Contrast-enhanced US evaluation in patients with blunt abdominal trauma[☆]

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KEYWORDS

Ultrasonography;
Contrast agent;
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Abstract *Introduction:* To evaluate the use of contrast-enhanced ultrasonography (CEUS) in patients with blunt abdominal trauma.

Materials and methods: A total of 133 hemodynamically stable patients were evaluated using ultrasonography (US), CEUS and multislice Computer Tomography (CT) da eliminare.

Results: In 133 patients, CT identified 84 lesions: 48 cases of splenic injury, 21 of liver injury, 13 of kidney or adrenal gland injury and 2 of pancreatic injury. US identified free fluid or parenchymal abnormalities in 59/84 patients positive at CT and free fluid in 20/49 patients negative at CT. CEUS revealed 81/84 traumatic injuries identified at CT and ruled out traumatic injuries in 48/49 negative at CT. Sensitivity, specificity, positive and negative predictive values for US were 70.2%, 59.2%, 74.7% and 53.7%, respectively; for CEUS the values were 96.4%, 98%, 98.8% and 94.1%, respectively.

Conclusions: The study showed that CEUS is more accurate than US and nearly as accurate as CT, and CEUS can therefore be proposed for the initial evaluation of patients with blunt abdominal trauma.

Sommario *Introduzione:* Descrivere l'impiego dell'ecografia con mezzo di contrasto (CEUS) nella valutazione dei pazienti con trauma chiuso dell'addome.

Materiali e Metodi: 133 pazienti con trauma addominale chiuso emodinamicamente stabile sono stati esaminati con ecografia (US), CEUS e Tomografia Computerizzata multistrato (TC) da eliminare.

Risultati: I 133 pazienti avevano alla TC 84 lesioni, di cui 48 spleniche, 21 epatiche, 13 renali o dei surreni e 2 del pancreas. L'US ha identificato versamento libero o alterazioni parenchimali in 59/84 pazienti positivi alla TC e versamento libero in 20/49 pazienti negativi alla TC. La CEUS ha riconosciuto 81/84 lesioni traumatiche identificate dalla TC e ha escluso lesioni traumatiche in 48/49 pazienti negativi alla TC. Sensibilità, specificità, valore predittivo positivo e negativo per l'US sono stati rispettivamente 70.2%, 59.2%, 74.7% e 53.7%; per la CEUS sono stati 96.4%, 98%, 98.8% e 94.1%.

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Conclusioni: Lo studio ha dimostrato che la CEUS ha una accuratezza diagnostica maggiore dell'US e quasi sovrapponibile alla TC e può quindi essere proposta nella valutazione iniziale del paziente traumatizzato.

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Introduction

Blunt abdominal trauma is a primary cause of death in the adult population [1] but prompt diagnosis can reduce mortality. Computer Tomography (CT) is currently the diagnostic method of choice for assessing trauma patients, although CT usually requires transfer outside the emergency room [2–4] and thereby exposure to possible further harm. Ultrasonography (US) has shown a poor sensitivity in the evaluation of abdominal injuries, but being feasible immediately at the bedside without interrupting other resuscitation procedures, US is the first-line approach in the assessment of abdominal trauma [5–10]. “Focused Abdominal Sonography in Trauma” (FAST) is a specific method which aims at identifying hemoperitoneum [11]. The role of this procedure is clear in unstable patients where detection of free abdominal fluid leads to immediate surgical treatment [12]. The application of FAST is more questionable in stable patients, as US cannot exclude abdominal organ injuries, and contrast-enhanced CT is therefore required [13].

Contrast-enhanced ultrasonography (CEUS) has recently been used in patients affected by abdominal trauma. This method has proved effective in the identification of post-traumatic lesions of the abdominal organs showing an elevated sensitivity and specificity [14–18].

The aim of this study is to report the authors' experience in the use of CEUS in patients with blunt abdominal trauma and the results obtained in the clinical practice of emergency medicine.

