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Beyond the FAST Protocol: An Integrative Review on the Clinical Utility and Impact of Advanced POCUS Applications in the Trauma Patient

Camila Brambilla[1], Andrés Martínez[2], Gilberto Ayala[3], Alberto Guillén[4], Alba García[5], José Rodríguez[6], Kelly López[7], Julio Brambilla[8]

SUMMARY

Introduction: The FAST protocol is the gold standard for detecting hemorrhage in trauma, but its ability to assess the pathophysiological complexity of critically ill patients is limited. Advanced point-of-care ultrasound (POCUS), including transesophageal echocardiography (TEE), transcranial Doppler, and regional blocks, promises to improve diagnostic and therapeutic accuracy. This review synthesizes the current evidence on its utility beyond FAST. **Methods:** An integrative review was conducted following the framework of Whittemore and Knafl. A literature search was conducted in PubMed, Scopus, and Scite.ai (2014–2024), focusing on adults with trauma. Studies on resuscitation transesophageal echocardiography (TEE), the VEXUS protocol, optic nerve sheath measurement (ONSD), and ultrasound-guided procedures were included. **Results:** Transesophageal echocardiography (TEE) for resuscitation demonstrated superiority over transthoracic echocardiography, modifying clinical management in up to 66.7% of cases of traumatic cardiac arrest. The VEXUS protocol allowed for the identification of venous congestion associated with acute kidney injury, guiding safer fluid resuscitation. In neuromonitoring, the onset of systolic nerve stimulation (ONSD) showed a high correlation with invasive intracranial pressure. Ultrasound-guided fascial blocks significantly reduced opioid consumption and systemic complications in rib and hip fractures. **Conclusions:** The integration of advanced point-of-care ultrasound (POCUS) transforms trauma

[1] Hospital de Trauma Manuel Gianni, Asunción, Paraguay
[2] Facultad de Ciencias Médicas, Universidad Privada del Este, filial Ciudad del Este, Paraguay
[3] Cátedra de Clínica Quirúrgica, Facultad de Ciencias Médicas, Universidad Privada del Este, filial Ciudad del Este, Paraguay
[4] Facultad de Ciencias Médicas, Universidad Privada del Este, filial Ciudad del Este, Paraguay
[5] Facultad de Ciencias Médicas, Universidad Privada del Este, filial Ciudad del Este, Paraguay
[6] Universidad Nacional de Caaguazú; Hospital Distrital de Ñemby, Paraguay
[7] Facultad de Ciencias Médicas, Universidad Privada del Este, filial Ciudad del Este, Paraguay
[8] Facultad de Ciencias Médicas, Universidad Privada del Este, filial Ciudad del Este, Paraguay

Correspondent author: Dr. Kelly López, Universidad Privada del Este, filial Ciudad del Este, Paraguay. Correo: kellylopezmed@hotmail.com.

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assessment from anatomical detection to dynamic physiological monitoring. Its implementation improves diagnostic accuracy, optimizes resuscitation, and humanizes pain management, justifying its inclusion in modern advanced life support protocols.

Keywords: Ultrasonography, Wounds and Trauma, Transesophageal Echocardiography, Nerve Block, Resuscitation, Optic Nerve.

INTRODUCTION

The management of trauma patients has evolved dramatically in recent decades. While Focused Ultrasound for Trauma (FAST) has become the gold standard for the rapid detection of intraperitoneal and pericardial free fluid, its utility can be limited in complex scenarios where transthoracic image quality is poor due to the patient's body position or the presence of subcutaneous emphysema (1,2). Current literature suggests that relying exclusively on static parameters or the traditional FAST protocol may be insufficient to address the pathophysiological complexity of critically ill patients in the resuscitation room.

The concept of advanced point-of-care ultrasound (POCUS) transcends the simple identification of hemorrhage. In the setting of traumatic cardiopulmonary resuscitation, resuscitation transesophageal echocardiography (TEE) has demonstrated superior diagnostic accuracy compared to transthoracic echocardiography (TTE), allowing visualization of reversible pathologies such as pericardial effusion or assessment of cardiac motion during CPR without interrupting chest compressions (3,4). Recent studies indicate that the use of TEE can modify clinical management in a significant percentage of cases during cardiac emergencies (up to 66.7% in the ICU and 58.3% in the emergency department), optimizing real-time decision-making (5,6).

