Research paper

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POCUS-CRAFT: a novel integrated ultrasound trauma protocol

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Keywords

trauma; multiorgan injury; point-of-care ultrasound; POCUS-CRAFT; ultrasound protocol

Abstract

Aim: The purpose of the study was to create an ultrasound protocol dedicated to patients with multiorgan trauma. **Material and methods:** The authors aimed to develop an ultrasound protocol dedicated to patients with multiorgan trauma based on the following: Advanced Trauma Life Support management (ABCDE protocol), available ultrasound protocols for trauma patients, known point-of-care cardiac protocols, and the authors' experience. The indications for the test and the technical requirements necessary for its proper execution are also specified, and the technique of performing the CRAFT test is described. **Results:** POCUS-CRAFT represents five components of trauma patient evaluation. C (Cranium): Transcranial Doppler or transorbital ultrasound to assess for elevated intracranial pressure; R (Respiratory): Evaluation of the chest for pneumothorax and pleural hematoma; A (Abdomen): Evaluation of the peritoneal and pelvic cavity for free fluid; F (Cardiac Function): Diagnosis of pericardial tamponade and assessment of left ventricular systolic function; T (Trauma Integration): Integration of ultrasound findings with a complete physical examination of the trauma patient, with emphasis on the clinical context. **Conclusions:** POCUS CRAFT is an integrated ultrasound protocol designed for trauma patients. It expands upon the eFAST protocol by adding components for neurological and functional myocardial evaluation. Currently, CRAFT is the only point-of-care protocol that incorporates trauma-related sequelae that can be detected by ultrasound while highlighting the importance of clinical context.

Introduction

Ultrasonography is considered essential for the initial evaluation of patients with multiple trauma (polytrauma) in both prehospital and emergency department settings[1,2]. However, extended focused assessment with sonography for trauma (eFAST) protocols focus primarily on evaluating blunt abdominal and thoracoabdominal injuries[3]. Furthermore, none of the commonly used ultrasound trauma protocols include evaluation of the central nervous system.

The authors have developed a new ultrasound protocol for patients with multiorgan trauma. This protocol incorporates elements that were overlooked by previous point-of-care protocols.

Material and methods

The authors attempted to create an ultrasound protocol dedicated to patients with multiorgan trauma based on the following rationale:

- Advanced Trauma Life Support management: ABCDE approach[4];
- available ultrasound protocols for trauma patients: FAST (Focused Assessment with Sonography for Trauma) and eFAST (Extended Focused Assessment with Sonography for Trauma)[3,5];
- point-of-care cardiac ultrasound protocols: FATE (Focused Assessed Transthoracic Echocardiography)[6–9] and RUSH (Rapid Ultrasound for Shock and Trauma)[10];
- the authors' own experience in the use of point-of-care ultrasound in the prehospital setting[2–8].

The indications for the test and the technical requirements necessary for its proper execution are also specified, and the technique for performing the CRAFT examination is described.

Results

POCUS-CRAFT is a new integrated ultrasound protocol dedicated to trauma patients. It consists of five simple components: Cranium

(C), Respiratory (R), Abdomen (A), Cardiac Function (F), and Trauma Integration (T) (Tab. 1, Fig. 1).

Evaluation of the central nervous system (C – Cranium) should be performed in patients with known or suspected head injuries. The POCUS-CRAFT protocol focuses on identifying ultrasound signs of elevated intracranial pressure in such cases. Transcranial Doppler (TCCD – Transcranial Color-Coded Duplex Sonography) is the recommended first-line ultrasound modality. The primary point of assessment is analyzing the flow spectrum in the middle cerebral artery (MCA) using pulsed-wave Doppler (PWD). An elevated pulsatility index (PI) and a high-resistance spectrum may suggest elevated intracranial pressure. If the examiner is inexperienced or the temporal acoustic window is unavailable, transorbital ultrasound can be used as an alternative. Measuring the optic nerve sheath diameter (ONSD) is also recommended, as an increase may indicate elevated intracranial pressure.

