Patient-Ventilator Interaction: 
Physiology of the Triggering Function

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Introduction

The incorporation of microprocessors into the design of ventilators has produced a confounding array of products, each with its own peculiar features and modes of operation. This confusion has been compounded in the medical literature with unproved statements favoring one new device or mode of ventilation over another. We believe that physicians concerned with the ventilatory management of patients with respiratory failure must base their approach on physiologic principles and an understanding of patient-ventilator interactions [1].

According to the American Association for Respiratory Care [2], positive-pressure breaths delivered by a mechanical ventilator can be categorized by three variables:

1) the trigger variables (what initiates the breath);
2) the limit variable (what controls gas delivery); and
3) the cycle variable (what concludes the breath).

The best patient-ventilator interaction is obtained when the patient’s ventilatory drive, his spontaneous inspiratory flow demand, and his ratio of inspiratory time to total breath cycle (Ti/Tot) are matched by these variables. In this chapter, we will examine the physiology of the patient-ventilator interaction at the beginning of the breath, when the patient ventilatory drive interacts with the mechanically delivered breath through the ventilator trigger mechanism.

The trigger function is defined as the variable that is manipulated to deliver inspiratory flow [3]. This variable may be a set time, pressure of flow. Time-triggering operates when the ventilator delivers a breath according to a set frequency, independent of the patient’s spontaneous effort [4]. With pressure- and flow-triggering, the ventilator delivers a breath once the set pressure, or flow sensitivity is attained, independently of the set frequency [4]. The following discussion on the trigger variable will be based on data obtained using a ventilator system only (Puritan-Bennett 7200ae, Puritan-Bennett Corp., Carlsbad, CA). However, when the act of initiating a breath from a ventilator is analyzed, the ventilator response algorithm should also be taken into account, remembering its important effects on the imposed work. The ventilator response algorithm may substantially vary for different ventilators, and hence data obtained with a single ventilator while illustrative, do not reflect the broad range of possible responses available.
Pressure-Triggering

During pressure triggering, a breath is initiated by the contraction of the patient's respiratory muscles against the occluded airway. The resulting inspiratory effort reduces the airway pressure to a pre-set negative Pao value necessary to open the inspiratory demand valve and initiate the breath. While pressure is declining, the patient receives no flow from the ventilator and this period of no flow may burden the patients with additional work [5, 6].

Flow-Triggering (Flow-By®)

Prior to the patient's inspiratory effort, the ventilator delivers a level of constant flow into the patient circuit at a rate that can be set between 5 and 20 L/min. Before the patient initiates a breath, the delivered flow and the returned flow are equal. As the patient begins to inhale, the returned flow decreases. The ventilator recognizes this drop well before the delivered flow is consumed, and cycles on to deliver the specified breath. Therefore, the initial constant flow (base flow) satisfies the patient's initial inspiratory efforts while the deficit in returned flow (flow sensitivity) causes the ventilator to cycle on either spontaneous breath (CPAP), volume assisted breaths (AMV or SIMV) or pressure assisted breaths (pressure support or pressure control ventilation) [7–9].

Several studies [5, 6] showed that ventilator systems equipped with pressure-triggering systems create an inspiratory load that may compromise the weaning process. On the other hand, a relevant reduction in work of breathing has been described when demand flow systems were replaced by continuous flow systems during continuous positive airway pressure (CPAP) ventilation [5, 10]. Effects of flow-by triggering on work of breathing have been extensively studied by Sassoon and co-workers during spontaneous mode ventilation (i.e. CPAP) [7–9]. In normal subjects, they found that the work of breathing was significantly less with flow-by-triggered CPAP than with pressure-triggered CPAP [7]. In patients being weaned from mechanical ventilation, the same authors found that both 5 cm H₂O of flow-by-triggered CPAP and pressure support ventilation decreased PTP compared to T-piece [8]. In a more recent study, Sassoon and co-workers [9] compared the effects on work of breathing of flow-by CPAP with conventional continuous-flow CPAP in 9 COPD patients recovering from acute respiratory failure related to COPD. They found that work of breathing during flow-by CPAP is comparable to the continuous-flow CPAP and less than that with pressure-triggered CPAP. In a recent study, we found [11] that flow-triggering significantly decreased inspiratory muscle effort compared to pressure-triggering also during volume and pressure-assisted breaths. These results were explained by two factors:

1) the smaller drop in Pao observed with flow-triggered CPAP; and
2) the increase in airway pressure above atmospheric pressure that occurs immediately after trigger sensitivity is obtained and that is maintained through-