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ORIGINAL ARTICLE

Chest Abdominal-Focused Assessment Sonography for Trauma during the primary survey in the Emergency Department: the CA-FAST protocol

M. Zanobetti[1] · A. Coppa[1] · P. Nazerian[1] · S. Grifoni[1] · M. Scorpiniti[1] · F. Innocenti[1] · A. Conti[1] · S. Bigiarini[1] · S. Gualtieri[1] · C. Casula[1] · P. F. Ticali[1] · R. Pini[1]

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Abstract
Purpose To evaluate the feasibility of a new protocol, Chest Abdominal-Focused Assessment Sonography for Trauma (CA-FAST), during the primary survey and to estimate its diagnostic accuracy when compared with thoracoabdominal computed tomography (CT) scan.
Methods A prospective accuracy study was performed from November 2012 to November 2013 at the Emergency Department. Only adult trauma patients who underwent a CA-FAST examination prior to a thoracoabdominal CT scan were enrolled. In addition to standard patterns detected by Extended-FAST (E-FAST) such as pneumothorax (PTX), hemothorax (HTX), pericardial and intraabdominal effusion, CA-FAST protocol also included the research of lung contusions (LCs).
Results Six hundred and one patients were enrolled. The mean time for protocol execution was 7 ± 3 min. Chest ultrasonography showed the following results (all $p < 0.001$): LCs sensitivity 59 %, specificity 98 %, positive predictive value (PPV) 92 %, negative predictive value (NPV) 86 %, accuracy 87 %; PTX sensitivity 84 %, specificity 98 %, PPV 93 %, NPV 95 %, accuracy 95 %; HTX sensitivity 82 %, specificity 97 %, PPV 87 %, NPV 95 %, accuracy 94 %. The standard 4-views FAST examination showed a diagnostic accuracy of 91 % with a sensitivity of 75 %, specificity of 96 %, PPV of 81 % and NPV of 94 %.
Conclusion According to our results CA-FAST protocol proved to be a rapid bedside method, with good accuracy and high NPV in detection of ultrasonographic patterns suggestive of serious injury in trauma patients; moreover, the additional research of LCs did not cause a delay in the diagnosis. Ultrasonography should be used as initial investigation during the primary survey, sending to further diagnostic studies (CT scan) only those patients not clearly classified.

Keywords Trauma · Emergency ultrasonography · Diagnosis · Emergency medicine

Abbreviations

FAST	Focused Assessment Sonography for Trauma
CA-FAST	Chest Abdominal-Focused Assessment Sonography for Trauma
CT	Computed tomography
E-FAST	Extended-FAST
PTX	Pneumothorax
HTX	Hemothorax
LCs	Lung contusions
PPV	Positive predictive value
NPV	Negative predictive value
ED	Emergency Department
ATLS	Advanced trauma life support
US	Ultrasonography
X-ray	Radiography
EP	Emergency physician
ISS	Injury Severity Score

Introduction

Trauma is the leading cause of death in the developed world in subjects between the ages of 5 and 44 and generates a number of disabling outcomes [1, 2].

✉ M. Zanobetti
zanomau@libero.it

[1] Emergency Department, Careggi University Hospital, Largo Brambilla, 3, 50134 Florence, Italy

In the Emergency Department (ED) trauma patients can rapidly become hemodynamically unstable and need a rapid evaluation ("golden hour") to identify and treat potential sources of bleeding or other severe injuries in order to reduce complications, length of stay, and overall cost of hospitalization.

Computed tomography (CT) scanning is widely accepted as the investigation of choice in trauma injury, however it might not be appropriate in hemodynamically unstable patients as it is expensive, exposes patients to radiation and usually requires a bolus of intravenous contrast material.

Since 70 s the ultrasonographic evaluation [3–5] has gradually acquired an important role in the rapid evaluation of trauma patients and, as suggested by the advanced trauma life support (ATLS) [2], it is currently performed after the primary survey.

Ultrasonography (US) is a useful initial imaging modality: It is rapid, repeatable and a noninvasive bedside method. In addition it can be performed simultaneously with other resuscitative cares, providing vital information without the time delay caused by the execution and interpretation of radiographs or CT scan [6]. In the literature, Focused Assessment with Sonography for Trauma (FAST) showed an accuracy of 92–97 % [7, 8] in recognizing intraperitoneal and intrapericardial bleeding in unselected trauma patients, and it is nearly 100 % sensitive in hypotensive patients who need an emergency laparotomy and in patients with penetrating trauma and suspicion of cardiac injury [9–12].