Patients with chest injuries should undergo evaluations of their respiratory (R – Respiratory) and cardiac (F – Cardiac Function) systems. Lung assessment (R) includes evaluating the chest for pneumothorax by checking for abolished pleural sliding, the presence of the lung point, and the barcode sign on M-mode. Confirming or excluding the presence of free fluid in the costophrenic angles due

Tab. 1. POCUS-CRAFT protocol views

Letter	Explanation	Ultrasound modality	Ultrasound views	Parameters
C	**C**ranium	Transcranial Doppler Transorbital ultrasound	MCA Optic nerve	Flow spectrum in MCA ONSD
R	**R**espiratory	Lung ultrasound	Upper anterior PLAPS points	Pneumothorax evidence Pleural fluid
A	**A**bdomen	Abdominal ultrasound	RUQ LUQ Pelvic	Free peritoneal and/or pelvic fluid
F	Cardiac **F**unction	Echocardiography	PLAX PSAX SC4CH	Pericardial tamponade Hyper/hypodynamic LV function
T	**T**rauma Integration	Clinical integration with physical examination	N/A	HR, BP, RR, SaO_2, temperature, GCS, NRS scales

LUQ – left upper quadrant; LV – left ventricular; MCA – middle cerebral artery; ONSD – optic nerve sheath diameter; PLAPS – posterolateral alveolar and/or pleural syndrome; PLAX – parasternal long axis; PSAX – parasternal short axis; RR – respiratory rate; RUQ – right upper quadrant; SC4CH – subcostal 4-chamber

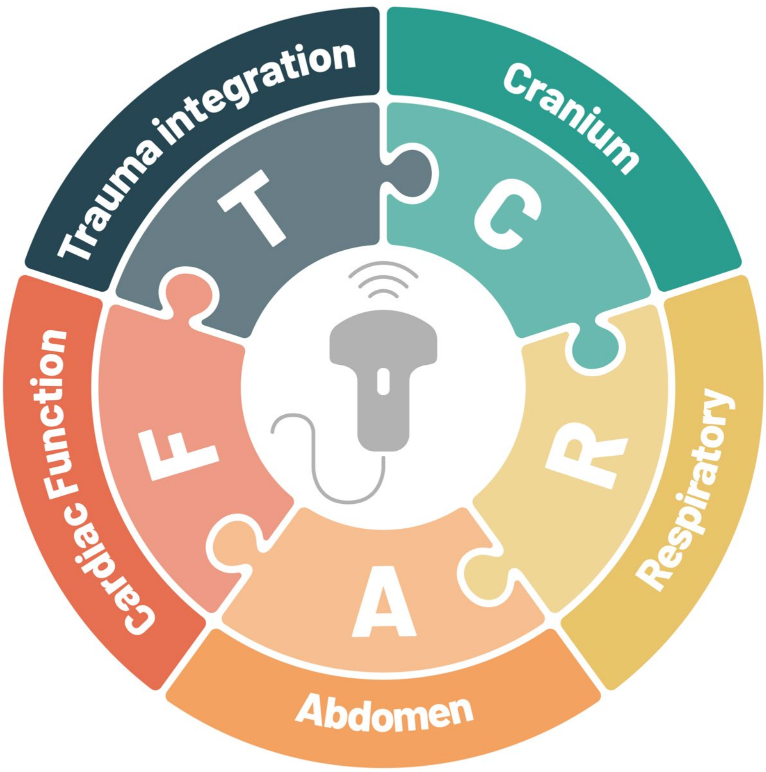

Fig. 1. *POCUS-CRAFT flowchart*

to bleeding or post-traumatic effusion should also be performed by checking for the PLAPS point.

The following echocardiographic views are recommended for cardiac evaluation (F – Cardiac Function): parasternal long axis (PLAX), parasternal short axis (PSAX), and subcostal four-chamber (SC4CH). Post-traumatic assessment of the heart should focus on diagnosing cardiac tamponade, which is indicated by the presence of pericardial effusion and diastolic collapse of the free wall of the right atrium and/or right ventricle, as well as evaluating global systolic left ventricular (LV) function. Assessing left ventricular filling and global contractility allows for an initial hemodynamic evaluation of the patient following multiorgan trauma. Hyperdynamic LV function may indicate an empty ventricle and confirm hypovolemic shock when supported by other findings. Conversely, reduced global LV contractility may indicate myocardial contusion or infarction (types 1 and 2). Additionally, a decreased left ventricular ejection fraction always reflects the hemodynamic status of a trauma patient and should prompt timely intervention to increase cardiac output.

