# Abnormally Increased Power of Breathing as a Complication of Closed Endotracheal Suction Catheter Systems

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## Introduction

Tracheobronchial suctioning is an essential part of routine care for mechanically ventilated patients. Closed, rather than open, suction catheters are preferred for their advantages, which include minimizing risk of hypoxemia and containment of potentially infected secretions during suctioning.[1,2]

A closed-suction catheter is situated between the endotracheal tube (ETT) and the Y-piece of the breathing circuit, and thereby remains integrated in the circuit at all times. After suctioning, the catheter is retracted from the ETT into the suction catheter's protective sleeve and is thus out of the airflow path to and from the ETT and breathing circuit. We report a case where the tip of a closed-suction catheter was inadvertently left in the tracheostomy tube, thereby increasing the patient's work of breathing (WOB), evidenced clinically only by increased effort to breathe.

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## Case Report

A 74-year-old man (body weight 68 kg) was admitted to the surgical intensive care unit with sepsis due to an infected aorto-bifemoral artery graft. He was intubated for respiratory failure on admission. The infected arterial graft was resected on hospital day 2, following an axillo-femoral artery bypass. His hospital course was further complicated by ischemia of the sigmoid colon, treated with sigmoid colectomy, end-colostomy, and a Hartmann's pouch. He had a tracheostomy (7.0-mm inner-diameter tracheostomy tube) performed on hospital day 21 because of ongoing surgical problems requiring mechanical ventilation.

On hospital day 28 his only remaining active problem was ventilator dependence. He was ventilated (model 840, Puritan Bennett, Pleasanton, California) with pressure-support ventilation at 10 cm $H_2O$, intermittent mandatory ventilation rate of 2 breaths/min, tidal volume ($V_T$) of 0.6 L (approximately 8.5 mL/kg), positive end-expiratory pressure of 5 cm $H_2O$, and fraction of inspired oxygen ($F_{IO_2}$) of 0.4. Spontaneous breathing trials of increasing duration were started, using a T-piece and $F_{IO_2}$ of 0.4.

The patient was enrolled into a study (approved by our institutional review board) that allowed for measurement of WOB per minute (also known as the *power of breathing* [POB]) during spontaneous breathing. POB was measured by integrating changes in esophageal pressure ($P_{es}$) (which is an indirect measurement of intrapleural pressure, measured via balloon catheter) and $V_T$ (via a sensor that measures both pressure/flow and carbon-dioxide [NICO cardiopulmonary monitor, Novametrix Medical Systems/ Respironics, Murrysville, Pennsylvania]) positioned between the ETT and breathing circuit, and those signals were applied to a Campbell diagram.[3] Correct esophageal position of the balloon catheter was confirmed using the occlusion test described by Baydur et al.[4] The work per breath was summed over 1 min to yield the POB.

The patient was seen on hospital day 30, during the first 10 min of his daily spontaneous breathing trial. He was awake, alert, and oriented to time, place, and person. He

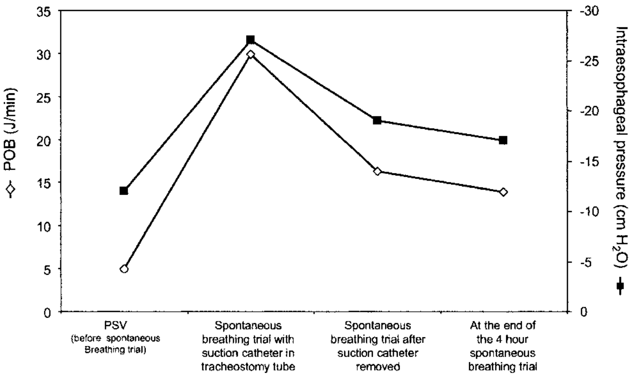


Fig. 1. Power of breathing (POB) and change in intraesophageal pressure with the suction catheter advanced about 8 cm into, and completely out of, the tracheostomy tube, as well as during spontaneous breathing with and without pressure-support ventilation (PSV).

indicated that his spontaneous breathing required more effort than when he was connected to the ventilator. This increased effort was thought to be the result of no pressure support while breathing on ambient pressure with a T-piece. There was no paradoxical breathing or use of accessory respiratory muscles. His spontaneous breathing frequency was 24 breaths/min, with $V_T$ of 0.35–0.4 L, and minute ventilation was 9.6 L/min. His oxygen saturation (measured via pulse oximetry) was 99%, his heart rate was 88 beats/min, and his blood pressure was 146/74 mm Hg. These were within ±10% of the values he had on the ventilator.

