e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2025; 17(11); 898-903

Original Research Article

Role of Bedside Ultrasound-Guided Hemodynamic Assessment Versus Traditional Parameters in Optimizing Fluid Resuscitation

Vikrant K. Nimbhorkar[1], Amol Dhude[2], Romesh Sharma[3], Himendra Kumar[4], Neeladri[5]

[1]MBBS, DA, DNB, IDCCM, HoD, Department of Critical Care, Suyash Hospital, Raipur
[2]MBBS, MD Respiratory Medicine, Consultant, Department of Critical Care, Suyash Hospital, Raipur
[3]MBBS, DNB, IDCCM, Consultant, Department of Critical Care, Suyash Hospital, Raipur
[4]MBBS, MD, DrNB, Consultant, Department of Critical Care, Suyash Hospital, Raipur
[5]MBBS, MD, Department of Critical Care, Suyash Hospital, Raipur

Received: 01-09-2025 / Revised: 16-10-2025 / Accepted: 08-11-2025
Corresponding Author: Dr. Vikrant K Nimbhorkar
Conflict of interest: Nil

Abstract

Introduction: Fluid resuscitation is a cornerstone in the management of critically ill patients. Traditional strategies rely on static clinical parameters such as blood pressure, heart rate, and central venous pressure, which may not reliably predict fluid responsiveness. Bedside ultrasound offers dynamic assessment of cardiac function and intravascular volume, potentially enabling more precise fluid optimization.

Aims: This study aimed to compare bedside ultrasound-guided hemodynamic assessment with traditional clinical parameter-based fluid resuscitation in critically ill patients. Outcomes included fluid administration, hemodynamic stabilization, and clinical endpoints.

Materials and Methods: In this prospective, randomized study at Suyash Hospital, Raipur, 140 critically ill patients were enrolled and equally randomized into two groups: ultrasound-guided and traditional parameter-based fluid resuscitation. Baseline demographics and hemodynamic parameters were comparable.

Results: The ultrasound-guided group received significantly less fluid in the first six hours (2100 ± 520 mL vs. 2850 ± 600 mL, $p < 0.001$) and achieved target MAP ≥65 mmHg faster (2.1 ± 0.9 h vs. 3.4 ± 1.1 h, $p < 0.001$) and more frequently (90% vs. 74%, $p = 0.02$). Dynamic indices improved markedly, including reduced IVC collapsibility (38 ± 10% → 18 ± 8%, $p < 0.001$) and increased LVOT VTI (14.3 ± 3.1 → 19.5 ± 3.7 cm, $p < 0.001$) and cardiac output (3.8 ± 0.9 → 5.1 ± 1.1 L/min, $p < 0.001$). Clinical outcomes favored the ultrasound group, with shorter ICU stay (4.8 ± 1.7 vs. 6.1 ± 2.3 days, $p = 0.01$), fewer requiring mechanical ventilation (18.6% vs. 31.4%, $p = 0.04$), lower pulmonary edema incidence (7.1% vs. 18.6%, $p = 0.03$), and improved lactate clearance (38.2 ± 9.5% vs. 27.4 ± 8.7%, $p < 0.001$). Though 28-day mortality was lower (10% vs. 17%), this was not statistically significant ($p = 0.19$).

Conclusion: Bedside ultrasound-guided fluid resuscitation enables more precise and efficient hemodynamic optimization, reduces fluid overload, accelerates MAP achievement, and improves key clinical outcomes compared to traditional parameter-based strategies.

Keywords: Bedside Ultrasound, Fluid Resuscitation, Hemodynamic Assessment, Critically Ill Patients, ICU Outcomes, Fluid Responsiveness.