An abdominal ultrasound assessment (A – Abdomen) incorporates FAST views of the right upper quadrant (RUQ), left upper quadrant (LUQ), and pelvis. The examination focuses on the detection of free peritoneal and pelvic fluid.

The integration of POCUS findings (T – Trauma Integration) with the results of physical examination, the patient's medical history, and vital signs (heart rate, blood pressure, respiratory rate, SpO_2, GCS, NRS, and temperature) is a crucial aspect of POCUS-CRAFT. The overarching goal of this final element of the protocol is to provide clinical context for the POCUS examination, enabling an accurate diagnosis and appropriate management of trauma patients (Tab. 2).

Technical aspects of using the CRAFT protocol:

- The patient should be positioned supine for the examination.
- To quickly and comprehensively assess all components, the examination should be performed with a sector transducer. This is the only transducer capable of conducting both TCCD and cardiac examinations as well as allowing a reliable assessment of the other components (lungs and abdomen).
- The preset depends on the area being examined. When evaluating flow in the MCA, use the dedicated TCCD presets or select the cardiac preset.
- The examination should be performed after the initial stabilization of the trauma patient, taking into account clinical priorities from the perspective of patient survival. The POCUS examination should not delay the implementation of necessary emergency medical measures or the transport of the patient to a dedicated trauma center.

Examination technique

C – Cranium:

- Place the sector probe with the tracer facing the patient's eyeball in the temporal acoustic window, which is located just above the zygomatic arch (Fig. 2).
- A correct acoustic window for the examination is characterized by the imaging of the contralateral temporal bone scale, which should be visible in the lower part of the image (Fig. 2).
- One of the most important anatomical landmarks is the midbrain, which is visible as a hypoechoic structure that resembles a butterfly (Fig. 2).
- When placing the color Doppler gate in the midbrain region, look for the middle cerebral artery (MCA), which is characterized by flow toward the transducer, appearing as red flow (Fig. 2).
- Using pulsed-wave Doppler (PWD), obtain a flow spectrum in the vessel by placing the Doppler gate preferably in the long axis of the vessel, ideally in the M1 segment, to obtain the most reliable measurement. Under physiological conditions, the MCA exhibits low-resistance flow, which is characterized by a small difference between systolic velocity (Vs) and diastolic velocity (Vd). When intracranial pressure increases, a high-resistance spectrum develops (Fig. 2).

Tab. 2. POCUS-CRAFT protocol: ultrasound findings and their clinical significance

Letter	Explanation	Ultrasound findings	T (Trauma Integration)	Clinical conclusion
C	**C**ranium	MCA PI >1.2 ONSD >5 mm	Unconsciousness High GCS High BP	Possible elevated ICP
R	**R**espiratory	Abolished pleural sliding, PLAPS point, barcode sign	Dyspnea Low BP High respiratory rate Tachycardia Low SpO_2	Pneumothorax
		Presence of pleural free fluid		Pleural bleeding or effusion
A	**A**bdomen	Free peritoneal and/or pelvic fluid	Low BP Tachycardia Low SpO_2 High NRS	Peritoneal or pelvic bleeding/effusion
F	Cardiac **F**unction	Pericardial effusion Diastolic collapse of right atrium and right ventricle	Dyspnea Low BP Tachycardia Low SpO_2 High NRS	Cardiac tamponade
		Small LV Hyperdynamic LV function		Hypovolemia
		Depressed LV systolic function		Cardiac contusion Myocardial infarction

LV – left ventricle, left ventricular; ICP – intracranial pressure; MCA – middle cerebral artery; ONSD – optic nerve sheath diameter; PI – pulsatility index

