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Commentary
Endotracheal tubes and imposed work of breathing: what should we do about it, if anything?

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Abstract

Concerns about the work of breathing imposed by the endotracheal tube have led clinicians to routinely use pressure support to overcome this resistive component. More recently, ventilator manufacturers have introduced systems to automatically overcome endotracheal tube resistance, regardless of tube diameter or patient demand for flow. Despite the theoretical advantages, neither method appears to provide superior performance. Stepping back, the real question may be, is overcoming endotracheal tube resistance really important?

Keywords endotracheal tube, mechanical ventilation, tube compensation, work of breathing

Techniques and equipment to accomplish endotracheal (ET) intubation were the precursor to modern day invasive mechanical ventilation. In recent years, however, the popularity of the ET tube has waned. Clinically, the ET tube is seen as an impediment to spontaneous breathing, a transit route for bacteria to the lower airway, and – with the advent of noninvasive ventilation – a device to be avoided when possible. Of particular interest has been the effect of the ET tube on work of breathing and methods to eliminate this work. Commonly, pressure support ventilation (PSV) has been suggested as the technique of choice for eliminating imposed work due to the ET tube. More recently, the technique of automatic tube compensation (ATC) has become available to specifically address this issue. In this issue of *Critical Care*, Maeda and colleagues [1] compare the technique of ATC, as provided by the Drager Evita 4 (Dragerwerks, Lubeck, Germany) and the Puritan Bennett 840 (Carlsbad, CA, USA), versus PSV in reducing imposed work of breathing in a lung model.

Before I comment on the merits of the study, it is worthwhile exploring the merits of overcoming ET tube resistance. Clearly, before the advent of pressure support ventilation in the early 1980s, patients were successfully weaned using T-piece trials and intermittent mandatory ventilation, with no apparent untoward effects. In fact, the routine use of spontaneous breathing trials today supports this concept. In 1986, Shapiro and coworkers [2] presented data from three normal volunteers breathing through ET tubes at a constant tidal volume of 500 ml. That report is widely quoted but is limited by the use of unintubated normal individuals and the requirement for a constant tidal volume during increasing respiratory rates. Additionally, close review of the data demonstrates that with a size 8.0 ET tube the work of breathing in joules per minute does not become excessive until minute ventilation exceeds 15 l/min.

Brochard and colleagues [3] compared work of breathing during assisted ventilation, four levels of pressure support, continuous positive airway pressure, and after extubation in an effort to determine the role of pressure support in overcoming the imposed work presented by the ET tube. That trial evaluated both patients with normal lungs and those with chronic obstructive pulmonary disease (COPD). The authors concluded that the pressure support level that eliminated imposed work was between 3 and 14 cmH_2O. Interestingly, this was determined retrospectively by matching the work of breathing after extubation to the level of pressure support that resulted in equivalent work of breathing during mechanical

ATC = automatic tube compensation; COPD = chronic obstructive pulmonary disease; ET = endotracheal; PEEP = positive end-expiratory pressure; PSV = pressure support ventilation.

ventilation. Recent work suggests that the work of breathing postextubation may actually increase compared with work of breathing through the ET tube, raising questions about the conclusion of the study by Brochard and colleagues [4,5].

Weissman [6] evaluated flow–volume loops in 18 postoperative patients intubated with size 7.0 and 8.0 ET tubes and found that only 'minimal limitation to airflow' occurred at volumes and frequencies associated with tidal breathing. That study is one of the very few that contemplate the idea that ET tube resistance may not be important when the appropriate size is chosen and the patient's pulmonary function has improved to the point that weaning may be considered. Of course, there are numerous other studies that suggest that ET tube resistance may represent a significant impediment to spontaneous breathing. However, it is important to note that although there remains concern about ET tube resistance, and the literature is replete with lung model studies of increased work of breathing, there is not a single clinical trial that suggests that spontaneous breathing through the ET tube results in untoward outcomes.

The report by Maeda and coworkers [1] in this issue of *Critical Care* evaluates the two most popular methods of overcoming ET tube resistance, namely PSV and ATC. The authors concluded that tube compensation could not overcome the pressure–time product associated with triggering and that pressure support is as effective as ATC at 100%. The conclusions are valid. There are, however, tremendous disadvantages to a lung model study in comparing these techniques. Calculating the pressure–time product and work includes the work required to trigger the ventilator, which can only be overcome by direct measurement of tracheal pressure and triggering from the tracheal signal. This method has been proposed by many, and advanced by the group from Gainesville [7]. Additionally, although the lung model allows consistency, it cannot react to differences in gas delivery. In several human studies comparing PSV with ATC, the slow flow and longer inspiratory time associated with PSV has been associated with dysynchrony [8,9]. When used in a patient with COPD, the patient's high airway resistance and increased compliance allow even small amounts of PSV to cause hyperinflation and auto-PEEP (positive end-expiratory pressure). Alterations in pulmonary mechanics, along with the preference of the COPD patient for short inspiratory times and long expiratory times, result in neuromechanical dysynchrony during PSV. ATC in this setting might provide improved patient–ventilator interaction while avoiding hyperinflation [10].

The main proposed advantages of ATC over PSV are reduced work of breathing as patient demand varies, preservation of a normal, variable breathing pattern, and improved synchrony. In a recent trial of spontaneous breathing before extubation, Haberthur and coworkers [11] failed to show any advantage of ATC over PSV or T-tube trials. This would appears to support the findings of Maeda and colleagues. One issue not addressed in the study by Maeda and coworkers is the role of expiratory compensation. One distinct difference in the operation of the Drager Evita 4 and Puritan Bennett 840 is that Evita 4 provides both inspiratory and expiratory compensation for ET tube resistance. In these cases, the airway pressure may be allowed to drop below PEEP to facilitate expiratory flow. The advantages or disadvantages of this method remain to be elucidated.

New modes and new techniques are developed in the hope of resolving clinical problems and often concentrate on a short-term physiologic end-point. This appears to be true in the case of ATC. Conventional wisdom suggests that the ET tube is an impediment to efficient spontaneous breathing, yet clinical evidence during spontaneous breathing trials appears to argue to the contrary. The real question may be whether overcoming ET tube resistance is necessary, not whether ATC is as good as or better than PSV. The future of ATC, like many new techniques, may not be in overcoming ET tube resistance, but as a method of support during spontaneous breathing that improves patient–ventilator synchrony as compared with PSV. Additional clinical studies are required to complement the excellent laboratory work by the group from Osaka reported in this issue.

Competing interests

None declared.

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