

# Ventilator-Disconnect and Death: A Case Study and a Safety Device

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**Deaths and injuries related to accidental ventilator disconnection occur in complex ways. A death related to accidental ventilator disconnection is presented from a subacute ventilator facility, and corrective action is discussed. Single-limb ventilators are now equipped with a flow-bypass coupling that prevents patient-side occlusion during disconnect and therefore prevents low-pressure alarm malfunction. Physicians and respiratory therapists can consider this device to prevent partial or total occlusion of the ventilator tracheostomy adapter, thus allowing a low-pressure alarm in the event of a disconnect.** *Key words: ventilator; mortality; patient safety; mechanical ventilation; safety.* [Respir Care 2010;55(6):774–776. © 2010 Daedalus Enterprises]

## Introduction

Ventilator wards and subacute units are required continuously to provide adequately trained staff as well as properly functioning ventilator equipment to ensure life-saving therapy. My subacute unit monitors patients every 1–2 hours by nursing staff and every 4 hours by respiratory therapists. We use single-limb, volume-controlled ventilators that have an internal low-pressure alarm and an extension of that alarm that is positioned at the patient's door for improved audible and visual monitoring. Continuous pulse oximetry and cardiac telemetry are not standard in subacute units. Between direct patient assessments we rely on the low-pressure ventilator alarm to detect a ventilator disconnect. Despite this standard of care, ventilator disconnect accidents continue to occur. I share the case of a death due to ventilator-related disconnect that occurred because of occlusion of the distal ventilator connection and resulted in failure of the low-pressure alarm to detect the disconnection. Among our corrective actions was the development of a flow-bypass coupling that prevents partial or total occlusion if the circuit disconnects from the tracheostomy tube. This device has improved the reliabil-

ity to detect a ventilator disconnection, and it has become a standard ventilator safety feature in my subacute ventilator unit.

## Case Report

A 75-year-old man with a history of moderate chronic obstructive pulmonary disease (COPD) and a 3-week history of a left-middle cerebral artery stroke was admitted to a community subacute unit. His acute hospitalization in the preceding 3 weeks was complicated by intubation and prolonged mechanical ventilation for depressed level of consciousness. Attempts at liberation from the ventilator were unsuccessful, secondary to severe right hemiplegia and his COPD. A tracheostomy and a percutaneous gastrostomy were performed prior to transfer to the subacute facility.

On admission to the subacute unit the patient was awake, aphasic, and unable to move the right side. Vital signs were stable. Ventilator settings on a volume-controlled ventilator (PLV-102, Respironics, Murrysville, Pennsylvania) included a tidal volume of 600 mL, continuous mandatory ventilation rate of 12 breaths/min,  $F_{IO_2}$  of 0.3, and inspiratory flow of 90 L/min. The ventilator circuit included a single-limb circuit (AirLife, Allegiance Healthcare, McGaw Park, Illinois), a biofilter, and a heat-and-moisture exchanger (Thermovent 1200, Portex/Smiths Medical, Dublin, Ohio). A closed-suctioning device (Trach Care, Kimberly-Clark Health Care, Roswell, Georgia) was present between the ventilator circuit and the tracheostomy tube. Physical examination was consistent with COPD and a dense right-sided stroke. Laboratory and chest ra-

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Dr Lowery has a patent pending for the device described in the paper.

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diograph findings showed no other causes for inability to liberate from mechanical ventilation. Peak inspiratory pressure was in the range 35–50 cm H<sub>2</sub>O. T-piece spontaneous-breathing trials with an F<sub>IO<sub>2</sub></sub> of 0.3 were brief, due to dyspnea and desaturation to as low as 80%. Despite some improvement in the duration of the T-piece trials, the patient remained ventilator-dependent after 4 weeks.

On the second month of his subacute-unit admission the patient was found unresponsive on early morning rounds and the ventilator circuit was disconnected from the tracheostomy and occluded on the patient's chest. The ventilator was operating correctly but the peak inspiratory pressure generated by the circuit occlusion was above the 20 cm H<sub>2</sub>O setting for the low-pressure alarm. Thus, the ventilator low-pressure alarm did not activate because of the occlusion of the circuit. Ventilator settings and pressures were unchanged from baseline. The patient was observed to be warm but cyanotic. Despite resuscitation efforts, he could not be revived. An autopsy was not done. However, given his respiratory limitations and the circumstance in which his ventilator was found, ventilator disconnection was considered the main contributor to his demise. Because he was receiving deep-vein-thrombosis prophylaxis, other causes, such as pulmonary embolism, were felt to be unlikely.

Root-cause analysis by a multidisciplinary hospital team revealed that there was no ventilator malfunction, no other circuit obstruction, and appropriate staffing at the time. A full survey by the California Department of Health Services concluded that ventilator disconnection was the likely cause of death.