POB was 26.9 J/min, and total work per breath was 2.8 J/L (normal adult ranges for POB and WOB are 4–8 J/min and 0.3–0.7 J/L, respectively).[5] Thus, his POB was about 240% of normal and was considerably higher than during the spontaneous breathing trial on the previous day (5 J/min). The increased respiratory work load was confirmed by a $P_{es}$ change of –28 cm $H_2O$ during spontaneous inhalation, which was also substantially greater than the previous day (–12 cm $H_2O$). The initial hypothesis as to the etiology of this change was that the tracheostomy tube was partially obstructed with secretions. On closer inspection, prior to suctioning, we noticed that the closed-suction catheter was already advanced about 8 cm into the tracheostomy tube. When the catheter was pulled back, POB and the change in $P_{es}$ immediately decreased to 16.3 J/min and –19 cm $H_2O$, respectively (Fig. 1). The patient's breathing was considerably less labored (respiratory rate 16 breaths/min, $V_T$ 0.4 L, and minute ventilation 6.4 L/min), and he completed an uneventful 4-hour spontaneous breathing trial.

## Discussion

Total WOB for an intubated or tracheotomized patient connected to a ventilator includes physiologic work (elastic work to expand the lungs and chest wall, and flow-resistive work to overcome the resistance to airflow in the bronchial airways), plus the imposed WOB from the ETT or tracheostomy tube, the breathing circuit, and the inspiratory demand valve of the ventilator (Fig. 2).[3] While imposed WOB was not directly measured in this patient, it was probably the major component of the increased POB, since there was an immediate and dramatic decrease in POB upon pulling the suction catheter out of the tracheostomy tube.

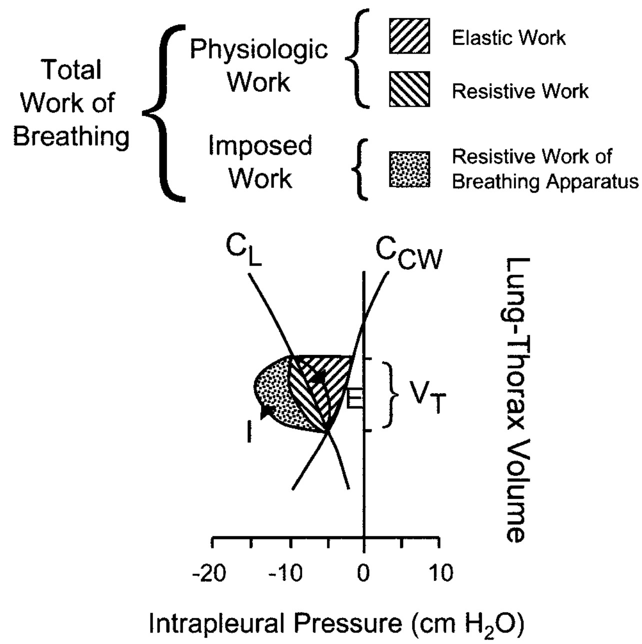


Fig. 2. Schematic of total work of breathing, using a modified version of the Campbell diagram.[3] The compliance curves of the lungs ($C_L$) and the chest wall ($C_{CW}$) of an adult, shown in relation to volume and intrapleural pressure, intersect at the functional residual capacity. Total work of breathing during spontaneous inhalation is the sum of (1) the physiologic work required to expand the elastic structures of the respiratory system and overcome bronchial airways resistance and (2) the imposed flow-resistive work to inhale through the breathing apparatus (ETT and breathing circuit). This figure does not show actual data from this case, in which the presence of the suction catheter in the tracheostomy tube increased the total work by augmenting imposed resistive work (stippled area). $V_T$ = tidal volume. I = inhalation. E = exhalation.