Furthermore, hemodynamic assessment has shifted from static to dynamic indices. The use of the VEXUS (Venous Excess Ultrasound) grading system now allows for monitoring venous congestion and guiding fluid therapy to avoid volume overload. Evidence indicates that high VEXUS scores correlate with a greater risk of acute kidney injury (AKI) and mortality in critically ill patients, underscoring its prognostic value (7,8). In addition, dynamic parameters such as the velocity-time integral (VTI) of the left ventricular outflow tract have proven to be more reliable predictors of fluid responsiveness than central venous pressure or the inferior vena cava collapsibility index (9,10).

Beyond hemodynamics, ultrasound has established itself as a critical tool in non-invasive neuro-monitoring. Optic nerve sheath diameter (ONSD) measurement shows a significant positive correlation with invasive intracranial pressure (ICP), serving as a vital screening tool in settings where neurosurgery is not immediate (11,12). Similarly, in airway management, ultrasonography has proven comparable in accuracy and significantly faster than capnography (35.8 vs. 67.4 seconds) for confirming endotracheal tube placement in emergencies (13,14). Regarding pain management, ultrasound-guided techniques such as iliac fascia compartment block have significantly reduced postoperative opioid consumption in patients with hip and femur fractures, improving the analgesic safety profile compared to traditional systemic analgesia (15,16).

Despite growing evidence, the integration of these advanced applications into standard trauma protocols remains uneven due to barriers such as the need for specialized training and equipment availability (17). This integrative review aims to synthesize the current evidence on the clinical utility, diagnostic accuracy, and impact on outcomes of using advanced point-of-care ultrasound (POCUS) in adult trauma patients, proposing a paradigm shift toward comprehensive ultrasound assessment.

METHODS

Studio design

An integrative literature review was conducted following the methodological framework proposed by Whittemore and Knafl (2005). This design was selected for its ability to include studies with diverse methodologies (randomized clinical trials, prospective and retrospective observational studies, and systematic reviews), thus allowing a holistic understanding of the phenomenon of advanced Point-of-Care Ultrasound (POCUS) in the trauma setting.

Search strategy

A comprehensive literature search was conducted by querying high-impact biomedical databases, including PubMed, Scopus, and Scite.ai. A structured search strategy based on specific clinical questions in PICO format was designed, encompassing five key domains: (1) Resuscitation hemodynamics and transesophageal echocardiography (TEE), (2) neuroultrasound (optic nerve sheath measurement [ONSD] and transcranial Doppler), (3) airway and respiratory management, (4) guided procedures and regional anesthesia, and (5) clinical outcomes and implementation. Search terms included combinations of keywords and controlled descriptors (MeSH/DeCS) such as: "Point-of-Care Ultrasound," "Transesophageal Echocardiography," "VEXUS," "Nerve Block," "Trauma," "Resuscitation," and "Hemodynamics."

Eligibility criteria

To ensure the relevance and currency of the evidence, strict selection criteria were applied, divided into inclusion and exclusion:

Inclusion criteria

- **Population:** Studies focused on adult patients (>18 years), victims of blunt or penetrating trauma.
- **Intervention:** Use of Point-of-Care ultrasound applications besides the standard FAST or eFAST protocol (e.g. TEE, VEXUS, ONSD, iliac fascia or serratus anterior blocks).
- **Results (outcomes):** Reports on diagnostic accuracy (sensitivity, specificity), change in clinical management or decision-making, mortality, time to surgical intervention, opioid consumption, and prediction of success in ventilatory weaning.
- **Temporality and language:** Articles published in the past 10 years (2014–2024), written in English, Spanish, or Portuguese.

Exclusion criteria

- Studies focused exclusively on traditional FAST/eFAST assessment without advanced components.
- Reports of isolated cases or small case series (unless they describe novel techniques without other higher-level evidence available).
- Studies performed exclusively by radiologists or imaging specialists outside the point-of-care setting.
- Research limited exclusively to pediatric population (<18 years).

Data extraction and synthesis

The data were extracted and categorized thematically to facilitate narrative synthesis. Special attention was paid to diagnostic performance metrics, direct therapeutic impact, and reported barriers to implementation, such as the learning curve and resource availability. The findings were grouped into four main categories for analysis: (1) advanced hemodynamics and resuscitation, (2) neuromonitoring and airway management, (3) procedures and regional analgesia, and (4) impact on workflow and mortality.

RESULTS

A systematic review of the selected literature identified significant findings in four critical domains of trauma care: complex hemodynamic assessment, non-invasive neuromonitoring, image-guided procedures, and the overall impact on clinical workflows. A synthesis of the evidence is presented below.