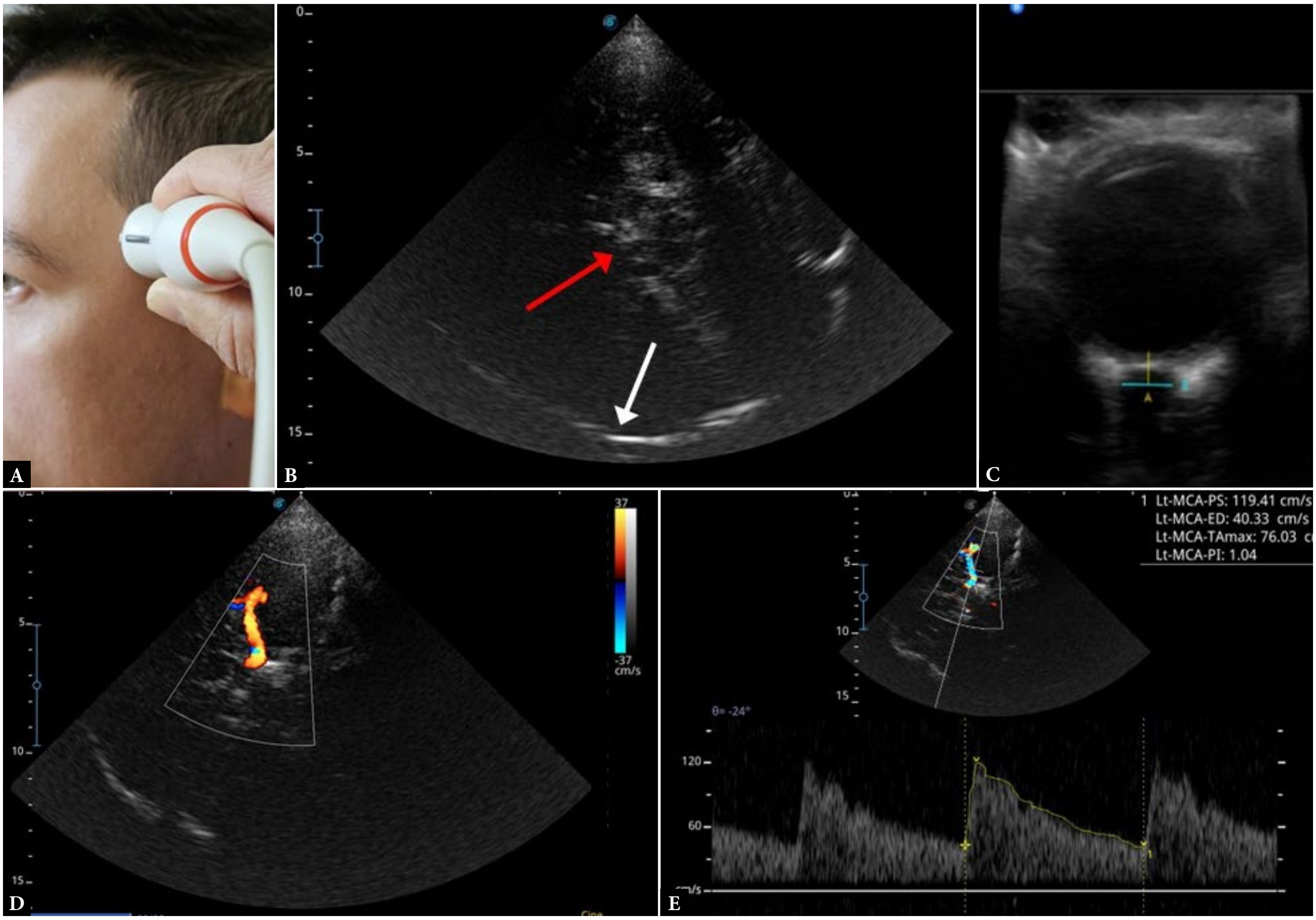

Fig. 2. *Temporal acoustic window (***A***); imaging of the contralateral temporal bone (white arrow), midbrain – butterfly sign (red arrow)(***B***); measurement of the optic nerve sheath diameter (***C***). Color Doppler imaging of the middle cerebral artery (***D***); PW Doppler imaging of MCA low-resistance flow with PI calculation (***E***)*

