Type of the Paper (Systemic Review)

Ultrasound guided Noninvasive parameter in Evaluation of volume status in ventilated patient

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Abstract:

When evaluating critically ill patients, it is crucial to obtain an accurate evaluation of their volume status and determine whether a rise in cardiac output indicates a response to a fluid challenge. We intend to evaluate FR in mechanically ventilated patients by measuring ratio of FVD / FAD in mechanically ventilated patients by evaluating US and comparing its accuracy with PPV as a noninvasive parameter. Our systematic review included Prospective, observational, cross-sectional and analytical trials published in the last few years: An assessment Utilizing pulse pressure variation to compare diameters of femoral vein and femoral artery as a diagnostic tool for fluid responsiveness in mechanically ventilated patients. We excluded articles that were originally published in languages other English. Evaluations, guiding principles, or categorizations. Case reports, brief case series, or conference papers are acceptable alternatives to letters to the editor. The meta-analysis includes five research studies with a total of 770 individuals. The FVA/FAD ratio is a good indicator to assess volume status in post-resuscitation patients who received fluids, but it should be combined with other parameters in hypovolemic pre-resuscitation patients to get the highest accuracy.

Key words: Femoral; Vein; Diameter; Artery; Mechanical Ventilated.

1. Introduction

When evaluating critically ill patients, it is crucial to obtain an exact evaluation of their volume status and determine whether a rise in cardiac output indicates a response to a fluid challenge. Volume expansion is implemented in the event of hypovolemia detection in order to improve hemodynamics as well as reinstate baseline blood pressure [1, 2]

Critically ill patients undergo hemodynamic tests, including right atrial pressure, pulmonary artery occlusion pressure, and cardiac output, to evaluate preload. However, it should be noted that while these indexes may serve as dependable indicators of fluid status, they do not guarantee the same [3, 4]

Fluid administration is hypothesized to increase cardiac output by increasing preload, which defines a positive correlation among the length of cardiac muscle fibers as well as contractility, in accordance with the Starling law. However, beyond its ascending limb, the Starling curve plateaus, and further fluid administration may be harmful as it can cause right ventricular overload and pulmonary edema [5–7]

The determination of blood volume status can be achieved through invasive or non-invasive methods. Invasive procedures include assessments like mean pulmonary artery pressure (mPAP) and central venous pressure (CVP) [8, 9]. CVP is affected by a multitude of factors, such as thoracic, pericardial, and abdominal pressures, among others. Although CVP can be utilized as an indication for fluid management, it can also be erroneously employed to determine blood volume or mislead therapy approaches [10].

Static indices are inferior to dynamic indices, like stroke volume variation (SVV) and pulse pressure variation (PPV), when it comes to determining volume status. Nevertheless, the dependability of these dynamic indices is compromised in situations involving acute respiratory distress syndrome (ARDS) and limited tidal volume ventilation, where the tidal volume fails to substantially alter intrathoracic pressure [11, 12]. Assessment of fluid status via US assessment of the inferior vena cava (IVC) may be beneficial [13].

Numerous variables, including abdominal trauma, elevated intra-abdominal pressure, and obesity, as well as the individual's position at the time of evaluation, have a significant impact on the determination of the IVC diameter using ultrasound, obtaining an accurate measurement of the IVC diameter by the US is more than getting an accurate measure of the superficial vein. A positive passive leg-raising (PLRT) test also predicts fluid responsiveness (FR) [14, 15].

Researchers have investigated another non-invasive technique for determining blood volume by using the using the US to measure the femoral vein diameter (FVD). However, investigations demonstrate that FVD has a decent relationship with CVP. In addition, individual FVDs vary substantially and are impacted by age, gender, height, BMI, and other factors [16–20].

2. Methods

2.1. Literature search

The results of the online search came to a total of 2937 references. Following the removal of 837 duplicates, the screening of titles and abstracts continued with 2100 records. We had a total of 30 suitable articles for full-text screening, but only five of them met the requirements to be included, while the remaining 25 were disqualified. There were no additional articles imported as a result of the manual search of references. In the end, a total of five studies were incorporated into the qualitative analysis.