Materials and methods

From 2004 to 2008, 1584 patients were evaluated at the emergency department of our university hospital. All patients underwent US examination (FAST) to identify hemoperitoneum during the initial workup in the emergency room. Of the 1584 patients, 133 (99 males and 34

females; mean age 40.2 years) had suspected abdominal injuries with pain at palpation, bruises of the abdomen, probable fracture of the lower ribs or presence of abdominal free fluid at FAST. The 133 selected patients were hemodynamically stable (heart rate < 100 bpm, differential blood pressure < 40 mmHg, breathing frequency < 20) and underwent CEUS and contrast-enhanced CT. The causes of blunt abdominal trauma were road accident, sports injury, accidental fall or accident at work.

US and CEUS were performed consecutively by one radiologist, and CT was performed by another radiologist maximum 1 h after US and CEUS examination. The latter was informed of the US/CEUS diagnosis but was blinded to the images.

All patients and/or their family members were informed of the study protocol and requested to give their written consent. The study was approved by the ethics committee of the hospital (clinical study no 1/2004/O).

US and CEUS

US examinations were performed with ATL 5000 HDI and Philips iU22 using 2–5 MHz and 1–5 MHz convex probes, equipped with Pulse Inversion (PI) and Power Modulation Pulse Inversion (PMPI) software set at a low mechanical index for the contrast-enhanced examination using second generation contrast agent.

US was carried out to identify possible hemoperitoneum using the technique described by Rothlin et al. [19]. In addition to FAST assessment, a complete study of the solid organs of the abdomen was performed in all patients to search for possible alterations. US outcome was considered positive when peritoneal free fluid or alterations in the parenchymal echo pattern consistent with traumatic injury were found [20].

CEUS was performed after baseline US. A standard protocol was followed and contrast agent was injected in two separate doses of 2.4 ml to permit an adequate study

Fig. 1 Blunt abdominal trauma. A) US: hypoechoic lesion of the right hepatic lobe with irregular contours consistent with traumatic injury (calipers). B) CEUS shows extended liver rupture (arrows) and the presence of a second adjacent contusion (asterisk). C) Contrast-enhanced CT confirms rupture (white arrow) and contusion (black arrow).

Fig. 2 Left flank trauma. A) US of the left kidney: no evidence of traumatic injuries. B) CEUS shows complete rupture at the middle third of the left kidney, the profile is interrupted by a thin perirenal hematoma (arrow). C) Contrast-enhanced CT confirms rupture (arrow) and a thin perirenal hematoma.

Table 1 Number of positive, false-positive, negative and false-negative patients at US compared to contrast-enhanced CT.

		Contrast-enhanced CT	
		+	–
US	+	59	20
	–	25	29

of the solid organs of the right upper and left quadrant. CEUS outcome was considered positive when a perfusion defect of the studied organ was found characterized by hypoechogenicity with or without interruption of the organ profile. In case of non-perfusion of part of or the whole organ, the finding was interpreted as a sign of vascular injury, and the passage of micro bubbles outside the damaged organ was interpreted as active bleeding.

After CEUS, CT was performed in the venous phase before and after administration of non-ionic contrast agent. In the presence of free fluid collection, late-phase evaluation was carried out at 3–15 min to identify active bleeding or urine collection.

The examination results were stored in digital form until 2006 and subsequently on picture archiving and communications system (PACS). CEUS and CT images were graded according to the Organ Injury Scale of the American Association for the Surgery of trauma (AAST) [21].

Statistical analysis

The “gold standard” of comparison used for both methods was CT. The values of sensitivity and specificity including positive and negative predictive values with 95% confidence interval (CI 95%) for US and CEUS compared to CT were calculated using the following online calculators: <http://statpages.org/ctab2x2.html> and <http://araw.mede.uic.edu/cgi-bin/testcalc.pl>. US and CEUS examinations were subsequently evaluated by two operators not involved in the examination to determine the correlation between the two methods related to the final diagnosis using a 5-point scale to define the diagnosis as possible or not possible.

Results

Eighty-four injuries were identified in 133 patients (63%): 48 cases of splenic injury, 21 of liver injury, 13 of renal or

Fig. 3 Right flank trauma. A) Subcostal oblique scan: US evidences a small fluid collection in the hepatorenal space (arrow). B) CEUS evidences a shaded hypoechoic area at the upper pole of the right kidney (arrow) which appears well-delineated. On revision of the case, this hypoechoic area was interpreted as adrenal gland contusion. C) Contrast-enhanced CT shows inhomogeneous enlargement of the adrenal gland (arrow). This patient was monitored for 48 h while the contusion cleared up.