- Using the system's measurement package, calculate the Gosling pulsatility index (PI), which is defined as the quotient of the difference in systolic and diastolic velocities divided by the mean velocity. PI = (Vs – Vd) / Vm.
- The normal range of PI is 0.6–1.2. Values greater than 1.2 suggest high-resistance flow, which may be indicative of elevated intracranial pressure resulting from trauma (Fig. 2).
- If there are equipment limitations or operator inexperience with TCDD examinations, the optic nerve sheath diameter (ONSD) should be measured. An ONSD greater than 5 mm in an adult patient may indicate increased intracranial pressure (ICP) (Fig. 2).
- TCD examinations and ONSD measurements should be performed symmetrically.

R – Respiratory:
- Place the transducer at the highest points on the chest in a supine patient to obtain the bat sign.
- Optimize the image by adjusting the depth and gain settings to confirm or exclude the sliding sign. If you are unsure about the sliding motion of the pleura, use the M-mode imaging option. Evaluate the chest symmetrically.
- To evaluate the costophrenic angles for free fluid, place the transducer in the X–XII intercostal spaces in both the left and right posterior axillary lines. When visualizing the dome of the diaphragm, look for the curtain sign in the absence of free fluid in the pleural cavity. Bleeding will appear as an anechoic reservoir just above the diaphragm. Over time, the extravasated blood coagulates, increasing the echogenicity of the free fluid.

A – Abdomen:
- Using the same positioning of the ultrasound transducer as when evaluating the costophrenic angles, move the transducer a few centimeters toward the patient's legs. Visualize Morrison's recess on the right and Keller's recess on the left. Include both the upper and lower poles of the kidneys in the examination to check for areas of potential fluid accumulation. Also evaluate the parenchymal organs (the liver and the spleen), paying particular attention to the subdiaphragmatic space and the organ capsules (the interface between the surface of the parenchymal organs and the kidneys).
- To evaluate the pelvis, place the ultrasound transducer just above the pubic symphysis. In men, a potential site of fluid accumulation is the retrovesical pouch, which is located between the bladder and rectum. In women, free fluid tends to collect just behind the uterus in an area known as the vesicouterine pouch. To increase the sensitivity of the examination, the pelvic area should be assessed in two planes, in both short-axis and long-axis views.

F – Cardiac Function:
- Use one of the available echocardiographic acoustic windows to evaluate the presence of free pericardial fluid and to assess global left ventricular (LV) systolic function. From a practical standpoint, the parasternal long axis view (Fig. 3) is the easiest to obtain in most adult patients.
- Pericardial tamponade is a clinical diagnosis. Features indicative of pericardial tamponade include right atrial systolic and right ventricular free wall diastolic collapse.
- In the context of post-traumatic evaluation, global left ventricular systolic function should also be assessed. Hyperkinetic LV contractility may suggest hypovolemic shock, whereas depressed LV function may indicate cardiac contusion or myocardial infarction.

T – Trauma Integration:
- Conduct a complete physical examination based on trauma assessment and the patient's history. Correlate the results with the ultrasound evaluation of the aforementioned areas to implement appropriate management.

Indications for performing the CRAFT protocol
- Multiorgan injury,
- Suspected craniocerebral injury,
- Abdominal trauma,
- Chest injury,
- Concussion following trauma,
- Trauma in a patient with impaired consciousness or who is unconscious,
- Monitoring response to implemented management.

Sites where the protocol can be applied:
- Emergency medical team,
- Hospital emergency department/emergency room,
- Intensive care unit,
- Trauma center.

Discussion

Polytrauma management requires a well-developed and standardized management system or protocol. The Advanced Trauma Life Support (ATLS) is a universal system that combines evaluation and management of injured patients[4]. The ABCDE approach is a systematic, prioritized method for assessing and treating critically ill or injured patients by addressing five essential elements: Airway, Breathing, Circulation, Disability, and Exposure. It is a core component of the ATLS protocol, emphasizing rapid initial assessment and management of life-threatening conditions. Using the ABCDE approach to each patient enables systematic and simultaneous evaluation.