2.2. Study characteristics

Details for involved trials are summarized in Table 1.

2.3. Risk of Bias Within researches

For the RCTs, we used the Risk of Bias 2.0 tool developed by the Cochrane Collaboration to evaluate the potential for bias resulting from the randomization method, missing outcome data, deviation from intended interventions, measuring the result, as well as selection of reported outcomes. In the quasi-experimental research, the RoBINS-I tool was applied to evaluate bias caused by confounding variables in intervention classification, the selection of participants, missing outcome data, deviation from intended interventions, the measuring of outcomes, as well as the selection of reported outcomes. All the research showed either low or unclear risk across different parameters, with an overall moderate to high quality.

Inclusion criteria

Prospective, observational, cross-sectional and analytical trials published in the last few years: An assessment Utilising pulse pressure variation to compare diameters of femoral vein and femoral artery as a diagnostic tool for fluid responsiveness in mechanically ventilated patients.

Exclusion criteria

- Articles that were originally published in languages other English.
- Evaluations, guiding principles, or categorizations.
- Case reports, brief case series, or conference papers are acceptable alternatives to letters to the editor.

2.4. *Statistical analysis*

Using the mean and standard deviation, we aggregated data on continuous outcomes. When just a range was given, the expected standard deviation was determined by using range/4 for small to medium-sized samples (15–70 n) and range/6 for large samples (n > 70). The extracted results were merged, and the chi-squared test with Fisher's correction was used to objectively evaluate IKDC scores. Standardized mean variances (SMDs) of extracted data suggested better treatment options. We synthesized dichotomous outcome data using OR. Standardized mean variances and ORs were pooled using a random-effects model. For each outcome, 95% CI were determined. The I2 test revealed between-trial heterogeneity, with values > 50% indicating significant heterogeneity. Everything was analyzed using Comprehensive Meta-Analysis (Version 3.3.070).