Table 2 Number of positive, false-positive, negative and false-negative patients at CEUS compared to contrast-enhanced CT.

		Contrast-enhanced CT	
		+	–
CEUS	+	81	1
	–	3	48

adrenal injury and 2 of pancreatic injury. Of the 133 patients, 49 (37%) showed no injuries on CT.

US findings were positive for free fluid or alterations in the parenchymal echo pattern in 59 patients, and CEUS identified 81 of the 84 injuries identified by CT (Figs. 1 and 2).

Twenty-five patients with no peritoneal fluid at US resulted false-negative, whereas 20 patients who had a small peritoneal fluid collection at US had no post-traumatic injuries on CT and were therefore considered false-positive (Table 1).

CEUS yielded 1 false-positive and 2 false-negative results. In a patient who had a direct impact left flank trauma, CEUS showed a hypoechoic lesion of the inferior pole of the spleen. Subsequent CT showed that it was an ischemic lesion (Fig. 3) and the result was therefore classified as false-positive. In 2 patients, CEUS did not evidence a lesion of the right kidney and an adrenal hematoma, which were later identified at CT and these results were therefore classified as false-negative. None of these cases were treated surgically and the patients were discharged after 3 days observation (Table 2).

In 7 patients CEUS identified contrast agent extravasation, a specific sign of active bleeding, and these patients were all treated surgically or by embolization (Fig. 4).

Sensitivity, specificity, positive and negative predictive values of US were 70.2%, 59.2%, 74.7% and 53.7%, respectively; of CEUS 96.4%, 98%, 98.8% and 94.1%, respectively (Table 3).

In the subsequent comparison with CT, CEUS showed a high correlation with CT in the evaluation of the lesion volume according to the AAST classification (Table 4) and permitted a definitive diagnosis in a significantly higher number of patients than US (Table 5).

Discussion

US is widely used in the emergency room for evaluation of patients with blunt abdominal trauma. The role of this method is well-established in hemodynamically unstable patients in whom the presence of hemoperitoneum immediately leads to surgical treatment [12–19,21].

The role of diagnostic imaging is quite different in stable patients, as accurate assessment of the organ damage is necessary in order to proceed with the most suitable therapy: conservative treatment, surgery or interventional radiology [22]. However, US has shown a low sensitivity in identifying injury to abdominal organs [13,23].

CEUS is significantly more accurate in identifying post-traumatic injury to abdominal solid organs, reaching a sensitivity almost equal to that of CT [16,17]. The use of CEUS has recently been included in the guidelines issued by the European Society of Ultrasound in Medicine and Biology (EFSUMB) on the study of abdominal trauma if CT is not available or contra-indicated for previous allergic reactions to iodinated contrast agent or if CT is not conclusive due to artifacts. CEUS is also recommended in the monitoring of already diagnosed injuries and in the investigation of minor blunt traumas [24].

In the reported experience, CEUS permitted identification of a greater number of injuries than US. CEUS also permitted a definition of the extension of the lesions, demonstrating an elevated correlation with CT, and evidenced extravasation of contrast agent in cases of active bleeding [16].

In a patient with left flank trauma, complete absence of contrast-enhancement was observed in the left kidney adjacent to a complicated lesion of the spleen. This finding led to the diagnosis of injury to the vascular pedicle of the kidney, subsequently confirmed by splenectomy–nephrectomy.

CEUS was used in the monitoring of patients treated conservatively, thus avoiding transfer to the CT room and exposure to ionizing radiation and iodinated contrast agent [25].

Twenty patients with false-positive outcome at US were correctly identified as negative at CEUS. On the basis of these results, it may be possible to avoid CT in traumatized women of childbearing age who have a small fluid

Fig. 4 Trauma due to road accident. A) US of the left flank: diffused alteration of the splenic echo pattern but no evidence of free fluid. B) CEUS showed a large rupture of the lower half of the spleen with extravasation of contrast agent within the hematoma (arrow). C) CT scan confirmed splenic rupture and bleeding (arrow).