A later proposal with the aim of detecting pneumothorax (PNX) and hemotorax (HTX) in addition to intraperitoneal and intrapericardial bleeding became know as Extended-FAST (E-FAST) examination [13–18]. A large number of studies showed that bedside chest US is at least equivalent, if not more accurate than chest radiography (X-ray) for identifying HTX or PTX in trauma patients [13, 14, 19, 20]. Lung contusions (LCs) are a frequent clinical entity in blunt chest trauma and are associated with a 10–25 % mortality rate [21]. Despite its relatively high incidence, it is difficult to identify LCs in the ED as traditional radiology will underestimate its prevalence [22], needing to rely on a more advanced method such as CT. However, some studies have shown that chest US can accurately detect LCs with good accuracy in trauma victims [17, 23, 24].

For this reason we developed a new protocol (CA-FAST, Chest Abdominal FAST) that integrates the detection of LCs in the E-FAST examination which can be performed during the primary survey. The aim of this study was to evaluate the feasibility and the diagnostic performance of CA-FAST examination when compared to the gold standard, thoracoabdominal CT.

Methods

Study design and setting

A prospective accuracy study was performed at the Emergency Department (ED) of an urban academic level I trauma center with an annual census of 120,000 visits. The study, which is consistent with the principles of the Declaration of Helsinki on clinical research involving human subjects, was approved by an Institutional Review Board.

Selection of participants

Consecutive adult trauma patients presenting to the ED from November 2012 to November 2013 that underwent a thoracoabdominal CT scan were enrolled if a CA-FAST examination was previously performed; CT scan was either required or not at discretion of the emergency physician (EP), independently of patient's participation to the study. Informed verbal consent for study participation was asked to each patient or to next of kin.

Interventions

A CA-FAST examination was performed at ED presentation during the primary survey and before CT scan by 12 physicians (7 senior EPs, 5 residents in emergency medicine). The minimum requirement for the sonographer was to have previously attended a 12-hour course in emergency chest-abdominal US and a hands-on training with execution of at least 25 FAST and 25 chest US scans, as suggested by ACEP guidelines [25]. The multi-probe machines used were the following: two MyLab 30 Gold and one MyLab alpha (Esaote, Genoa, Italy).

CA-FAST protocol consisted of a combined ultrasonographic evaluation of chest and abdomen in order to detect the presence of the following ultrasonographic patterns: PTX, HTX, LCs, pericardial and intraperitoneal effusion. The full examination consisted of 8 chest scans and 4 abdominal scans acquired with the patient in obligated supine position due to spinal boards and cervical collars.

Chest US was performed by a 4- to 8-MHz linear probe or a 3.5- to 5-MHz curved array probe, and as suggested by the international evidence-based recommendation for point-of-care lung ultrasound [26], each hemithorax was divided into 4 areas: 2 anterior and 2 lateral. It was not possible to evaluate posterior chest areas due to the obligated supine position of patients.

A scan for each area (four scans per hemithorax) was obtained in order to detect the presence of specific ultrasound patterns: PTX, HTX and LCs, as described in the recommendations mentioned above [26], and in the literature [16, 17].

The abdominal US was performed by 5-MHz curved array probe using the standard 4-views FAST examination (perihepatic, perisplenic, pelvic and pericardial subxiphoid); FAST was considered positive if free fluid was identified in any location [3].

Methods and measurement

In order to compile a written report, the following information was obtained for each patient: personal data, time for completing the CA-FAST examination, ultrasonographic findings and their location. On the base of CT scan results, the Injury Severity Score (ISS) value was calculated.

Data collection and statistical analysis were done by the authors.

Outcomes

The diagnostic performance of the CA-FAST examination, in order to identify pathological patterns considered in the protocol, was assessed considering the CT scan as the gold standard: For chest evaluation due to obligated supine position of patients, we compared only anterior and lateral lung areas. CT scans were performed with AS128 (Siemens, Erlangen, Germany) using contrast medium if not contraindicated and were reviewed by expert radiologists not participating in the present study.