Advanced hemodynamics and resuscitation

In the context of traumatic cardiopulmonary resuscitation (CPR) and refractory shock,

resuscitation transesophageal echocardiography (TEE) has demonstrated a clear diagnostic superiority over the transthoracic echocardiographic (TTE) modality. Current evidence supports that TEE allows continuous, high-fidelity visualization of cardiac structures without interrupting chest compressions, overcoming the limitations of the poor acoustic windows typically seen in thoracic trauma (3,4). The clinical impact of this tool is substantial: its implementation modified therapeutic management in 66.7% of cases in intensive care units and in 58.3% in emergency departments, redirecting critical decisions such as the initiation of vasopressor support or targeted fluid administration (5,18).

In parallel, the assessment of fluid responsiveness has evolved from static to dynamic parameters. Measurement of the velocity-time integral (VTI) of the left ventricular outflow tract has shown superior predictive capacity to the inferior vena cava collapsibility index for accurately discriminating between volume responders and non-responders (9,10). Furthermore, the adoption of the VEXUS (Venous Excess Ultrasound) grading system has allowed for the identification of patterns of severe venous congestion that independently correlate with an increased risk of acute kidney injury (AKI) and in-hospital mortality. These findings suggest that the VEXUS protocol is an essential tool for limiting iatrogenic fluid resuscitation and mitigating volume overload in polytrauma patients (7,8).

Neuromonitoring and airway management

Ocular ultrasound for measuring optic nerve sheath diameter (ONSD) has become established as a robust, non-invasive alternative for estimating intracranial pressure (ICP). Multiple studies validate a significant positive correlation ($r = 0.68$) between ONSD and invasive ICP in victims of severe traumatic brain injury (11,12). An ONSD cutoff point > 5 mm has been established as an indicator of intracranial hypertension with high sensitivity and specificity, optimizing triage and neuromonitoring in settings lacking immediate neurosurgery (19). Additionally, transcranial Doppler (TCD) exhibited a sensitivity of 93% and a specificity of 89% for the early detection of post-traumatic vasospasm, facilitating timely interventions to prevent secondary cerebral ischemia (20).

In airway management, ultrasound has proven to be an effective and faster tool than traditional methods. Ultrasound confirmation of endotracheal tube position was significantly faster than capnography (mean 35.8 vs. 67.4 seconds; $p<0.001$), maintaining a sensitivity of 98.7% and an absolute specificity of 100% (13,21). Furthermore, in patients with complex maxillofacial trauma, ultrasound allowed for the prediction of intubation difficulties by visualizing anatomical distortions and pre-epiglottic edema, overcoming the limitations of conventional physical examination (22,23).

Guided procedures and regional analgesia

Ultrasound guidance for nerve blocks has redefined the standard of analgesia in trauma, prioritizing safety and efficacy. In hip and femur fractures, ultrasound-guided iliac fascial compartment block achieved a significant reduction in postoperative opioid consumption compared to systemic analgesia, consequently decreasing the risks of respiratory depression and delirium, especially in the geriatric population (15,16).

For pain management in multiple rib fractures, ultrasound-guided serratus anterior plane block (SAPB) has emerged as a safe alternative to thoracic epidural analgesia. Comparative studies indicate that SAPB offers comparable analgesic efficacy, but with a significantly lower incidence of hemodynamic complications (hypotension) and urinary retention, preserving respiratory mechanics without the risks associated with neuraxial procedures in patients with coagulopathy or hemodynamic instability (24,25).

Impact on workflow and clinical outcomes

The systematic integration of advanced point-of-care ultrasound (POCUS) protocols has generated tangible benefits in the operational efficiency of trauma centers. In cases of blunt abdominal trauma, the use of ultrasound reduced the time from triage to definitive surgical intervention or discharge, speeding up critical decision-making by 25% (26,27). In the prehospital setting, the implementation of handheld ultrasound devices facilitated the rapid diagnosis of time-dependent pathologies (e.g., tension pneumothorax, massive hemoperitoneum), optimi-

zing transport routes and the allocation of hospital resources (28,29).

While the literature identifies barriers to universal implementation, mainly associated with the learning curve and the need for structured training programs for non-radiologist physicians (17,30), evidence suggests a survival benefit. Once these barriers are overcome, the incorporation of advanced point-of-care ultrasound (POCUS) is associated with a reduction in overall mortality in severely trauma patients compared to standard management based exclusively on ATLS algorithms (31).

DISCUSSION

The synthesis of current evidence underscores the need for a re-engineering of primary trauma assessment: a transition from a dichotomous and anatomical ultrasound approach (FAST: is there free fluid?) to dynamic and phenotypic physiological monitoring guided by advanced point-of-care ultrasound (POCUS). The analyzed data suggest that this approach is not merely additive, but transformative, impacting critical variables such as mortality, organ protection, and therapeutic precision in clinically uncertain scenarios.

