Blunt abdominal trauma: contrast-enhanced ultrasound (CEUS) in the detection and staging of abdominal traumatic lesions compared to US and CE-MDCT.

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Purpose

The aim of the study is to evaluate the sensibility of contrast-enhanced ultrasound (CEUS) in the detection and staging of abdominal traumatic lesions in patients with low-energy isolated abdominal trauma in comparison with baseline ultrasound (US) and contrast-enhanced computed tomography (CE-MDCT), considered the gold standard.

The management of patients with mild or low-energy trauma is still the subject of controversy. CT examination is the most accurate and panoramic imaging tool in the evaluation of patients involved in a high-energy accident in stable condition [1-3].

Baseline abdominal US is the first step protocol in many emergency centers and it’s recommended to be performed before the CT study.

It’s rapid, repeatable, noninvasive and inexpensive but the sensibility in the detection of abdominal solid organ traumatic lesions is quite low (also below 50% in literature) [4].

Contrast-enhanced ultrasound in traumatic patients has been shown to be more sensitive than US for the detection of solid organ injuries, improving the identification and grading of traumatic abdominal lesions with levels of sensibility and specificity similar to CT (up to 95% in literature) [1-5].
Methods and Materials

PATIENTS

Between January 2010 and December 2012 a total of 352 consecutive patients who arrived in our Emergency Department with an history of low-energy isolated abdominal trauma and in stable haemodynamic conditions were analyzed (224 males; 128 females - mean age 27±2.8 years).

The major causes of blunt abdominal trauma are reported in Table 1 on page 5.

All patients underwent US and CEUS with the use of a second-generation contrast agent (Sonovue, Bracco-Milan, Italy).

Written informed consent was obtained from all the patients or from their relatives in case of minors.

Only the patients with positive CEUS findings for abdominal injury were then studied with CE-MDCT.

The patients with negative CEUS findings and negative clinical and laboratory tests underwent no further imaging investigation; a phone call was made to all patients one week later to know whether they had got any symptom related to the trauma. Patients who referred symptoms and presented any alteration in laboratory tests were recalled and subjected to a new CEUS examination.

EXAMINATION TECNIQUE

Conventional ultrasound and contrast-enhanced ultrasound were performed with a Siemens ACUSON Sequoia 512 (Siemens Medical Systems, Forchheim, Germany) using a curved array 4 Mhz multi-frequency.

After the abdominal baseline ultrasound, in the same session, CEUS was performed with an intravenous bolus injection of a second-generation blood pool contrast agent (Sono Vue, Bracco, Milan, Italy) consisting of stabilized microbubbles (MB) of sulfur hexafluoride gas covered by a stabilizing phospholipidic membrane.

The Sequoia system was equipped with contrast pulse sequences (CPS) software which detects the MB's fundamental nonlinear response; a continuous low mechanical index (MI 0,15-0,19) real time tissue harmonic imaging (Cadence) allows real-time gray scale imaging.

A total of 4,8 ml of Sonovue was administrated through a 18G needle put in an antecubital vein, fractionated into two 2,4 ml doses followed by 5-10 ml of saline [1-4].
For pediatric patients Sono Vue dose has been calculated as follows: age in years /10 in ml [5].

Immediately after the first bolus the right-sided organs (the right kidney and the liver subsequently) were explored for 1-3 min. With the second dose left side organs (the left kidney and finally the spleen) were focused for other 3-4 minutes [3].

Only patients with positive CEUS findings underwent CE-MDCT examination within 1 hour after CEUS, using a standard arterial and venous protocol with a 16 detector CT scanner (16 LightSpeed, GE Healthcare, USA).

No patients received oral contrast medium and all patients had a pre-contrast acquisition series.

A non ionic contrast medium volume of 100-150 ml was injected at 2-4 ml /sec through a 18-20 G angiocatheter. A delay ranged from 40 to 50 sec was used for the arterial phase and from 80 to 100 sec for the second acquisition; in presence of collections, a late-phase study (3-15 min) was performed to identify any active bleeding or urinoma.

DATA COLLECTIONS

On US a parenchymal traumatic lesion was depicted as an intraparenchymal hyper or hypoechoic area or a distorsion of the normal echoic structure [1-4]. On CEUS examination traumatic injury was identified as a perfusion defect represented by an hypoechoic area with ill- or well-defined margins with or without interruption of the organ profile. Lacerations can appear as a hypoechoic linear lesion, usually oriented perpendicular to the organ surface. (Fig. 1 on page 5)

Haematomas are represented by non-enhancing areas. (Fig. 2 on page 6).

Focal extravasation of microbubbles outside a lacerated organs suggest active bleeding (Fig. 3 on page 7).

We evaluated the presence and number of traumatic lesions in US, CEUS and CE-MDCT and the lesions’ grading on CEUS and CE-MDCT, comparing CEUS results with US findings for lesion numbers and with CE-MDCT values for number and grading.

For the CEUS and CT grading of lesions we used the America Association for the Surgery of Trauma (AAST) classification [6-7].
## Table 1: Major causes of blunt abdominal trauma

<table>
<thead>
<tr>
<th>CAUSE</th>
<th>N. of PATIENTS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motocycle and car crashes</td>
<td>193</td>
<td>55%</td>
</tr>
<tr>
<td>Working trauma</td>
<td>74</td>
<td>21%</td>
</tr>
<tr>
<td>Accidental trauma</td>
<td>56</td>
<td>16%</td>
</tr>
<tr>
<td>Sport trauma</td>
<td>29</td>
<td>8%</td>
</tr>
</tbody>
</table>

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Fig. 1: Traumatic liver lesion classified as IV grade according to the AAST scale. A) Baseline US shows an hyperechoic area within the VII-VI hepatic segments. B) CEUS examination shows a well defined hypoechoic area involving the VII and the VI hepatic segments (IV grade laceration). C) Axial-CE-MDCT image confirms the CEUS findings.