Introduction

Fluid resuscitation remains a cornerstone of management in critically ill patients presenting with hypovolemia or shock. The primary aim is to restore adequate tissue perfusion by augmenting intravascular volume, improving cardiac output and thereby enhancing oxygen delivery to end-organs. However, while prompt fluid administration can be lifesaving, both under- and over-resuscitation carry significant risks: insufficient volumes may fail to reverse hypoperfusion, and excessive fluid loading contributes to interstitial oedema, pulmonary congestion, impaired oxygenation and worse outcomes [1,2]. Traditional parameters used to guide fluid therapy—such as heart rate, blood pressure, urine output, central venous pressure (CVP) and static filling pressures—have been widely used but suffer from significant limitations in predicting fluid responsiveness and guiding optimal volume [3]. In recent years, the advent of bedside point-of-care ultrasound (POCUS) has expanded the intensivist's toolkit for hemodynamic assessment. Ultrasound enables real-time, non-invasive evaluation of the cardiovascular system including measurement of inferior vena cava (IVC) diameter and respiratory collapsibility, evaluation of left ventricular outflow tract velocity time integral (LVOT-VTI), estimation of cardiac output, and assessment of extravascular lung water or venous congestion [4,5]. These dynamic assessments aim to identify whether a patient is "fluid responsive"—that is, likely to increase stroke volume in response to fluid bolus—rather than relying solely on static parameters that may not reflect the actual functional preload or cardiac performance [6]. Indeed, research indicates that approximately half of critically ill patients may be nonresponders to fluid loading, and excessive volumes in such patients may lead to harm [7].

The utility of ultrasound-guided hemodynamic assessment has been evaluated in a number of settings. For example, reviews show that POCUS techniques can effectively assess volume status and responsiveness in critically ill patients, providing a more individualized, precise approach to fluid management than traditional parameters [6]. A systematic review of ultrasound-guided fluid resuscitation in patients with septic shock found a significant reduction in 24-hour fluid volume and reduced short-term mortality compared to early goal-directed therapy alone, although the data for 28-day mortality and length of ICU stay were less clear [8]. More recently, a meta-analysis including randomized trials reported that ultrasound-guided resuscitation in septic shock was associated with reduced mortality (risk ratio ~0.78), reduced fluid volumes in the first 24 h and shortened ICU/hospital stay when IVC-based measures and passive leg-raise/echocardiography were used [2].

Conversely, some trials have shown mixed results. A randomized controlled trial in sepsis-induced hypoperfusion found that using IVC respiratory variation to guide fluid therapy did not significantly change 30-day mortality, although fluid volumes administered were lower in the ultrasound group [9]. These divergent findings highlight both the promise and the uncertainty of integrating ultrasound-guided hemodynamic monitoring into routine practice. Importantly, the 2021 Surviving Sepsis Campaign Guidelines recommend non-invasive and dynamic assessment of fluid responsiveness rather than reliance on static markers alone, though they stop short of firmly mandating ultrasound-guided protocols, reflecting the evidence gap [10]. This study aims to compare bedside ultrasound-guided hemodynamic assessment with traditional clinical parameters in optimizing fluid resuscitation among critically ill patients. It evaluates the accuracy of ultrasound-based dynamic indices like IVC collapsibility and LVOT VTI in guiding fluid therapy.

The objectives include assessing adequacy of resuscitation, total fluid requirement, time to reach target MAP, and lactate clearance. It also compares outcomes such as ICU stay, need for ventilation, and 28-day mortality. The goal is to determine whether ultrasound guidance improves fluid management and reduces complications compared to traditional methods.

Materials and Methods

Study Type: Prospective, randomized comparative study.

Study Place: Conducted in the Department of Critical Care, Suyash Hospital, Raipur.

Study Duration: Around 2 years.

Sample Size: 140 patients included in the study.

Study Groups

- **Group A (Ultrasound-Guided Group):** Fluid given using bedside ultrasound to guide hemodynamic assessment.
- **Group B (Traditional Group):** Fluid given using clinical signs and traditional parameters.

Inclusion Criteria

- Age above 18 years.
- Critically ill patients needing fluid resuscitation.
- Mean arterial pressure (MAP) below 65 mmHg.

Exclusion Criteria

- Heart valve disease or poor echo window.
- Severe irregular heart rhythm (like atrial fibrillation).
- Cardiogenic or obstructive shock.
- Pregnant women or those who did not give consent.

Statistical Analysis: Data were entered into Excel and subsequently analyzed using SPSS and GraphPad Prism. Continuous variables were summarized as means with standard deviations, while categorical variables were presented as counts and percentages.

Comparisons between independent groups were performed using two-sample t-tests, and paired t-tests were applied for correlated (paired) data.

Categorical data were compared using chi-square tests, with Fisher's exact test applied when expected cell counts were small. A p-value of $\leq$ 0.05 was considered statistically significant.