3. Results

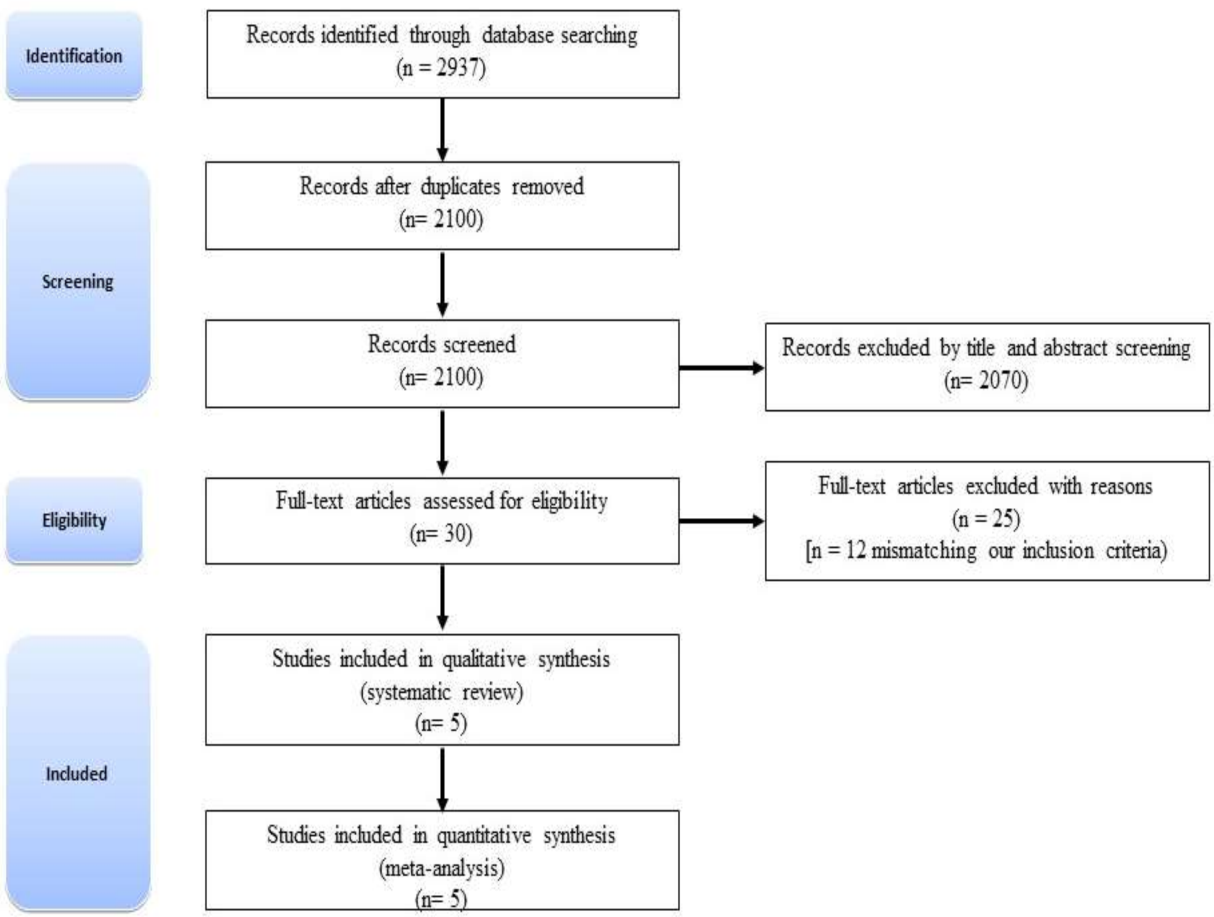

Figure 1: PRISMA Flow diagram of search process.

Table 1. Basic characteristics of patients in the included studies.

Authors	Year	Country	Type of study	Gender	Age (years)
Bayraktar et al. [21]	2022	China	Prospective	32%M + 33%F	65.5 ± 10.2
Cho et al. [22]	2016	Minnesota	Prospective, single-center, cross-sectional	54%M + 45%F	59 ± 15
Begum et al. [23]	2023	Pakistan	Cross-sectional, analytical	72.7%M + 27.3%F	36.5 ± 13.8
Zaki et al. [24]	2023	Egypt	Prospective observational	51.1%M + 48.9%F	36 (18-45)
Ma et al. [25]	2021	China	Prospective randomized	46%M + 54%F	65.5 ± 10.2

Table 2. The main findings in the included studies.

Authors	The main findings
Bayraktar et al. [21]	• Significant positive correlation found between FVD/FAD ratio and both CVP and mPAP. • FVD/FAD ratio ≥ 1.495 showed best characteristics for predicting CVP ≥ 12 cm H_2O. • FVD/FAD ratio ≤ 1.467 showed best characteristics for predicting CVP ≤ 10 cm H_2O. • FVD/FAD ratio ≥ 2.03 had optimal characteristics for predicting mPAP ≥ 25 mmHg. • Simple linear regression showed FVD/FAD ratio ≤ 0.854 when predicted CVP ≤ 5 cm H_2O. • Researchers concluded robust correlation between FVD/FAD ratio measured via US and CVP/mPAP. • Non-invasive approach offers prompt and reliable evaluation of blood volume status with clinical support.
Cho et al. [22]	• Moderate correlation observed between CVP and FVD (r = 0.66; *P* < 0.001). • Most accurate predictor of CVP < 10 mm Hg was FVD ≤ 0.8 cm (AUC = 0.894; 95% CI: 0.82–0.97). • Predictions of low CVP were most accurately predicted by FVD ≤ 0.7 cm (AUC = 0.97; 95% CI: 0.94–0.99). • High CVP best predicted by FVD ≥ 1.0 cm (AUC = 0.80; 95% CI: 0.72–0.89). • Specificity highest (94%) for elevated CVP with FVD ≥ 1.2 cm.

