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Evaluation of pulse pressure variation validity criteria in critically ill patients: a prospective observational multicentre point-prevalence study

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Editor's key points

- Respiratory variation in pulse pressure is commonly used to predict fluid responsiveness in critically ill patients.
- The validity of this measure was assessed on a single day in a multicentre survey of French intensive care units.
- Very few patients satisfied all criteria for valid use of pulse pressure variation in this setting, in large part due to widespread use of low tidal volume ventilation.

Background. Respiratory variation in pulse pressure (ΔPP) is commonly used to predict the fluid responsiveness of critically ill patients. However, some researchers have demonstrated that this measurement has several limitations. The present study was designed to evaluate the proportion of patients satisfying criteria for valid application of ΔPP at a given time-point.

Methods. A 1 day, prospective, observational, point-prevalence study was performed in 26 French intensive care units (ICUs). All patients hospitalized in the ICUs on the day of the study were included. The ΔPP validity criteria were recorded prospectively and defined as follows: (i) mechanical ventilation in the absence of spontaneous respiration; (ii) regular cardiac rhythm; (iii) tidal volume $\geq$8 ml kg^{-1} of ideal body weight; (iv) a heart rate/respiratory rate ratio $>$3.6; (v) total respiratory system compliance $\geq$30 ml cm H_2O^{-1}; and (vi) tricuspid annular peak systolic velocity $\geq$0.15 m s^{-1}.

Results. The study included 311 patients with a Simplified Acute Physiology Score II of 41 (39–43). Overall, only six (2%) patients satisfied all validity criteria. Of the 170 patients with an arterial line in place, only five (3%) satisfied the validity criteria. During the 24 h preceding the study time-point, fluid responsiveness was assessed for 79 patients. ΔPP had been used to assess fluid responsiveness in 15 of these cases (19%).

Conclusions. A very low percentage of patients satisfied all criteria for valid use of ΔPP in the evaluation of fluid responsiveness. Physicians must consider limitations to the validity of ΔPP before using this variable.

Keywords: fluid responsiveness; haemodynamic monitoring; pulse pressure variation

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Intravascular volume expansion is important in the treatment modality in hypotensive critically ill patients, but is not always effective, that is, fluid infusion is not always followed by an increase in stroke volume.[1 2] Given that ineffective volume expansion can even be harmful, it is essential to predict fluid responsiveness in guiding therapy.[3] Several static indices (such as central venous pressure, pulmonary artery occlusion pressure, and ventricular end-diastolic volume) have been studied, but none accurately predicts fluid responsiveness.[2] More recently, a dynamic index [respiratory variation in pulse pressure (ΔPP)] has been described as an accurate tool for predicting fluid responsiveness,[4] and confirmed by several studies over the last decade.[5] Thus, ΔPP and its surrogates (e.g. stroke volume variation) have been implemented in several devices for continuous monitoring of fluid responsiveness.[6] However, there are a number of limitations to this approach.[7–11] Unfortunately, the extent to which these limitations are actually encountered in intensive care units (ICUs) has not been evaluated in a large multicentre study. The aim of this prospective study was to evaluate the proportion of critically ill ICU patients meeting all validity criteria for the use of ΔPP (or a surrogate) in the prediction of fluid responsiveness.

Methods

Patients

This was a 1 day point-prevalence study of ΔPP validity criteria in 26 ICUs in 22 French hospitals. General, medical, and surgical ICUs for adults with eight or more beds were included. The independent ethics committee at Amiens University Hospital approved the study's objectives and procedures and waived the need for informed consent.

Data collection

Data were collected (using two questionnaires) by a clinician nominated as the principal investigator for each centre. A specific form was completed for each patient in each ICU. The investigators had a time window of 3 h in the morning to fill out the forms. Data were then entered into a database at the coordinating centre (Amiens University Hospital). The coordinating centre was available throughout the study to answer queries and provide feedback.

ICU data

The data collected for each ICU were: type of hospital (university or general), type of ICU (general or specialized), whether or not the ICU used a device to automatically calculate ΔPP (or a surrogate), and whether ΔPP was part of a written haemodynamic monitoring protocol.

Patient characteristic data

The patient's age, BMI, primary diagnosis, Simplified Acute Physiology Score II on admission, and Sequential Organ Failure Assessment score on inclusion were recorded.

Haemodynamic monitoring

The use of haemodynamic monitoring devices (especially arterial lines) and each patient's arterial pressure and heart rate (HR) values were recorded. Vasopressor use and the volume of fluid received over the previous 24 h were also recorded.

Ventilator settings

In mechanically ventilated patients, the type of ventilation, tidal volume (V_t), and respiratory rate (RR) were recorded. For patients on controlled mechanical ventilation in the absence of spontaneous breathing, total respiratory system compliance was calculated as V_t divided by the plateau pressure minus the positive end-expiratory pressure.

ΔPP validity criteria

The following ΔPP validity criteria were defined: regular cardiac rhythm[9] (defined as no arrhythmia or extrasystoles on the monitor screen); controlled mechanical ventilation in the absence of spontaneous breathing;[9 12] $V_t \geq 8$ ml kg^{-1} [7] of ideal body weight (IBW); HR to RR ratio >3.6;[8] total respiratory system compliance (C_{TRS}) >30 ml cm H_2O^{-1};[10] and tricuspid annular peak systolic velocity (S_t) >0.15 m s^{-1}.[11]

Fluid infusion

The need for an assessment of fluid responsiveness on inclusion and during the 24 h before the study time-point was recorded for each patient. The methods and parameters used to assess fluid responsiveness were also recorded.

Statistical analysis

Categorical variables were expressed as number (%). Continuous variables were expressed as mean (95% confidence interval, CI) or median (inter-quartile range), depending on their distribution. A Kolmogorov–Smirnov test was performed to assess the normality of distribution. Patients with an arterial line were compared with those without an arterial line. The data for categorical variables were analysed using the χ^2 test (with Yate's correction, if necessary) or Fisher's exact test. Continuous data were analysed in a two-sided *t*-test or a Mann–Whitney test (depending on the distribution). The threshold for statistical significance was set to $P<0.05$.

Results

The 26 participating ICUs included a total of 313 patients. Two patients were excluded because of missing data, so the final data set comprised 311 patients. There were 24 university hospital ICUs and two general hospital ICUs. Twelve ICUs admitted both non-surgical and surgical patients, 11 admitted only surgical patients, and three admitted only non-surgical patients. The mean number of beds was 13 (2). Although 23 (88%) of the ICUs were equipped with a device that automatically calculated ΔPP, this variable was a part of a written haemodynamic monitoring protocol in only three (12%) units.