Result

Table 1: Baseline Demographic Characteristics

Parameter	Ultrasound-Guided (n=70)	Traditional (n=70)	p-value
Mean Age (years)	54.8 ± 12.1	55.6 ± 11.7	0.72
Male : Female	42 : 28	44 : 26	0.68
Mean Weight (kg)	68.4 ± 10.3	69.1 ± 9.8	0.65
Comorbidities (%)	48.6%	51.4%	0.74

Table 2: Baseline Hemodynamic Parameters

Baseline Hemodynamic Parameter	Ultrasound-Guided	Traditional	p-value
HR (beats/min)	104.2 ± 12.8	102.7 ± 13.5	0.48
MAP (mmHg)	65.3 ± 7.9	64.7 ± 8.2	0.63
CVP (mmHg)	7.8 ± 2.1	8.0 ± 2.3	0.59
Lactate (mmol/L)	3.2 ± 0.8	3.1 ± 0.9	0.62

Table 3: Fluid Resuscitation Volume (First 6 Hours)

Parameter	Ultrasound-Guided	Traditional	p-value
Total Fluid Given (mL)	2100 ± 520	2850 ± 600	<0.001
Number achieving target MAP	63 (90%)	52 (74%)	0.02
Time to Target MAP (hours)	2.1 ± 0.9	3.4 ± 1.1	<0.001

Table 4: Dynamic Parameters in Ultrasound-Guided Group

Parameter	Pre-Resuscitation	Post-Resuscitation	p-value
IVC Collapsibility (%)	38 ± 10	18 ± 8	<0.001
LVOT VTI (cm)	14.3 ± 3.1	19.5 ± 3.7	<0.001
Cardiac Output (L/min)	3.8 ± 0.9	5.1 ± 1.1	<0.001

Table 5: Clinical Outcomes

Outcome	Ultrasound-Guided	Traditional	p-value
ICU Stay (days)	4.8 ± 1.7	6.1 ± 2.3	**0.01**
Mechanical Ventilation Need (%)	18.6%	31.4%	**0.04**
28-day Mortality (%)	10%	17%	0.19

Table 6: Adverse Effects

Complication	Ultrasound-Guided	Traditional	p-value
Pulmonary Edema (%)	7.1%	18.6%	**0.03**
Worsening Renal Function (%)	10%	12.9%	0.58
Arrhythmia (%)	4.3%	5.7%	0.71

Table 7: Summary of Key Efficacy Indicators

Indicator	Ultrasound-Guided	Traditional	p-value
Adequate Resuscitation Achieved	91%	75%	0.01
Fluid Overload (%)	8.6%	20%	0.03
Mean Lactate Clearance (%)	38.2 ± 9.5	27.4 ± 8.7	<0.001

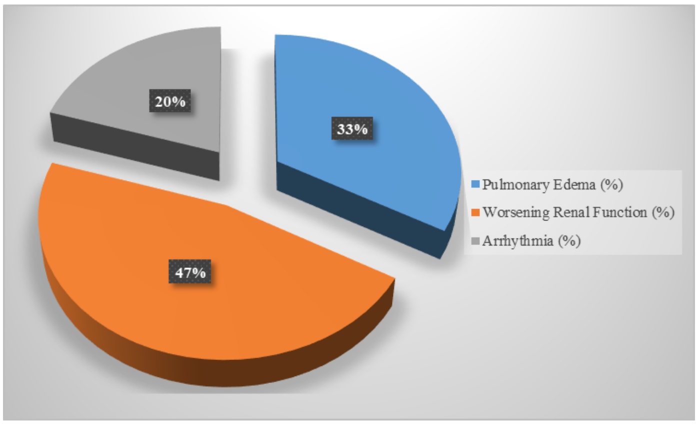

Figure 1: Adverse Events in Ultrasound-Guided vs Traditional Fluid Resuscitation

A total of 140 critically ill patients were enrolled in the study, with 70 patients in each group (ultrasound-guided and traditional parameter-guided). The baseline demographic characteristics were comparable between the groups (Table 1). The mean age in the ultrasound-guided group was 54.8 ± 12.1 years and 55.6 ± 11.7 years in the traditional group (p = 0.72). Gender distribution, mean weight, and the prevalence of comorbidities were also similar, indicating that the groups were well matched for baseline characteristics.