For many years, the classic eFAST (Extended Focused Assessment with Sonography for Trauma) protocol has been routinely used to quickly evaluate trauma patients using ultrasound[2,3]. The protocol involves evaluating the peritoneal cavity for bleeding, the pleural cavity for pneumothorax and pleural hematoma, and the pericardial sac for tamponade. Despite its remarkable effectiveness in detecting trauma-related injuries, the eFAST protocol entirely omits evaluation of intracranial structures, which can be affected in craniocerebral trauma, a leading cause of death in trauma patients[11,12].

POCUS-CRAFT is a new proposal that integrates point-of-care ultrasound with clinical data. The study protocol expands the traditional eFAST protocol by adding components for neurological and functional myocardial evaluation. Designed for point-of-care ultrasound assessments, this protocol aims to detect life-threatening conditions resulting from trauma. By incorporating a cranial assessment component that uses transcranial Doppler ultrasound (TCCD) into the expanded eFAST protocol, clinicians can perform a comprehensive evaluation of trauma patients in settings with limited access to computed tomography, identify early elevated intracranial pressure (ICP), and select patients at significant risk of sudden neurological deterioration. It also enables decision-making regarding the implementation of detailed diagnostic imaging or neurosurgical intervention.

Integrating the Cranium (C) and Trauma Integration (T) components into the CRAFT protocol facilitates a more comprehensive approach to treating trauma patients. This approach combines imaging to detect pathologies and assess organ function with consideration of the patient's clinical context, an aspect often overlooked in emergency protocols. The CRAFT protocol unifies and integrates the main diagnostic areas that require assessment following trauma into a single examination scheme. Moreover, the CRAFT assessment can be performed in parallel with the ABCDE assessment, as these two protocols overlap in many areas. Trauma guidelines emphasize the importance of comprehensive patient evaluation for proper management. Due to its modular structure, each component of the protocol can be performed independently, depending on the clinical situation

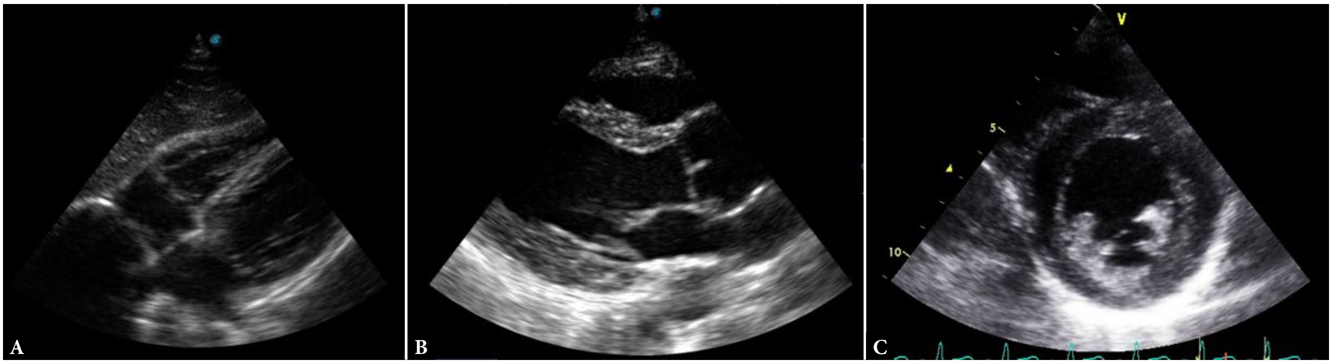

Fig. 3. *Cardiac views: subcostal 4-chamber (**A**), parasternal long axis, (**B**) and parasternal short axis (**C**)*

and the operator's skills and experience. Currently, CRAFT is the only point-of-care examination protocol that incorporates ultrasound-detectable trauma sequelae while emphasizing clinical context.

Study limitations

The protocol has several potential limitations. First, it requires a sector transducer, which is not standard for all point-of-care ultrasound settings. Second, about 20% of patients lack an adequate temporal acoustic window. Finally, the examiner may lack sufficient experience, especially with TCCD.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contributions

Original concept of study: JC. Writing of manuscript: JC, DS. Final acceptation of manuscript: JC, DS. Critical review of manuscript: DS.

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