Table 3 Values of diagnostic features for US and CEUS (IC 95%).

Diagnostic feature	US	CEUS
Sensitivity	70.2 (63.8–76.1)	96.4 (93.0–97.4)
Specificity	59.2 (48.2–69.2)	98.0 (92.1–99.6)
Positive predictive value	74.7 (67.9–80.9)	98.8 (95.3–99.8)
Negative predictive value	53.7 (43.8–62.7)	94.1 (88.5–95.7)

collection in the pouch of Douglas, thus confirming the conclusions made by Brown and colleagues [26].

The erroneous results obtained at CEUS were one false-positive splenic injury and missed identification of one renal lesion and one adrenal hematoma. Ischemic lesions of the spleen are relatively frequent, and at CEUS they appear as areas of no vascularization [27,28]. In connection with a left flank trauma, this finding is easily misinterpreted, and a modest overestimation of these lesions is in our opinion justified considering the possible serious damage in case of non-recognition. In the patients with injuries to the kidney and adrenal gland not identified at CEUS, CT scans showed that they were minor injuries which did not require surgical treatment. In these cases the lack of recognition did not alter the clinical outcome in the patients, who were kept under observation for a short period.

CEUS cannot overcome the limitations of the US technique in general, such as the difficulties encountered in macrosomic patients, although newly developed US equipment permits examination also in cases where this examination was previously considered impossible. On the whole, patients who are unsuitable for B-mode examination should not undergo CEUS.

Mesenteric and intestinal traumas are still difficult to diagnose using US; the contrast agents available today do not permit an adequate study of the excretory system of the kidney as there is no urine elimination. Further

Table 4 Dimensions of the lesions measured at CEUS and compared to CT grading.

	CT grading ^a	Dimensions at CEUS (mm)
Liver (<i>n</i> = 21)	Grade I: <i>n</i> = 3	<10 (2)
	Grade II: <i>n</i> = 13	<20 (4), <30 (9)
	Grade III: <i>n</i> = 5	>30 (5)
Spleen (<i>n</i> = 48)	Grade I: <i>n</i> = 4	<10 (4)
	Grade II: <i>n</i> = 32	<30 (11), <50 (21)
	Grade III: <i>n</i> = 12	>50 (12)
Kidneys and adrenal glands (<i>n</i> = 13)	Grade I: <i>n</i> = 2	Not identified
	Grade II: <i>n</i> = 5	≤10 (5)
	Grade III: <i>n</i> = 6	>10 (6)
Pancreas (<i>n</i> = 2)	Grade II: <i>n</i> = 1	10 (2)

^a Organ Injury Scale of the American Association for the Surgery of trauma (<http://www.trauma.org/archive/scores/ois.html>).

Table 5 Comparison of diagnostic yield using the different methods.

Confidence	US	CEUS	CT
Definitive diagnosis	34	81	84
Possible diagnosis	11	1	0
Uncertain diagnosis	14	0	0
Diagnosis not possible	25	2	0
Various findings	0	0	0
Total	84	84	84

investigation involving a larger patient population is required to study the effectiveness of CEUS in abdominal trauma in order to evaluate repeatability and operator dependence.

Conclusions

Our study showed that CEUS is an accurate diagnostic tool in stable patients with abdominal trauma. This method seems to be particularly useful in patients with minor abdominal trauma, as false-positive results caused by physiological peritoneal fluid collections are rapidly recognized.

CEUS may be proposed in traumatized patients with abnormal laboratory values (e.g. increased transaminases or serum amylase, hematuria, anemia) or bone fractures that raise suspicion of intra-abdominal injuries (lower ribs, transverse processes of the lumbar vertebrae), or in cases of major trauma [12] when US outcome is negative for peritoneal fluid.

CEUS is particularly useful in monitoring the evolution in patients with traumatic injuries which are not submitted to immediate surgical treatment. The patient can be examined at the bedside avoiding transfer to the CT room and exposure to ionizing radiation and iodinated contrast agent.

Conflict of interest statement

The authors have no conflict of interest.

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