The Use of Critical Care Ultrasound, E. Brogi, G. Bozzetti, M. Romani et al.
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Bedside Point-of-Care Ultrasound Use in the Critically Ill: Historical Perspectives and a Path Forward, C. Bryant
The Clinical Utility of Estimated Plasma Volume in Critical Care

An overview of clinical evidence that demonstrates the prognostic value of estimated plasma volume (ePVS) in critically ill patients.

With ePVS determination and progress monitoring over time (ePV), volume status can be assessed. This allows for prompt initiation of therapy and, if necessary, an adjustment of therapy. In general, the measurement of PV is often difficult. Simple, non-invasive methods, such as medical history, weight, radiographs, and invasive techniques, such as transcardiopulmonary methods (PiCCO), are used for ePVS determination. Both approaches are labourious, costly, and not always available (Metkus 2022; Rosner and Mullholland 2022).

Alternatively, based on measured haemoglobin and haematocrit values, ePVS can be calculated using the Strauss formula:

$$\text{ePVS} = \frac{100 - \text{hematocrit} \text{(% after)}}{\text{hemoglobin} \text{ (g/dL) after}} - \frac{100 - \text{hematocrit} \text{(% before)}}{\text{hemoglobin} \text{ (g/dL) before}}$$

There is another formula that can also help with ePV estimation. It is an extension of the Strauss formula by Duarte et al. It provides an instantaneous measurement of PV using haematocrit and haemoglobin data from a single time-point (Kobayashi et al. 2021).

$$\text{ePVS} = \frac{100 - \text{hematocrit} \text{(%)}}{\text{hemoglobin} \text{ (g/dL)}}$$

**Clinical Studies and Case Studies**

Congestion is a well-established predictor of outcomes in patients with HF, as it can lead to worsening disease and is associated with high mortality. In the event of inadequate therapy or residual congestion at discharge, there is a high risk of rehospitalisation. Therefore, a better understanding of the pathophysiology of congestion is extremely important, as is the need for finding more personalised therapies (Kobayashi et al. 2021; Boorsma et al. 2020).

In patients with acute HF, PV could increase by nearly 40%. This can lead to impairment of pulmonary function (Kobayashi et al. 2021). Volume overload with haemodynamic and clinical congestion can be a complex process in patients with acute and chronic HF. Multiple factors contribute to the accumulation and redistribution of fluid, ultimately resulting in volume overload and organ congestion. While clinical signs and symptoms can help alert clinicians of a change in volume status, there is still a need for quantitative measurement of blood volume in the patient as it can help guide treatment and/or adjust therapy (Miller 2017).

Findings from a study with 324 HF patients showed that the extent and composition of intravascular volume expansion significantly affected clinical outcomes. The impact of volume profiles varied with the progression of HF. Intravascular volume profiles were also predictive of the risk of HF admission, readmission or death (Kelly et al. 2021).

Transcatheter aortic valve implantation (TAVI) is an essential treatment option for severe aortic stenosis (AS). Subclinical congestion in patients undergoing TAVI is associated with worse clinical outcomes. However, this congestion often remains undetected during routine clinical assessment. Non-invasive techniques to calculate PV based on weight and haematocrit can improve prognosis in patients with HF. In 2021, in a prospective study of 859 patients undergoing TAVI, Seoudy et al.
(2021) investigated the association between increased PV and poorer patient outcomes. Increased PV occurred in 535 patients. A significant increase in rehospitalisations and all-cause mortality within one year after TAVI (p = .001) were demonstrated. These findings show that increased PV in the subclinical range is a reliable marker (Seoudy et al. 2021).

In ARDS, a severe but common complication in ICU patients, optimal fluid management is extremely important (Niedermeyer et al. 2021).

In a study with 3165 ARDS patients a mean and median PVS of 5.9% was determined. Yet 68% of those patients had a positive PVS. Variations from the median were associated with outcome: a PVS above median resulted in a 30.6% mortality rate, whereas a lower PVS resulted in a 21.6% mortality rate (Niedermeyer et al. 2021).

Sepsis is often associated with haemorrhagic shock, Clarkson's syndrome and vasodilation. To ensure haemodynamic stability, plasma replacement therapy is often necessary (Marx et al. 2021). Volume status assessment and therapy monitoring are essential in these patients to detect and avoid lung or kidney congestion. Inadequate and aggressive fluid administration can lead to poor patient outcomes. Hence, fluid management needs to be carefully considered and monitored (Kalantari et al. 2013; Vincent 2019).

In a study with 1502 patients with fever at the emergency department, researchers evaluated the ePVS value registered at the time of admission and derived from complete blood count. 3.4% of the patients died at 30 days, and 5.3% of patients had a diagnosis of sepsis. The median ePVS in patients who died was higher compared to patients who survived (6.01 dL/g vs 4.49 dL/g, p < .0001). Hence, the ePVS value appears to be an effective tool for predicting the presence of sepsis and 30-day mortality (Turcato et al. 2020).

In another prospective study with 100 patients admitted to the ICU with sepsis or septic shock, in-hospital mortality was 47%, and the ePVS was found to be correlated with the amount of total fluids administered 24 hours before admission. The mean ePVS in patients who died was higher than in those who survived (7.7 ± 2.1 dL/g vs. 6.6 ± 1.6 dL/g, P = 0.003). These findings also show that ePVS can be used as a novel prognostic factor in patients with sepsis or septic shock.

Conclusion
The clinical evidence clearly shows the prognostic value of ePVS. Using Strauss or Duarte’s formula to estimate PV is a useful strategy that can help improve patient outcomes. PV must be closely monitored and assessed through measurements of ePVS as ePVS is associated with in-hospital mortality and worsening outcomes. ePVS estimation remains an underutilized strategy despite clinical evidence of its prognostic value in heart failure and sepsis.

Key Points
- Monitoring and managing volume status in critically ill patients are essential, whether in sepsis, cardiology, post-operatively or in dialysis.
- Estimated plasma volume (ePVS) is a useful diagnostic and prognostic tool.
- Elevated ePVS is associated with clinical outcomes in critically ill patients.
- Volume overload with haemodynamic and clinical congestion can be a complex process in patients with acute and chronic HF.
- Volume status assessment and therapy monitoring are also essential in patients with sepsis.
- ePVS estimation remains an underutilized strategy despite clinical evidence of its prognostic value in critical care.

For more information on ePV and its use in critical care, download the white paper here.

Disclaimer
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References
Plasma volume status is vital in testing critically ill patients but is extremely difficult and costly to obtain, particularly as a POC test. Plasma volume assessment affects almost every aspect of a patient’s care, including giving IV fluids, diuresing, starting vasopressors, initiating renal replacement therapy, deciding on transfusion requirements and intubation and extubation.1,2

Nova’s Prime Plus® blood gas analyzer automatically calculates patient plasma volume status using the Strauss formula, which requires measured hemoglobin (Hb) and measured hematocrit (Hct) in order to calculate ePV (estimated plasma volume). Prime Plus reports ePV as part of a comprehensive panel including tests for kidney function, electrolytes, metabolites, gases, and acid/base. It also stores prior ePV values and displays them as a patient trend (ΔePV) graph.