Analysis

Statistical analysis was performed using SPSS Package 21.0 software (SPSS Inc. Chicago, IL, USA). All continuous parameters are reported as means ± standard deviations, and frequency values are written as absolute values and percentages. Dichotomous variables and percentages were compared by Chi-square test. A two-tailed value of $p < 0.05$ was used to indicate statistical significance. Diagnostic performance of CA-FAST was evaluated by calculating sensitivity, specificity, positive predictive value, negative predictive value, and negative and positive likelihood ratios for each chest pathological findings (PTX, HTX, LCs) and for detection of free fluid in each FAST examination view.

Results

Characteristics of study subjects

Six hundred and one (467, 75 % male) consecutive patients with a mean age of 46 ± 20 years were enrolled in the study. The mean ISS of trauma victims was 16 ± 12; 281 patients had ISS > 15.

At chest CT 440 PTX, 170 HTX and 526 LCs were detected in the anterior and lateral areas; at abdomen CT free fluid was detected in 125 cases, 110 of whom intraperitoneal and 15 intrapericardial.

Main results

The mean time for CA-FAST protocol execution was 7 ± 3 min (4 ± 2 min for chest US and 3 ± 1 min for abdominal US).

Chest US examinations detected 411 PTX, 109 HTX and 293 LCs with an overall accuracy for each chest pathological findings of 95 % (95 % CI 91–97), 94 % (95 % CI 87–95) and 87 % (95 % CI 85–92), respectively. Table 1a reported the diagnostic performance of chest US.

FAST examinations detected free fluid in 116 cases showing an overall accuracy of 91 % (95 % CI 85–93). Considering each single standard view of the FAST examination, the accuracy of perihepatic, perisplenic, pericardial sub-xiphoid and pelvic views was 96, 96, 98 and 95 %, respectively. Table 1b reported the diagnostic performance of FAST examination.

Limitations

Our study was conducted in a single center. The obligated supine position of patients, due to spinal boards and cervical collars during the primary survey, did not allow for posterior chest US scans; therefore, we evaluated and compared only the anterior and lateral chest areas. Radiologists were not blinded to CA-FAST results.

Discussion

The average time for CA-FAST examination was similar to the traditional E-FAST examination. In the literature, execution time of E-FAST examination was 2.3 ± 2.9 min [27] for chest US and ≤5 min [28] for standard FAST [16, 17]. Therefore, the addition of four supplemental chest scans (2 per hemitorax) to the Extended-FAST scans and the research of LCs in each area considered in the CA-FAST protocol did not cause a significant delay.

Previous studies considered only chest US and did not analyze an integrated chest-abdominal US examination in detecting the three pathological findings (PTX, HTX and LCs) [16, 17]. Results of our study regarding chest US confirmed data already published in the literature, in particular regarding PTX and HTX: Our sensitivities (84 and 82 %) and specificities (98 and 97 %) were similar to previous studies [14–17, 27, 29]. Concerning

Table 1 Diagnostic performance of CA-FAST

Pathological patterns	Sensitivity (%) (95 % CI)	Specificity (%) (95 % CI)	PPV (%) (95 % CI)	NPV (%) (95 % CI)	+LR (95 % CI)	−LR (%) (95 % CI)
(a) Chest US						
PNX	84 (77–89)	98 (96–99)	93 (87–96)	95 (93–97)	39 (21–73)	0.2 (0.1–0.2)
PE	82 (74–88)	97 (95–98)	87 (79–92)	95 (93–97)	25 (16–41)	0.2 (0.1–0.3)
LC	59 (51–66)	98 (96–99)	92 (86–96)	86 (82–89)	29 (15–55)	0.4 (0.4–0.5)
(b) 4 view—FAST						
Perihepatic free fluid	75 (63–86)	98 (96–99)	79 (67–88)	97 (896–98)	35 (20–62)	0.3 (0.2–0.4)
Perisplenic free fluid	77 (63–87)	98 (97–99)	78 (65–89)	98 (96–99)	40 (22–72)	0.2 (0.1–0.4)
Pelvic free fluid	65 (53–76)	98 (97–99)	84 (71–92)	96 (94–97)	39 (20–77)	0.4 (0.3–0.5)
Pericardial free fluid	53 (27–79)	99 (98–100)	62 (32–86)	99 (98–100)	64 (24–173)	0.5 (0.3–0.1)
4 view—FAST	75 (67–83)	96 (93–97)	81 (73–88)	94 (91–96)	17 (11–26)	0.3 (0.2–0.4)

CA-FAST Chest Abdominal FAST, *PNX* pneumothorax, *PE* pleural effusion, *LC* lung contusion, *FAST* Focused Assessment with Sonography of Trauma