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**Fig. 2:** Grade III traumatic splenic lesion. A) Baseline US does not show any parenchimal lesion. B) CEUS shows two parenchimal traumatic lesions; the spleen is surrounded by a hematoma. C) CE-MDCT overlaps the CEUS findings.

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**Fig. 3:** IV grade hepatic traumatic lesion. A) Baseline US shows only a fine inhomogeneity in VI-VII segments. B) CEUS examination shows an hypoechoic area with evidence of active bleeding with capsule rupture (red arrow). C) Axial CE-MDCT examination overlaps CEUS findings

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Results

In the 352 Patients included in the study CE-MDCT identified 74 Patients with abdominal positive findings (20%), with a total of 83 traumatic lesions due to the presence of two lesions in 9 patients (liver= n 30, spleen= n 35, Kidney= n 18), with a diameter range of 1 to 10 cm.

On the basis of CE-MDCT findings, considered as the reference standard, we analyze the capacity of US and CEUS to identify the number of traumatic lesions.

US depicted 45/83 traumatic intraparenchymal lesions (liver= 19/30, spleen= 16/35, Kidney= 10/18), with a sensibility of 54%.

83/83 lesions were identified at CEUS examination (liver= n 30, spleen= n 35, Kidney= n 18) with a sensibility of 100% (Table 2 on page 10).

CE-MDCT has successfully staged all the 83 traumatic injuries using the AAST criteria [5-6].

Liver lesions (n=30) were classified as: grade I (n=5), grade II (n=7), grade III (n=13) and grade IV (n=5); splenic lesions (n=35) were classified as: grade I (n=6), grade II (n=10), grade III (n=13), grade IV (n=6). Kidney lesions (n=18) were so distributed: grade I (n=3), grade II (n=6), grade III (n=8), grade IV (n=1).

On the basis of these values CEUS had successfully staged 74/83 traumatic lesions: 28/30 liver lesions (Fig. 4 on page 10), 31/35 splenic lesions and 15/18 Kidney lesions with a sensibility of 89% (Table 3 on page 10).

Nine lesions were understaged at CEUS examination: in 5 cases CEUS understaged minor traumatic injuries that needed a conservative, nonsurgical management; in 3 cases CEUS did not recognize the presence of active bleeding (in 1/2 liver lacerations and in 2/4 splenic injuries) with a sensibility of 50%; finally, in 1 case, CEUS did not demonstrate a lesion of the urinary tract, undestaging a IV grade kidney lesion on CE-MDCT (Fig. 5 on page 11).

Therefore, our main CEUS limitations are the poor visualization of active bleeding and the inability to demonstrate unirary tract lesions, findings that are instead clearly depicted on CE-MDCT.

Only 3 patients with CEUS negative findings at the arrival in our Hospital and recalled on a phone-call one week later, referred clinical symptoms and were subjected to a new CEUS examination which showed negative results.
<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>CEUS</th>
<th>CE-MDCT</th>
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</thead>
<tbody>
<tr>
<td><strong>Liver</strong></td>
<td>19</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td><strong>Spleen</strong></td>
<td>16</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td><strong>Kidney</strong></td>
<td>10</td>
<td>18</td>
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</table>

**Table 2:** Number of lesions identified on US, CEUS and CE-MDCT.

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**Fig. 4:** Hepatic traumatic lesion. CEUS examination (A) shows a II grade traumatic hypoechoic lesion on VI segment (red arrow), confirmed by CE-MDCT axial-scan(B).

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<table>
<thead>
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<th></th>
<th>GRADE</th>
<th>CEUS</th>
<th>CE-MDTC</th>
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<tbody>
<tr>
<td>Liver</td>
<td>I</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>6</td>
<td>7</td>
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</tr>
<tr>
<td></td>
<td>IV</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Spleen</td>
<td>I</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>II</td>
<td>8</td>
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<td></td>
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<td>6</td>
</tr>
<tr>
<td>Kidney</td>
<td>I</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
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<td>II</td>
<td>4</td>
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<tr>
<td></td>
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</tbody>
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**Table 3:** Grading of lesions on CEUS and CE-MDTC.

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Fig. 5: Renal fracture. A) Longitudinal US only shows a fine cortical inhomogeneity at the middle third of the Kidney; perirenal iperechoic fluid B) CEUS shows a complete parenchimal fracture and the presence of perirenal fluid. Axial CE-MDCT in the venous phase (C) shows the renal fracture with perirenal fluid; the CE-MDCT late phase (D) shows that the perirenal effusion was a urinoma (red arrow).

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Conclusion

In patients with low-energy isolated abdominal trauma conventional US has a low sensibility in the identification of organ injuries and so it should be replaced by CEUS as the first line approach.

CEUS has shown an high sensibility both in the detection and grading of traumatic lesions.

CEUS negative patients with history of blunt abdominal trauma and without clinical symptoms or laboratory alteration tests, after a period of observation, may be discharged home, without undergoing CT examination.

In patient with CEUS positive findings CE-MDCT must always be performed to exclude any negative prognostic factors as active bleeding or rupture of urinary tract.
Personal Information

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