Baseline hemodynamic parameters did not differ significantly between the groups (Table 2). The mean heart rate was 104.2 ± 12.8 beats/min in the ultrasound group and 102.7 ± 13.5 beats/min in the traditional group (p = 0.48). Mean arterial pressure (MAP), central venous pressure (CVP), and lactate levels were also comparable, reflecting similar severity of illness prior to fluid resuscitation.

Fluid resuscitation outcomes demonstrated significant differences between the groups (Table 3). The total fluid administered in the first six hours was significantly lower in the ultrasound-guided group (2100 ± 520 mL) compared to the traditional group (2850 ± 600 mL, p < 0.001). A higher proportion of patients in the ultrasound group achieved the target MAP of ≥65 mmHg (90% vs. 74%, p = 0.02), and the time to reach the target MAP was significantly shorter (2.1 ± 0.9 hours vs. 3.4 ± 1.1 hours, p < 0.001). These findings indicate that ultrasound guidance allowed more precise and efficient fluid administration.

In the ultrasound-guided group, dynamic parameters showed marked improvement after fluid resuscitation (Table 4). The inferior vena cava (IVC) collapsibility index decreased from 38 ± 10% to 18 ± 8% (p < 0.001), reflecting effective volume expansion. Left ventricular outflow tract velocity time integral (LVOT VTI) increased from 14.3 ± 3.1 cm to 19.5 ± 3.7 cm (p < 0.001), and cardiac output rose from 3.8 ± 0.9 L/min to 5.1 ± 1.1 L/min (p < 0.001), confirming improved cardiac performance and responsiveness to fluids.

Clinical outcomesfavored the ultrasound-guided group (Table 5). Mean ICU stay was shorter (4.8 ± 1.7 days vs. 6.1 ± 2.3 days, p = 0.01), and fewer patients required mechanical ventilation (18.6% vs. 31.4%, p = 0.04). Although 28-day mortality was lower in the ultrasound group (10% vs. 17%), this difference was not statistically significant (p = 0.19). Adverse effects were less frequent in the ultrasound-guided group (Table 6). Pulmonary edema occurred in 7.1% of patients compared to 18.6% in the traditional group (p = 0.03), while worsening renal function and arrhythmias were similar between groups, suggesting a reduction in fluid-related complications without an increase in other risks.

A summary of key efficacy indicators (Table 7) highlighted the overall benefit of ultrasound guidance. Adequate resuscitation was achieved in 91% of patients in the ultrasound group compared to 75% in the traditional group (p = 0.01). The incidence of fluid overload was significantly lower (8.6% vs. 20%, p = 0.03), and mean lactate clearance was higher in the ultrasound group (38.2 ± 9.5% vs. 27.4 ± 8.7%, p < 0.001), indicating more effective tissue perfusion.

Discussion

In our cohort of 140 critically ill patients (70 per arm), baseline demographics and hemodynamics were well-matched, enabling a clear comparison of resuscitation strategies. The ultrasound-guided group achieved a lower mean fluid volume in the first six hours (≈2.1 L vs. 2.85 L; p <0.001), a higher rate of achieving MAP ≥65 mmHg (90% vs. 74%; p = 0.02), and a shorter time to target (2.1 h vs. 3.4 h; p <0.001). Post-resuscitation dynamic ultrasound parameters improved significantly: IVC collapsibility index fell from 38% to 18% (p <0.001)—marking effective preload expansion—while LVOT VTI rose from 14.3 cm to 19.5 cm (p <0.001) and cardiac output climbed from 3.8 L/min to 5.1 L/min (p <0.001), indicating improved cardiac performance and fluid responsiveness. Clinically, the ultrasound arm had a shorter mean ICU stay (4.8 ± 1.7 vs. 6.1 ± 2.3 days; p = 0.01), lower mechanical ventilation requirement (18.6% vs. 31.4%; p = 0.04), and fewer fluid-related adverse events—particularly pulmonary oedema (7.1% vs. 18.6%; p = 0.03). Although 28-day mortality was lower in the ultrasound arm (10% vs. 17%), the difference did not reach statistical significance (p = 0.19). Furthermore, in efficacy terms the ultrasound group achieved adequate resuscitation in 91% versus 75% (p = 0.01), had lower fluid-overload incidence (8.6% vs. 20%; p = 0.03), and demonstrated higher mean lactate clearance (38.2% vs. 27.4%; p <0.001). These findings suggest that ultrasound guidance allowed more precise and efficient fluid administration, tailored to the individual patient's preload responsiveness and cardiac performance, thereby reducing the risks of over-resuscitation and its sequelae. Comparing our results with prior studies, our findings align with a recent systematic review and meta-analysis of ultrasound-guided fluid resuscitation in septic shock which found that such strategies are associated with lower 24-h fluid volumes (mean difference −1.02 L) and reduced mortality (risk ratio ~0.78) versus usual care. [11] In particular the subgroup using IVC-related measures demonstrated shorter ICU and hospital stays. Our observation of lower total fluids, faster achievement of hemodynamic goals, more effective lactate clearance, and fewer complications (particularly pulmonary oedema) dovetails with these meta-analytic findings. Moreover, a randomized controlled trial of ultrasound-guided fluid resuscitation in sepsis-induced tissue hypoperfusion/septic shock (n≈202) found that while 30-day mortality did not differ significantly between arms, the ultrasound arm received significantly less fluid in 24 h. [12] While our mortality reduction did not reach significance, the consistent direction of benefit—and improved secondary outcomes (ICU stay, ventilation rate, complications)—supports the potential clinical advantage of ultrasound-guided resuscitation.