	• Interobserver variability of FVD measurements: 8.3±7.2 percent. • FVD could serve as an alternative method when imaging the IVC is challenging.
Begum et al. [23]	• Predictions of low CVP were most accurate with FVD ≤ 0.7 cm (AUC = 0.97; 95% CI: 0.94–0.99). • High CVP was best predicted by FVD ≥ 1.0 cm (AUC = 0.80; 95% CI: 0.72–0.89). • Specificity for elevated CVP was highest (94%) with FVD ≥ 1.2 cm. • Interobserver variability of FVD measurements: 8.3±7.2 percent. • FVD could serve as an alternative method when imaging the IVC is challenging.
Zaki et al. [24]	• CFV diameter increased significantly post induction compared to pre-induction, correlating with post-induction hypotension (PIH) in susceptible patients. • CFV diameter changes were synchronous with IVC diameter increase in PIH patients. • No significant diameter changes were observed between age groups for IVC or CFV. • The study suggests comparable predictability of CFV diameter to IVC diameter in anticipating PIH. • CFV can serve as a reliable alternative when IVC visualization is challenging or inaccurate. • Variations in CFV and IVC diameters were insignificant across different age categories, indicating reliability regardless of age group.
Ma et al. [25]	• Significant association between FVD/FAD ratio and both CVP (R = 0.87, $P < 0.0000$) and mPAP (R = 0.73, $P < 0.0000$). • ROC curve indicated FVD/FAD ratio ≥ 1.495 for predicting CVP ≥ 12 cmH2O and ≤ 1.467 for predicting CVP ≤ 10 cmH2O. • Optimal characteristics for predicting mPAP ≥ 25 mmHg were FVD/FAD ratio ≥ 2.03. • Simple linear regression showed FVD/FAD ratio ≤ 0.854 when predicted CVP ≤ 5 cm H_2O. • Ultrasound-obtained FVD/FAD ratio measurements highly correlated with CVP and mPAP, offering a non-invasive method for rapid and reliable blood volume status evaluation with clinical support.

4. Discussion

In their research, Nedel et al. concluded that the collapsibility of the femoral vein could only moderately predict fluid responsiveness in individuals with septic shock [26]. Furthermore, there was no correlation between the collapsibility of the inferior vena cava and unexpected MV in these cases. Kent et al. estimated that associations among IVC-CI and FV-/IJV-CI are weak, notwithstanding minor measurement biases, in their study [27]. These findings suggest that IJ-CI and FV-CI should not be utilized in the ICU as the primary tool for clinical decision support regarding intravascular volume assessment. According to the findings of Kim et al., the diagnostic accuracy of ultrasonographic measurement of respiratory variation in the diameter of the IVC for predicting fluid responsiveness in critically ill individuals is favorable [28]. Nevertheless, we have concluded that the available evidence regarding IJV, SCV, and FV diameters is inadequate to support their clinical application. This is in contrast to the findings of Ma et al., which established a robust correlation between FVD/FAD ratio measured via US and CVP [25]. The association between CVP and FVD/FAD ratio was linear. Malik et al. discovered a strong correlation between FVD and CVP measurements; this finding suggests an alternative non-invasive technique for determining the volume status in critically ill patients [29]. According to the findings of Bayraktar et al., there was a significant correlation between FVD/FAD ratio measured by US and both CVP and mPAP [21]. This correlation establishes a non-invasive approach to promptly and dependably evaluating blood volume status, while also offering valuable clinical support.

Conclusion

Our systematic review observed that FVD/FAD ratio is a good indicator to assess volume status in post-resuscitation patients who received fluids but should be combined with other parameters in hypovolemic pre-resuscitated patients to achieve the highest accuracy.

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Conflicts of Interest: All authors declare they have no conflicts of interest.

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