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COMMENT

Tidal volume and helmet: Is the never ending story coming to an end?

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Noninvasive ventilation (NIV) has been increasingly used in acute care setting with various indications[1–3,4] but its use in patients with acute hypoxemic respiratory failure (AHRF) is controversial.[5,6,7]

Although spontaneous patient activity during mechanical ventilation (MV) may reduce the likelihood of ventilation-perfusion mismatch, especially in dependent regions, close to the diaphragm, high transmural vascular and transpulmonary pressure swing may worsen vascular leakage and increase tidal volume (V_t), leading to self-inflicted lung injury (SILI).[8] From the clinical side, expiratory V_t of 6 mL/kg used in invasive MV during lung protective ventilation[1] is almost impossible to achieve in most of the patients receiving NIV for AHRF. This is particularly important in de novo AHRF patients undergoing NIV,[1,2] since large expiratory V_t may be generated[9,10] in assisted pressure controlled modes by the ventilator pressure and by the respiratory muscles.

In this setting, reliable monitoring of V_t and unintentional leaks is of the utmost importance. When using an intensive care unit (ICU) ventilator driven by high pressures in the double limb configuration, leaks are computed as the difference between inspired and expired V_t. As a consequence, the amount of V_t that the patient gets is usually quantified as expiratory V_t.

However, some points need to be clarified:

1) One characteristic of unintentional leaks is that they are dynamic, which means they can abruptly change during the inspiratory or expiratory phase of the respiratory cycle (even cycle by cycle). Therefore, expiratory V_t measurements using masks may cause concern, because measurements may become unreliable, unstable and difficult to continuously monitor {Carteaux:201dg}, where there may be unintentional expiratory leaks[11];
2) Although there is a strong belief that preset V_t is equal to the real delivered V_t, in volume controlled mode using ICU ventilator driven by high pressures, on study found that V_t indicated by the ventilator was lower than the delivered V_t, with a difference that was often greater than 10% of the preset V_t.[12] This is also true during pressure controlled mode using NIV, where the direct measurement of flow (and its integration over the time, namely V_t) by the pneumotachograph inside the ventilator, needs to be corrected for the compressible volume. This is the amount of gas which is compressed in the cir-

Abbreviations: AHRF, acute hypoxemic respiratory failure; CPAP, continuous positive airway pressure; ICU, intensive care unit; ILC, intentional leak single-limb vented circuit; IMV, invasive mechanical ventilation; MV, mechanical ventilation; NIV, noninvasive ventilation; SILI, self-inflicted lung injury; TDV, turbine driven NIV ventilator; V_t, tidal volume.

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Table 1 Differences in tidal volumes measured by turbine driven ventilator and lung simulator at different levels of PEEP in the bench study.

Simulated condition	(TDV-LS)PEEP 5 cmH2O	(TDV-LS) PEEP 8 cmH2O	(TDV-LS) PEEP 10cmH2O	(TDV-LS) PEEP 12 cmH2O	p Value
Restrictive	61 (3)°+§	104.4 (1.3)*+§	1.1 (1.6)*°§	−11.9 (1.9)*°+	<0.001

Data reported from Ref. 17. Data are expressed in ml and reported as mean (±SD). PEEP: positive end expiratory pressure; TDV: turbine driven ventilator; LS: lung simulator; (TDV-LS): difference between VT measurements by turbine driven ventilator and lung simulator. *Different from 5; °different from 8, +different from 10, §different from 12.

cuit and in the mask (the greater the internal volume of the mask the higher the compressible volume) for each cmH_2O of pressure delivered by the ventilator during inspiration. Although most of ICU ventilators are usually equipped with algorithms to calculate and compensate for the compressible volume of the circuit,[13] they do not compensate for the mask internal volume or compliance;

Many companies manufacture dedicated turbine driven NIV ventilators (TDV) with a high pressure O_2 inlet to preset a given FiO_2 and an intentional leak single-limb vented circuit (ILC),[11] where V_t is not measured but estimated.[14] Although this circuit configuration is extensively used, the accuracy of V_t estimate depends on many factors, including the pressure decrease across the limb, especially where there are high unintentional leaks. This is the reason why some ventilators use a mathematical algorithm to calculate this pressure drop or they still measure pressure close to the mask. Finally, the V_t and leakage estimation in the presence of random leaks remains a challenge when using ILC.[1,14] However, V_t estimation has been found to have around 15% when compared to the real measured V_t in restrictive disorders. This means that, when 500 ml of volume are generated, estimates may be around ± 75 ml, a bias not significantly different from the one measured by many pneumotachographs inside the ventilator.[14]

They may also allow better patient-ventilator synchrony than ICU pressure driven ventilators, even when coupled with their NIV algorithms.[15] Accuracy in estimating leakage is also crucial to improve patient-ventilator synchrony, especially when pneumatic (flow) trigger systems are used. Most of these systems automatically change their sensitivity level according to leakage estimates to avoid trigger asynchronies (autotriggering or ineffective efforts).

