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ORIGINAL ARTICLE

Decreased lung compliance increases preload dynamic tests in a pediatric acute lung injury model

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Abstract
Background: Preload dynamic tests, pulse pressure variation (PPV) and stroke volume variation (SVV) have emerged as powerful tools to predict response to fluid administration. The influence of factors other than preload in dynamic preload test is currently poorly understood in pediatrics. The aim of our study was to assess the effect of tidal volume (V_T) on PPV and SVV in the context of normal and reduced lung compliance in a piglet model.
Material and method: Twenty large-white piglets (5.2 ± 0.4 kg) were anesthetized, paralyzed and monitored with pulse contour analysis. PPV and SVV were recorded during mechanical ventilation with a V_T of 6 and 12 mL/kg (low and high V_T, respectively), both before and after tracheal instillation of polysorbate 20.
Results: Before acute lung injury (ALI) induction, modifications of V_T did not significantly change PPV and SVV readings. After ALI, PPV and SVV were significantly greater during ventilation with a high V_T compared to a low V_T (PPV increased from 8.9 ± 1.2 to 12.4 ± 1.1%, and SVV from 8.5 ± 1.0 to 12.7 ± 1.2%, both $P < 0.01$).
Conclusions: This study found that a high V_T and reduced lung compliance due to ALI increase preload dynamic tests, with a greater influence of the latter. In subjects with ALI, lung compliance should be considered when interpreting the preload dynamic tests.

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PALABRAS CLAVE
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Una compliance pulmonar disminuida incrementa los test dinámicos de precarga en un modelo pediátrico de lesión pulmonar aguda

Resumen
Introducción: Test dinámicos de precarga, variación de presión de pulso (PPV) y variación de volumen sistólico (SVV) han emergido como herramientas poderosas para predecir respuesta a la administración de fluidos. Actualmente la influencia de factores distintos a la precarga en la determinación de los test dinámicos de precarga es pobremente conocida en pediatría. Nuestro objetivo fue medir el efecto del volumen tidal (V_T) sobre PPV y SVV en un contexto de compliance pulmonar normal y disminuida en un modelo porcino.
Material y método: Veinte cerditos Large-White anestesiados y paralizados (5,2 ± 0,4 kg). PPV y SVV fueron medidos por análisis de contorno de pulso durante ventilación con V_T de 6 y 12 mL/kg (V_T bajo y alto, respectivamente), ambos previo y posterior a lesión pulmonar aguda (ALI) químicamente inducida con instilación traqueal de polisorbato 20.
Resultados: Previo a inducción de ALI, PPV y SVV no tuvieron cambios significativos al modificar el V_T. Sin embargo, después de ALI, PPV y SVV fueron significativamente mayores durante ventilación con V_T alto, respecto a V_T bajo (PPV aumentó de 8,9 ± 1,2 a 12,4 ± 1,1%, y SVV de 8,5 ± 1,0 a 12,7 ± 1,2%, ambos $P < 0,01$).
Conclusiones: Este estudio encontró que un V_T alto y una compliance pulmonar disminuida debido a ALI incrementan los test dinámicos de precarga, con una mayor influencia de esta última. En sujetos con ALI la compliance pulmonar debiera ser considerada al interpretar los test dinámicos de precarga.

Introduction

Intravenous fluid administration is a common therapy in critically ill patients, serving as the cornerstone of initial treatment in many conditions. Recent data suggest that fluid management has a major impact on the severity and outcome of critical illness.[1] Knowing that excessive administration of fluids and development of fluid overload are associated with negative effects, the main question when deciding fluid administration is whether there will be beneficial effect on hemodynamics, specifically on cardiac output (CO). Preload dynamic tests, pulse pressure variation (PPV) and stroke volume variation (SVV) have emerged as powerful tools to predict response to fluid administration in different clinical settings.[2–5] Many clinical and experimental studies have determined that PPV >10% and SVV >13% are associated with a significant increase in CO after fluid administration, thus predicting fluid responsiveness. These tests are based on the Frank–Starling Law, which describes the relationship between preload (end-diastolic volume or pressure) and stroke volume. As shown in Fig. 1 two zones can be identified: a steep portion of the curve where changes in preload produce significant changes in CO, and a flat portion of the curve where changes in preload do not significantly change CO (dark gray). Periodic changes in ventricular filling pressures (i.e. preload) occur due to cyclical positive pressure administered during mechanical ventilation. Cyclic changes in stroke volume are greater when the ventricles operate on the steep rather than flat portion of the Frank–Starling curve. Preload dynamic test can identify this particular situation and predict response to fluid administration.[6] Of note, due to complex cardiopulmonary interactions, preload dynamic indices do not depend only on cardiac preload.[7,8] Experimental and small clinical studies have demonstrated that pulmonary and other cardiovascular factors may play a role in the PPV and SVV measurements, though exact mechanisms are not well understood.[9–12]

Acute lung injury (ALI) is a frequent cause of hypoxemia, loss of respiratory system compliance (C_{RS}) and pulmonary edema. Caution has been claimed respect to the usefulness of dynamic preload tests in patients with ALI where due to low C_{RS} the transmission of positive pressure to the vascular compartment of the lungs, great thoracic veins and the heart may be decreased.[10] On the other hand, subjects with ALI have a decreased compliance resulting in higher changes in tracheal pressure for a given tidal volume (V_T).[11] In addition, the standard of care of ALI patients include MV with low V_T. This ventilatory strategy may theoretically decrease the pressure transmitted from the airways to the pleural and pericardial spaces, diminishing the variations of SV and PP.[12,13] Accordingly, the effect of a decreased V_T on preload dynamic tests in ALI is unpredictable.[14] Because there are marked differences in respiratory and cardiovascular physiology in children with respect to adults (e.g. chest wall compliance, airway wall compliance and resistance, heart rate, stroke volume, pulmonary and systemic vascular resistance, aortic elastance and compliance, metabolic rate), basis for many age-specific differences in the cardiovascular and metabolic responses to injury, these observations should be carefully examined.[15–19]

In summary, preload dynamic tests may be an inaccurate measure of filling in cases where C_{RS} or V_T are low, even more so considering the particular features pediatric physiology. The aim of this work was to determine the effect of