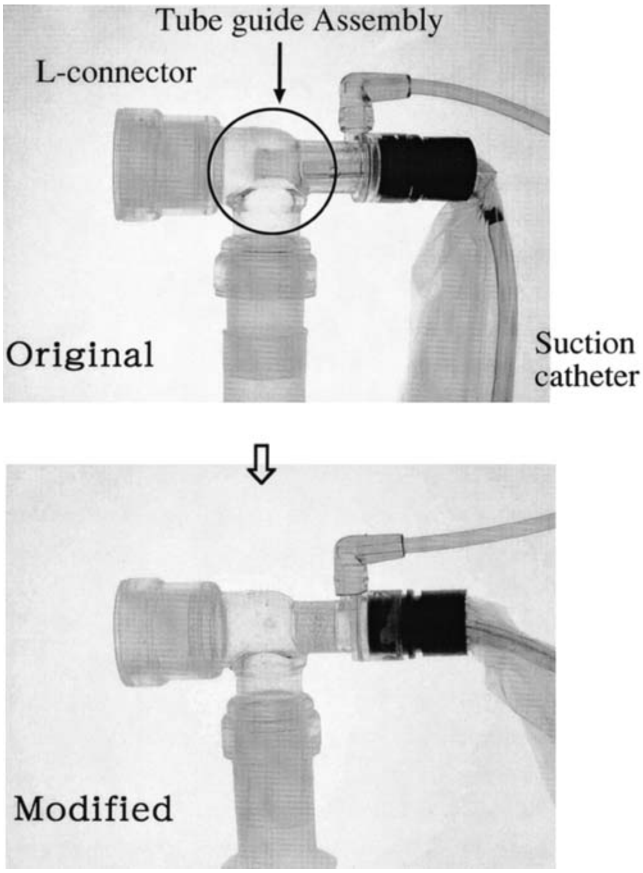

Fig. 1. The tube guide assembly of the closed suction system. The original closed suction system (*upper*). The modified system (*lower*), in which the tube guide assembly in the L-connector was removed

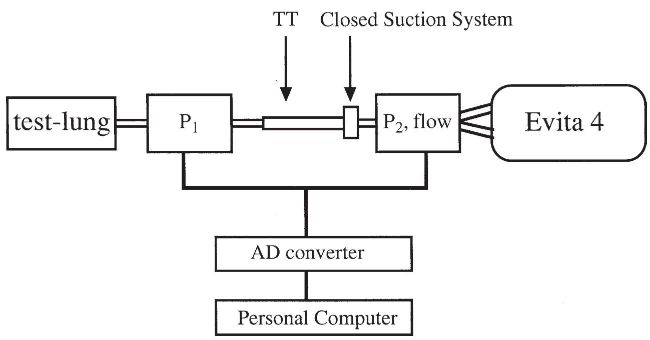

Fig. 2. Schematic diagram of the experiment. The test lung, a pressure sensor (P_1), tracheal tube (*TT*), a second pressure sensor (P_2), a flow sensor, and an Evita 4 ventilator were connected in series; *AD converter* (AD Instruments)

Table 1. Values of K_1 and K_2

		Original		Modified	
	TT size (mm)	K_1	K_2	K_1	K_2
Inspiratory phase	6.5	5.773 ± 0.376	4.916 ± 0.387	5.169 ± 0.248*	5.034 ± 0.528
	8.5	3.453 ± 0.091	1.648 ± 0.115	3.248 ± 0.067*	1.295 ± 0.073*
Expiratory phase	6.5	1.196 ± 0.229	13.699 ± 0.434	1.451 ± 0.262*	12.155 ± 0.545
	8.5	0.491 ± 0.126	5.306 ± 0.203	0.676 ± 0.175	4.495 ± 0.301*

* $P < 0.05$ vs original
Values are means ± SD
Original, original Ballard Trach Care Directional Tip Closed Suction System; Modified, system in which the tube guide assembly was removed; TT, tracheal tube

Table 2. Calculated values of airway pressure gradient

	TT size (mm)		Flow (l·s⁻¹) 0.5	1.0	1.5	2.0
Inspiratory phase	6.5	Original	4.12 ± 0.09	10.69 ± 0.06	19.72 ± 0.32	31.21 ± 0.81
		Modified	3.89 ± 0.05*	10.37 ± 0.05*	19.45 ± 0.29	31.14 ± 0.67
	8.5	Original	2.14 ± 0.02	5.10 ± 0.03	8.89 ± 0.13	13.50 ± 0.28
		Modified	1.95 ± 0.02*	4.54 ± 0.02*	7.79 ± 0.07*	11.68 ± 0.16*
Expiratory phase	6.5	Original	4.02 ± 0.05	14.90 ± 0.25	32.62 ± 0.69	57.19 ± 1.34
		Modified	3.76 ± 0.04*	13.61 ± 0.30*	29.69 ± 0.81*	51.52 ± 1.68*
	8.5	Original	1.57 ± 0.02	5.80 ± 0.08	12.68 ± 0.27	22.21 ± 0.57
		Modified	1.46 ± 0.02*	5.17 ± 0.13*	11.13 ± 0.42*	19.33 ± 0.86*

* $P < 0.05$ vs original
Values are means ± SD
Original, original Ballard Trach Care Directional Tip Closed Suction System; Modified, system in which the tube guide assembly was removed

cally ventilated patients [5]. This system is widely used throughout the world.

Because the external diameter of the tube guide assembly is about 7.0 mm, this assembly narrows the internal diameter of the L-connector and increases the resistance of the ventilator circuit. In this study, we used the method of Guttmann et al. [2] to examine the effect of the tube guide assembly on the resistance of the ventilator in both the inspiratory and expiratory phases, during respiratory care.

In both the inspiratory and expiratory phases, it was found that the tube guide assembly of the closed suction system instigated a higher airway pressure gradient at the same flow rate in comparison with the modified system, in which the tube guide assembly was removed. However, the differences in airway pressure gradient were very small and clinically insignificant.

In conclusion, for a given tracheal tube size, the tube guide assembly of the closed suction system showed a statistically significant increase in respiratory resistance and pressure gradient, but these effects this seemed to be clinically negligible.

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