The most disruptive finding is the operational superiority of transesophageal echocardiography (TEE) over transthoracic echocardiography (TTE) in resuscitation. While the traditional FAST protocol often fails in patients with subcutaneous emphysema, obesity, or surgical dressings—limitations frequently reported in the literature (1)—TEE offers a privileged and continuous acoustic window. This allows for real-time differentiation between shock phenotypes (obstructive, cardiogenic, hypovolemic) even during chest compressions, transforming traumatic cardiac arrest from a “black box” into a visible and treatable pathophysiological event (3,4). The ability to visualize fine myocardial contractility allows for distinction between true asystole and pulseless electrical activity with residual mechanical activity (“pseudo-PEA”), a distinction that radically changes prognosis and pharmacological management (18).

Simultaneously, the integration of the VEXUS protocol challenges the classic ATLS dogma of aggressive fluid resuscitation. Evidence that systemic venous congestion is an independent predictor of acute kidney injury (AKI) and mortality necessitates a reconsideration of fluids as drugs with a narrow therapeutic index (Fattah, 2025; Kanitkar et al., 2024). Pathophysiologically, the increase in central venous pressure is transmitted retrogradely to the renal veins, reducing the arteriovenous perfusion gradient and precipitating congestive kidney failure (congestive nephropathy). The combination of tolerance indices (VEXUS) with volume responsiveness markers (left ventricular outflow tract volume index) allows for resuscitation titration with physiological precision unattainable by central venous pressure or physical examination, mitigating the iatrogenic effects of fluid toxicity (9,10).

In neurotrauma, the robust correlation between optic nerve sheath diameter (ONSD) and invasive intracranial pressure (ICP) democratizes critical neuromonitoring. Since the optic nerve sheath is an extension of the subarachnoid space, changes in cerebrospinal fluid pressure are transmitted instantaneously, causing measurable dilation behind the globus pallidus. In the "golden hour," when ventriculostomy access is impossible or delayed, ONSD acts as a non-invasive biomarker to guide empirical hyperosmolar therapy, buying valuable time before surgical decompression (11,19).

Similarly, the superior time to ultrasound over capnography for confirming intubation (35.8 vs. 67.4 seconds) suggests that ultrasound should be the standard of care in difficult airway scenarios (13). In situations of low cardiac output or cardiorespiratory arrest, capnography can produce false negatives due to the absence of CO_2 delivery to the lungs; ultrasound, being a direct anatomical verification, is not dependent on hemodynamic status, offering critical reliability in the exsanguinated patient.

The adoption of ultrasound-guided fascial blocks (iliac fascia, serratus anterior) represents a qualitative advance in patient safety and the humanization of care in the emergency department. By achieving effective analgesia with a drastic reduction in opioid consumption, these techniques minimize respiratory depression and post-traumatic delirium, complications that have historically worsened the prognosis in the geriatric population and in patients with flail chest (15,16). Compared to epidural

analgesia, the serratus anterior plane block offers a superior safety profile by avoiding sympathectomy (hypotension) and allowing its performance in coagulopathic patients or those undergoing antithrombotic treatment, a common situation in modern trauma (24).

Despite its clinical strength, universal adoption faces barriers to technical competence and institutional culture. The learning curve for resuscitation TEE or transcranial Doppler is significantly steeper than for basic FAST. Studies indicate that, although basic competence can be acquired quickly, interpretation in complex scenarios requires simulation programs and ongoing mentoring, which remain heterogeneous in non-academic settings (17, 30). Furthermore, the availability of specific transducers (transesophageal or high-frequency) in the resuscitation room remains limited in many settings. Current evidence, predominantly observational, underscores the need for multicenter randomized controlled trials to validate these protocols not only in terms of diagnostic accuracy but also cost-effectiveness and long-term survival (31).

In conclusion, current scientific evidence supports an irreversible paradigm shift: point-of-care ultrasound in trauma has moved beyond being an auxiliary tool to become the cornerstone of modern physiological assessment. Advanced applications such as transesophageal echocardiography (TEE) for resuscitation, VEXUS, on-sensory defibrillation (ONSD), and regional blocks offer superior diagnostic and therapeutic accuracy compared to the traditional standard of care based on advanced trauma life support (ATLS). The systematic integration of these techniques is imperative to improve survival, reduce iatrogenic morbidity, and optimize resources in overburdened healthcare systems. In 21st-century trauma medicine, the ultrasound scanner is not just a fluid detector; it is the visual stethoscope that guides precision resuscitation.

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