Our corrective response to this sentinel event and the Department of Health Services included staff training in prompt attention to ventilator alarms. The Department of Health Services pointed out that, to prevent future disconnects from being unrecognized, a more reliable monitor would need to be in the correction plan. I was assigned, in conjunction with the respiratory care department, to solve this monitoring issue. We considered several solutions, including upgrading to a ventilator with a low-tidal-volume alarm and dynamic monitoring, such as pulse oximetry or capnography. However, those were not financially viable. Tracheostomy anti-disconnect devices such as the Dale Bridle (Dale Medical Products, Plainville, Massachusetts) were felt to be unacceptable because they limit emergency airway access. I realized that the current low-pressure alarms are excellent if they can detect low pressure in all disconnects. Therefore, if a non-obtrusive sleeve could be placed over the end of the ventilator circuit with escape notches through which air flow could escape unimpeded during a disconnect, this would lessen the chance of a failed alarm (Figs. 1–3). I fashioned a medical-grade plastic sleeve from an AirLife ventilator circuit that fits over



Fig. 1. Three ventilator safety couplings (at 3 angles). The notches allow flow bypass.



Fig. 2. Safety coupling attached to tracheostomy tube adapter.



Fig. 3. Safety coupling between tracheostomy tube adapter and a Shiley tracheostomy tube. The safety coupling can also be used with a Portex or Bivona tracheostomy tube.

the ventilator tracheostomy adapter but does not impede any articulation with the tracheostomy.

To make the 22-mm diameter sleeve, I began with the non-corrugated circuit plastic part, which interrupts the corrugated part in 5-cm lengths. I cut out the 5-cm non-corrugated part so I had the smooth 5-cm tubing section. Next, I cut that 5-cm tube in half, making two 2.5-cm tubes or sleeve units. The cut in the center is the base for each coupling, which slides on to the connection from the ventilator (eg, the inline suction catheter). Finally, I cut two 1-cm square notches from the top of the each 2.5-cm sleeve unit, diametrically opposite each other, being careful to avoid notching on the molding line, as this is a weak area. The cuts have to be smooth and without debris. The crown-shaped safety couplings were then ready to slip onto the tracheostomy adapter. The base of the crown goes on first, and I adjusted the notch distance beyond the tra-

cheostomy adapter by the 1-cm notch. In my experience, these devices do not migrate or slip off if made correctly. The part should be made as clean as possible, though it is outside the circuit, in a contaminated area. Further construction details are available at <http://www.e-symptom.com/coupling>.

This device prevents occlusion of the distal ventilator circuit following a disconnection. The notches on each side allow ventilator flow out of the circuit without creating an upstream pressure increase, thus allowing the low-pressure alarm in the event of a disconnection. It adapts to all brands of tracheostomy tubes that have a standard 15 mm outside-diameter ventilator connection. Medical-legal and safety concerns were discussed with risk managers and the institutional review board. In our first trial year of use of this device, informed consent was obtained from each patient or designated guardian prior to use.

Our testing found that with standard ventilator settings and circuits (including heat-and-moisture exchanger and biofilter) the open the circuit pressure was  $< 5$  cm H<sub>2</sub>O. In addition, we assessed the disconnect pressure without the safety coupling, in which the ventilator circuit was momentarily allowed to fall on the chest of a patient in a flush position. This partial occlusion consistently produced a pressure of 20 cm H<sub>2</sub>O. With the ventilator safety coupling the disconnect pressure has never been  $> 10$  cm H<sub>2</sub>O, even with a saturated heat-and-moisture exchanger in line. The typical peak inspiratory pressure in our patient population is 40 cm H<sub>2</sub>O, so we generally set the low-pressure alarm at 20 cm H<sub>2</sub>O, with confidence that alarm malfunction due to partial or total occlusion will not occur. After 3 years of use, our subacute unit has not seen an increase in disconnects related to the safety coupling.

### Discussion

Ventilator-disconnect morbidity and mortality is a complex issue, which has been addressed by the Joint Commission.<sup>1,2</sup> There is limited literature in the area of ventilator-related deaths and injuries, and most articles cite the

2 papers I cite here. Articles concerning state-of-the-art monitoring techniques, such as telemetry, oximetry, and capnography, are directed toward the intensive care unit and anesthesia settings. For budget-constrained subacute units this is impractical.<sup>3</sup>

In reviewing the root-cause analysis in our sentinel event and response, we found similarities with the recommendations of the Joint Commission. Of the 7 recommendations for risk-reduction strategies in ventilator-related deaths and injuries in the Sentinel Event Alert,<sup>1</sup> we felt there were areas applicable to us: improving staff awareness and action around ventilator alarms, and upgrading alarms and monitoring systems on ventilators (particularly the low-pressure alarm). As a result of this quality-improvement process, staff quickly respond to low-pressure alarms due to ventilator disconnection. In our experience, a ventilator disconnection occurring anywhere in the circuit will generate a low pressure and result in a low-pressure alarm, with the lone exception of a ventilator disconnection from the tracheostomy tube that produces a partial or total occlusion of the circuit. It was only after careful consideration and design that we produced a simple and non-obtrusive device that, in our 3 years of experience has prevented another occurrence such as the one described in this case. Other options were considered along the way but were financially unrealistic. After 3 years of experience using the safety coupling, our physicians, respiratory therapists, hospital administrators, and the California Department of Health Services believe that our low-pressure alarms are reliable and are contributing to patient safety.

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