Varying Leaks: A Challenge for Modern Ventilators?

Using patient-triggered ventilation, during which the patient is given the opportunity to trigger and cycle the ventilator, allows reducing the use of sedation,¹ reduces ventilator-induced diaphragmatic dysfunction,² facilitates weaning from mechanical ventilation,³ and improves patient comfort.⁴

To be efficient and comfortable, patient-triggered modes have to deliver pressurization in synchrony with the patient's inspiratory efforts. Despite technological improvements, delays between delivered ventilator pressurization and the patient's inspiratory effort can occur either at the beginning (triggering phase) or at the end of the inspiratory effort (cycling phase), resulting in patient-ventilator asynchrony.⁵ Severe asynchrony occurs in one fourth of invasively ventilated patients,⁶ and has been associated with increased respiratory muscles work load⁷ and prolonged mechanical ventilation.⁶ As ventilators use leak-sensitive pneumatic signals to detect the start of a patient's inspiratory effort and to manage the inspiration-expiration transition, patient-ventilator asynchrony dramatically increases in the presence of leaks,⁸ which can occur during invasive ventilation, related for example to a non-occlusive endotracheal tube cuff, the ventilator circuit, or bronchopleural fistula, and during noninvasive ventilation (NIV), because of the use of noninvasive interfaces.

Therefore, in the presence of leaks the quality of delivered mechanical ventilation is tightly related to the ventilator's performance. This is true both for ICU ventilators, originally designed to ventilate intubated patients without leaks, but now equipped with specific NIV algorithms,⁹ and for turbine-based NIV dedicated ventilators originally built to compensate for leaks. Choosing a "good" ventilator is crucial to deliver efficient ventilation in the presence of leaks, and underlines the need of having an extensive knowledge on how the various ventilators react to challenging clinical scenarios, for example, the occurrence of varying leaks. As patients and clinical scenarios cannot be standardized at the bedside, this requires the use of bench tests.

By assessing 8 ventilators' responses to varying amounts of increasing and decreasing leak, the study of Oto et al published in this issue of *RESPIRATORY CARE*, can be considered as a major contribution to current knowledge in the field.¹⁰ In this very interesting bench study, Oto et al simulated ARDS and COPD conditions and used a very realistic lung simulator and manikin setup, and elaborated

increasing and decreasing leakage scenarios to assess the ability of 7 ICU ventilators and of 1 NIV-dedicated ventilator to prevent triggering and cycling asynchrony caused by varying leaks during both invasive and noninvasive ventilation. They also recorded the number of breaths required to obtain acceptable synchrony when leak was changed, which is a very original approach.

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Oto et al report that at baseline conditions all the ventilators tested were able to synchronize with the lung simulator, but only 4 of the 8 tested ventilators synchronized to all the increasing and decreasing leakage scenarios during NIV conditions. During invasive ventilation conditions, only 2 of the 8 ventilators synchronized to all the scenarios. Interestingly, synchrony was obtained earlier during decreasing leak than during increasing leak, thus underlining which situation could be more difficult to manage at the bedside. The time required to reestablish stable ventilation (without miss-triggered efforts) after the leak was changed was higher in the COPD model, both during invasive and noninvasive ventilation conditions, thus confirming that, as previously shown in the literature,⁶ obtaining good synchrony in COPD patients can be particularly challenging. Another clinically relevant result was that the number of breaths required to reestablish synchronization was increased with a higher PEEP level.

Interestingly, and contrasting with previous results that suggested that NIV-dedicated ventilators outperformed ICU ventilators in the presence of leaks,¹¹ in the Oto et al study it was an ICU ventilator, the PB840, that was the fastest to reach stable and synchronized ventilation in the presence of varying leaks, during both invasive and noninvasive ventilation.

In summary, in the Oto et al study only a few ventilators were able to satisfactorily manage varying leaks during invasive and noninvasive ventilation. This points out the need for further technical improvement to help clinicians manage ventilation when leak is present. However, it must be underlined that Oto et al included very large leaks (up to 37 L/min during NIV, and up to 27 L/min during invasive ventilation), so the scenarios they tested were very challenging for the ventilators. Additionally, Oto et al defined "failure to synchronize" as failure to synchronize

within one minute, which can also be considered demanding. As a consequence, the results might have been different for some or all of the tested ventilators if lower leak levels had been used⁸; this calls into question the clinical applicability of the study's results and underlines the importance of performing additional bench tests using less challenging conditions. On the other hand, the results could be used as a solid base upon which to build a clinical study to assess, in difficult clinical situations (as for example in COPD patients during NIV), whether the top-performer ventilator (PB840) might improve clinical outcomes.

In conclusion, we can say that, even though we have greatly increased our knowledge about patient-ventilator asynchrony during the past 10 years, and we now know that asynchrony occurs frequently and can be clinically relevant, further research is needed to address unsolved issues. First, further improvements in ventilator performance are required to optimally manage challenging situations. Second, the clinical impact of delivering optimized ventilation in all challenging situations must be assessed. These aims require, respectively, the design of additional sophisticated bench tests that simulate clinical scenarios as realistically as possible, and large-scale clinical outcome studies.

Laurence Vignaux PT MSc
Cardiorespiratory Physiotherapy Unit
Hôpital La Tour
Meyrin, Switzerland

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Correspondence: Laurence Vignaux PT MSc, Cardiorespiratory Physiotherapy Unit, Hôpital La Tour, Avenue JD Maillard 3, 1217 Meyrin, Switzerland. E-mail: laurence.vignaux@hotmail.fr.

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Lise Piquilloud MD

Adult Intensive Care and Burn Unit
University Hospital of Lausanne
Lausanne, Switzerland

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