Minimizing imposed WOB is crucial for weaning a patient from mechanical ventilation. An ETT lumen may progressively narrow over the duration of intubation because of deposition of secretions and biofilm formation inside the tube.[6] After suctioning the airway and controlling for secretions, the remaining imposed WOB should be compensated for by using an appropriate amount of pressure support or automatic tube compensation.[7,8] Imposed WOB might be greatly underestimated if it is calculated using airway pressure measured at the Y-piece of the breathing circuit or inside the ventilator, as opposed to intratra-

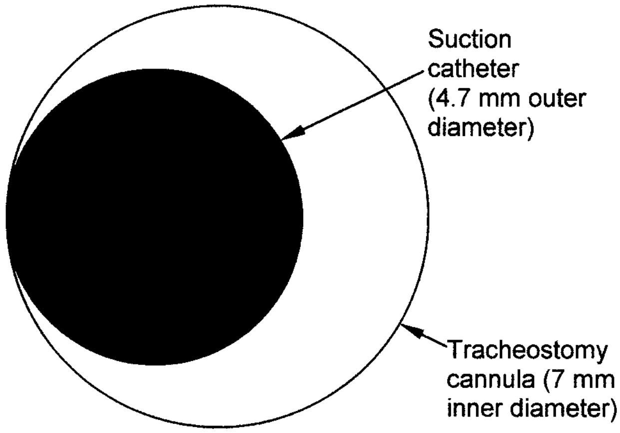


Fig. 3. Cross-section of 14 French suction catheter (black circle) inside a 7.0-mm inner-diameter tracheostomy tube. With the suction catheter inserted, the lumen for spontaneous breathing is equivalent to a 5.22-mm inner-diameter tube. The suction catheter in effect decreased the inner diameter of the tracheostomy tube, which increased the flow resistance, the imposed resistive work of breathing, and, in turn, the power of breathing and respiratory-muscle loading.

cheal pressure.[9,10] With an ETT, intratracheal airway pressure can be measured by using a commercially available ETT that has an additional lumen with an opening at the distal tip (Hi-Lo Jet tube, Tyco/Mallinckrodt, St Louis, Missouri).[9] Therefore, in evaluating a patient who is difficult to wean from mechanical ventilation, accurate measurement of imposed WOB is quite practical. Knowledge of imposed WOB allows the clinician to choose an appropriate level of pressure support to reduce the inspiratory resistance imposed by the ETT or tracheostomy tube and the breathing circuit.

The airflow resistance of an ETT or tracheostomy tube is proportional to the tube's inner diameter.[11] In this case, a 14 French suction catheter decreased the lumen diameter of the tracheostomy tube available for gas flow. This decrease is similar to changing the 7-mm inner-diameter tracheostomy tube to a 5.22-mm inner-diameter tube (25% decrease) if one subtracts the cross-sectional area of the suction catheter from that of the tracheostomy tube (Fig. 3). The resistance of the tracheostomy tube was increased because of the decreased inner diameter available for gas flow.

Regarding measurement of POB, as described in this report, accurate measurement of $P_{es}$ requires a skilled clinician for correct placement and inflation of the balloon catheter and the operation of special equipment for measuring and integrating pressure and volume data. Additionally, patient coughing and/or intolerance of the balloon catheter, swallowing, and cardiac-induced pressure artifacts can cause inaccurate $P_{es}$ measurements[4] and, thus, inaccurate POB data. Although knowing the patient's POB is potentially useful, because of the latter issues, daily monitoring of POB is impractical. An easy-to-use, noninvasive method (ie, without the need of an esophageal balloon catheter) for measuring POB is desirable and available, using an *artificial neural network*, which is a computerized approach.[12] This noninvasive method is an easy, practical way of monitoring patients for increased airflow resistance and, thus, POB, as described in this case.

In summary, a substantial decrease in the intraluminal diameter of an ETT or tracheostomy tube may substantially increase imposed WOB. A closed-suction catheter that is inadvertently left in an ETT or tracheostomy tube can make the imposed WOB intolerably high, causing respiratory-muscle fatigue.

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