Table 2 Sensitivity and specificity of chest US, literature data

Pathological patterns	Study, authors	Sensitivity (%)	Specificity (%)
Pneumothorax	Kirkpatrick et al. [14]	61	96
	Blaivas et al. [42]	96	100
	Lichtenstein et al. [15]	79	100
Pleural effusion	Hyacinthe AC al. [17]	37	96
	Brooks A et al. [30]	92	100
	Ma OJ et al. [19]	96	100
Lung contusion	Hyacinthe AC al. [17]	61	80
	Soldati G et al. [23]	95	96

LCs, CA-FAST showed a specificity of 98 % and a sensitivity of 59 % with a good NPV of 86 %. The sensitivity in our study is lower than values obtained in previous studies reported in the literature, in which, however, we found a large variability (sensitivity for LCs from 61 to 95 %) [17, 23] (Table 2). There are several explanations for this discrepancy. Patients with a different nature of thoracic lesions than that assessed, those with subcutaneous emphysema, or those who required mechanical ventilation were excluded from various former studies [16, 30]. In our study, according to the CT scan, we detected 136 cases in which LCs were associated with subcutaneous emphysema and/or PTX. It is been known for a long time that the first condition compromises the exploration of parietal pleura by thoracic US [16] while, in case of PTX, the presence of air in the pleural space acts as a specular reflector that covers all possible underlying artifacts, like B-Lines as in LCs [31].

In regard to the standard 4-views FAST examination, our study showed an overall accuracy comparable with previous studies [7, 8, 32–37] (Tables 1b, 3). Three of the standard 4-views (perihepatic, perisplenic and pelvic) showed good sensitivity and specificity and overlap between them. Only the pericardial sub-xiphoid view had a lower sensitivity (53 %) although with a high specificity. This result can be explained by the fact that echocardiography appears to be a more accurate imaging technique than CT scan in quantitative assessment of pericardial effusion [38, 39].

Table 3 Diagnostic accuracy of the standard 4-views FAST examination, literature data

Study, authors	Patients (*N*)	Sensitivity (%)	Specificity (%)	NPV (%)
Chiu et al. [32]	772	71	100	78
Shackford et al. [33]	234	69	98	98
Boulanger et al. [34]	400	81	97	96
Coley et al. [35]	107	55	83	50
Dolich et al. [36]	2576	86	98	98
Miller et al. [7]	359	42	98	93
Scalea et al.[3]	447	79	95	93
Tsui et al. [8]	242	86	99	98
Gaarder et al. [37]	104	62	96	88

FAST Focused Assessment Sonography for Trauma, *NPV* negative predictive value

Overall, we demonstrated high accuracy of US detecting both thoracic and abdominal patterns, placing this technique as a valuable tool in the process of differential diagnosis.

The reliability of the data has been confirmed by the results of PPV and NPV values, which revealed that the majority of ultrasonographic findings were confirmed by CT.

Particularly, the result of the NPV (PNX 95 %, LCs 86 %, HTX 95 %; FAST 4-views 94 %) is essential in emergency medicine, because it allows to exclude, with reasonable certainty, real-time diagnostic suspects, routing the patient to the most appropriate therapy.

In summary CA-FAST protocol, performed in the emergency setting, showed important advantages: It is a noninvasive, rapid, ionizing radiation-free and an easily repeatable method; in trauma patients it allows to accurately and immediately detect diagnostic information and ultrasonographic patterns of severe injury. Moreover, the addition of four chest scans and the research of LCs did not cause a delay in the diagnosis. In our work, we did not measure the learning curve, because the EPs who performed the US were already experienced operators.

As stated in literature [25, 40, 41], the learning curve of this method is relatively quick; therefore, US evaluation is easily applicable and feasible in emergency setting.

For all these reasons, CA-FAST protocol could represent an integrative tool of traditional CT scan in the management of trauma patients; it should be used as the initial investigation, during the primary survey, sending to further diagnostic studies only patients not clearly classified.

Compliance with ethical standards

Conflict of interest Maurizio Zanobetti, Coppa Alessandro, Nazerian Peiman, Grifoni Stefano, Scorpiniti Margherita, Innocenti Francesca, Conti Alberto, Bigiarini Sofia, Gualtieri Simona, Casula Claudia, Ticali Piero Francesco and Pini Riccardo declare that they have no conflict of interest.

Ethical standard All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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