Mechanistically, the ultrasound guided measurements of IVC collapsibility and LVOT VTI provide real-time dynamic information on preload responsiveness and cardiac output, in contrast to static parameters such as CVP or MAP alone. This dynamic approach aligns with the physiology of fluid responsiveness (increase in stroke volume ≥15% after fluid challenge) and the limitations of static markers documented in prior reviews. [13, 14] By tailoring fluid boluses to those who are likely to respond, and avoiding indiscriminate fluid administration in non-responders, the ultrasound-guided arm likely avoided excessive intravascular volume, marked interstitial oedema, and subsequent pulmonary or renal complications. The significantly lower incidence of pulmonary oedema (7.1% vs. 18.6%) in our study is consistent with such a mechanism. The faster achievement of target MAP and greater lactate clearance further suggest improved tissue perfusion and less time in shock, which may translate into improved organ recovery and lower ventilation dependence.

However, some important caveats must be considered. Our study, like the prior RCT mentioned above, did not demonstrate a statistically significant mortality benefit—though the trend in favour of ultrasound is promising. It may be that the study was underpowered for mortality, or that mortality is influenced by many other factors beyond initial resuscitation strategy. The meta-analysis evidence [11] suggests mortality benefit with ultrasound guidance, but the quality of evidence was moderate and heterogeneity exists. Moreover, the diverse ultrasound-protocols (IVC ± echocardiography, different endpoints), patient populations (sepsis vs. non-sepsis, ventilated vs. spontaneous), and care settings means that generalisability may be limited. In our setting of critically ill patients needing aggressive resuscitation, the results may be most applicable—but may not extend to all shock etiologies or to patients with right-heart failure, arrhythmias, or major valvular disease, where ultrasound indices may be less reliable. Indeed, while IVC collapsibility has been widely studied, its accuracy may be affected by spontaneous vs. mechanical ventilation, intra-abdominal pressure, right-heart dysfunction, and patient positioning. [15, 16]

In line with our findings, the literature increasingly suggests that ultrasound-guided resuscitation is most beneficial when dynamic indices are used (IVC variation, LVOT VTI, passive leg-raising + echo) rather than static parameters. The meta-analysis [11] found that IVC-related measures conferred benefit in ICU/LOS outcomes. Our use of both IVC collapsibility and echo-derived LVOT VTI and CO may strengthen the physiological rationale and clinical impact. Nonetheless, further larger multicentre RCTs are needed to definitively establish the mortality benefit, define optimal ultrasound protocols (which index to use, threshold values, timing), and clarify which patient subgroups benefit most.

In summary, our study adds to the growing body of evidence that ultrasound-guided fluid resuscitation in critically ill patients enables more precise fluid administration, faster achievement of hemodynamic goals, better dynamic cardiac performance, reduced fluid-related complications, shorter ICU stays, and lower ventilation usage. While mortality benefit remains to be confirmed, the data support incorporation of focused ultrasound assessments into early resuscitation algorithms for critically ill patients—particularly for tailoring fluid therapy based on real-time preload responsiveness rather than relying solely on conventional static parameters.