Another important concern during NIV in de novo AHRF is that, compared to IMV, it cannot often be used continuously on a daily basis. Although the use of total face mask may increase patient's tolerance and compliance to NIV and decrease unintentional leaks, the likelihood of maintaining patients under NIV with a mask round the clock for days is remote.

An alternative interface is the helmet, which consists of a transparent hood covering the patient's whole head with a soft collar neck seal.[16] It is kept in place by two armpit belts or by an annular extendable plastic ring positioned under an inflatable cushion that eliminates the need for armpits straps.[16] Helmet NIV resulted in higher levels of positive end expiratory pressure (PEEP) and a lower intubation rate in patients with AHRF in a single randomized controlled trial.[16] This study suggests that the helmet may allow more time on NIV, at higher PEEP, compared to mask NIV, possibly resulting in a lower rate of endotracheal intubation. However, although interesting in term of comfort and in avoiding skin breakdown, the helmet has restrictions in measuring V_t due to its mechanical properties.[16]

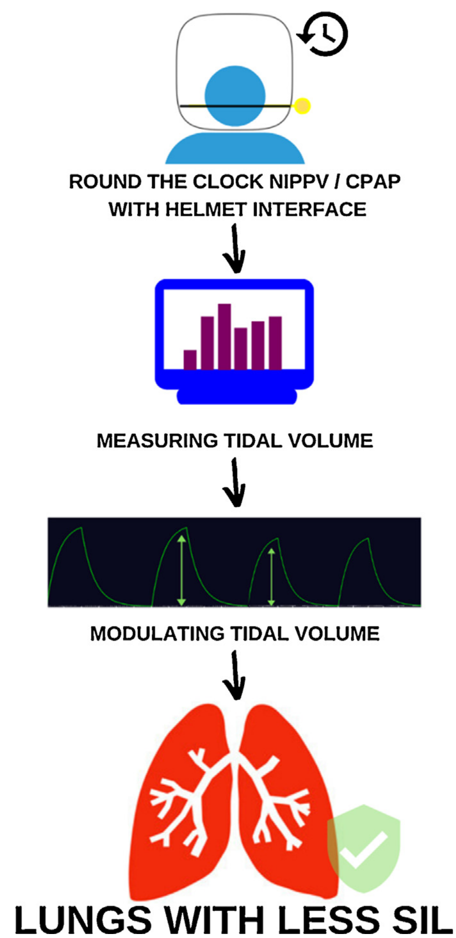

Figure 1 Modulating tidal volume in NIPPV/CPAP spontaneous breathing patients can reduce SILI.
Mechanism of reducing SILI through measuring and modulating Vt during round the clock cycles of mechanical ventilation with helmet interface.
CPAP: Continuous positive airway pressure; NIPPV: Noninvasive positive pressure ventilation; SILI: Self-induced lung injury.

We recently tested the hypothesis[17] that TDV coupled with a single limb ILC, setting intentional leak location at the helmet expiratory port,[18] would provide patient's V_t estimates. This configuration allows using the helmet even in continuous positive airway pressure (CPAP) mode without additional rebreathing,[18] as in ICU ventilator in double limb configuration.[19] Results of the bench simulation in restrictive conditions (Table 1[17]) show that we could potentially use helmet NIV knowing V_t. Besides, differences in V_t between TDV and lung simulator remained stable across different tested leak flows.

This feasibility bench and human study demonstrated that estimating V_t during helmet NIV seems to be feasible and accurate in restrictive conditions. Although there are now questions about use of NIV in AHRF, the possibility of continuous noninvasive support for patients, knowing V_t, even in CPAP mode, could open new scenarios (Fig. 1), especially in ''difficult-to-treat'' hypoxemic patients, such as in major burns[20] or in the immunocompromised.[21] Further clinical studies are required to verify this method.

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Authors' contribution

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Declarations of interests

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