Automation of Mechanical Ventilation

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KEYWORDS

• Intensive care unit • Mechanical ventilation • Closed loop ventilation • Weaning

KEY POINTS

- Mechanical ventilation is ubiquitous to intensive care.
- Mechanical ventilation has the potential for harm and management by experienced clinicians is mandatory.
- Automated control of ventilation may provide some advantages related to consistency of care and maintaining evidenced based protocols.

INTRODUCTION

Mechanical ventilation is ubiquitous to intensive care. In fact, the foundation of intensive care units (ICUs) can be traced to housing patients requiring mechanical ventilation for specialized care. In the past 2 decades, our understanding of mechanical ventilation and its complications has become steeped in evidence and physiology. After nearly 60 years of modern positive pressure ventilation, it seems that mechanical ventilation has a fairly narrow therapeutic index between the effective and lethal dose. Clearly, the impact of tidal volume (V_T) and airway pressures on ventilator-induced lung injury and mortality are firmly established.[1]

Yet, even in the presence of evidenced-based guidelines,[2] clinicians routinely ignore even the best proven strategies.[3] The complexity of mechanical ventilation and of ventilators has done little to improve this reality. Clinicians are influenced by local champions, manufacturers, and mentors. This is frequently manifest in the way individuals describe ventilation techniques by the proprietary names of devices, versus by function. In the face of this conundrum, the failure of trained clinicians to adopt evidence-based practices, automation of ventilation settings could provide a solution. However, this remains to be proven. This article reviews the evidence regarding the use of automated control of mechanical ventilation.

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DEFINITIONS

A closed loop control describes a system that changes its output based on a desired input. These systems are also referred to as feedback control systems. In the most basic forms, closed loop control is part and parcel of every mechanical ventilation system. Pressure support uses the pressure signal as a target and controls flow to reach and maintain the desired pressure. This is accomplished by a rapid initial flow followed by a quickly decelerating flow pattern. Wysocki and colleagues[4] have classified closed loop systems based on the level of sophistication into simple, physiologic signal based, and explicit computerized protocols (ECP). **Table 1** provides examples of these 3 types of closed loop systems.

A simple closed loop system includes pressure support or pressure control ventilation. A physiologic signal-based system would include neurally adjusted ventilatory assist (NAVA) or proportional assist ventilation. In these examples, output is increased or decreased in proportion to the input signal. In the case of NAVA, the pressure applied is proportional to the integral of the electrical activity of the diaphragm. Thus, as patient effort increases and electrical activity of the diaphragm is greater, the level of assistance is greater.[5]

Table 1
Classification of closed loop systems based on sophistication

Control	Example	Output	Input(s)	Comments
Simple	Pressure support ventilation	Flow	Airway pressure	
Physiologic signal based	NAVA	Pressure	EAdi	Delivered instantaneous airway pressure is proportional to the integral of the EAdi. During NAVA, the breath is triggered and cycled based on EAdi. The airway pressure applied by the ventilator is determined as: Airway Pressure = NAVA level × EAdi, where airway pressure (cm H_2O), EAdi is the instantaneous integral of the diaphragmatic electrical activity signal (μV), and the NAVA level (cm H_2O/μV) is a proportionality constant set by the clinician.
Explicit computerized protocol	SmartCarePS	Pressure	Delivered V_T Respiratory frequency End tidal CO_2	Smart care uses a number of clinician inputs to alter ventilator operation. The range of acceptable ventilation can be altered in the presence of COPD or neurologic injury. Additionally, the choice of 'night rest', prevents weaning during selected overnight hours.

Abbreviations: CO_2, carbon dioxide; COPD, chronic obstructive pulmonary disease; EADi, electrical activity of the diaphragm; NAVA, neurally adjusted ventilatory assist; V_T, tidal volume.