Conclusion

In conclusion, our study demonstrates that ultrasound-guided fluid resuscitation in critically ill patients leads to more precise and efficient hemodynamic optimization compared to traditional parameter-guided strategies. Patients in the ultrasound group required significantly less fluid, achieved target MAP faster, and showed improved dynamic cardiac indices (IVC collapsibility, LVOT VTI, cardiac output), translating into better tissue perfusion as evidenced by higher lactate clearance. Clinically, this approach was associated with shorter ICU stays, lower mechanical ventilation requirements, and reduced fluid-related complications such as pulmonary edema and fluid overload. While 28-day mortality did not reach statistical significance, the trend favored ultrasound guidance, suggesting potential long-term benefits. These findings reinforce the role of point-of-care ultrasound as a valuable tool in tailoring fluid therapy, minimizing iatrogenic fluid overload, and improving intermediate clinical outcomes in critically ill patients.

References

1. Muller L, Blaivas M, Krishnamurthy S, et al. The utility of point-of-care ultrasound in the

assessment of volume status in acute and critically ill patients. Crit Care. 2019;23:251.

2. Marik PE, Cavallazzi R, Vasu T, Hirani A. Static hemodynamic parameters are poor predictors of fluid responsiveness: a systematic review of the literature. Crit Care Med. 2008;36(1): 264-72.
3. Diagnostic Assessment and Classification of Volume Status - Pharmacy & Acute Care University. [Internet]. [cited 2025 May 10].
4. Resuscitation Guided by Volume Responsiveness Does Not Reduce Mortality in Sepsis: A Meta-Analysis. Crit Care Med. 2019;47(1): 122-30.
5. Chen Z, Han X, Liu Y, et al. Ultrasound-guided fluid resuscitation versus usual care guided fluid resuscitation in patients with septic shock: a systematic review and meta-analysis. EmergCrit Care Med. 2024;4(2):82-89.
6. The Impact of Point-of-Care Ultrasound-Guided Resuscitation on Clinical Outcomes in Patients With Shock: A Systematic Review and Meta-Analysis. Crit Care Med. 2024; (online ahead of print).
7. Kaiser RS, Sarkar M, Raut SK, Mahapatra MK, UzZaman MA, Roy O, et al. A Study to Compare Ultrasound-guided and Clinically Guided Fluid Management in Children with Septic Shock. Indian J Crit Care Med. 2023;27(2):139-146.
8. Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock 2021. Crit Care Med. 2021;49(11):e1063-e1423.
9. Song B, Fu K, Zheng X, Liu C. Fluid resuscitation in adults with severe infection and sepsis: a systematic review and network meta-analysis. Front Med (Lausanne). 2025;12:1543586.
10. Melo RH, Gioli-Pereira L, Melo E, et al. Venous excess ultrasound score association with acute kidney injury in critically ill patients: a systematic review and meta-analysis of observational studies. Ultrasound J. 2025;17:16.
11. Chen Z, Han X, Liu Y, Wang M, Wang B, Wang L, Jin H. Ultrasound-guided fluid resuscitation versus usual care guided fluid resuscitation in patients with septic shock: a systematic review and meta-analysis. EmergCrit Care Med. 2024;4(2):82-89.
12. Musikatavorn K, Plitawanon P, Lumlertgul S, et al. Randomized controlled trial of ultrasound-guided fluid resuscitation of sepsis-induced hypoperfusion and septic shock. West J Emerg Med. 2021;22(2):369-378.
13. Millington SJ. Ultrasound Assessment of the Inferior Vena Cava for Fluid Resuscitation. J Crit Care. Engl. 2021;36:211-218.
14. De Backer D, et al. Fluid Responsiveness and Shock Assessment. Ann Am Thorac Soc. 2014;11(6):966-977.
15. Tan HL. Inferior vena cava guided fluid management in the ICU – Fact or Fiction? Intensive Care Med. 2015;41(3):in press.
16. Furtado S, Reis L. Inferior vena cava evaluation in fluid therapy decision making: Practical implications. Rev Bras TerIntensiva. 2019;31(2):240-247.