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Usefulness of Contrast Enhanced Ultrasound for the evaluation of blunt abdominal trauma

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Abstract

Blunt abdominal trauma is more and more frequent in daily practice. Contrast computer tomography is the gold-standard method for the assessment of this kind of patients, but it is not always available and it is irradiant. Also, in most cases, solid organ injuries secondary to blunt abdominal trauma are absent or mild, and the most affected patients are young and healthy (often children or teenagers), so a new performant method, that could avoid radiation exposure, is required.

Such a method is contrast enhanced ultrasonography, very sensitive for the detection of small quantities of ultrasound contrast, due to the dedicated software of the US machine, able to detect and amplify the signal generated by a very small number of microbubbles. This is the typical case of hypovascular, slow blood flow areas, edging the lacerations caused by trauma, as well as the contusion areas, where the blood flow is hampered by the presence of edema.

Also, the liver, spleen and kidneys are richly vascularized, so they show intense enhancement following the injection of US contrast agents. Posttraumatic lesions being hypovascular (contusion) or avascular (ruptures, hematomas), will be revealed after contrast, clearly appearing as hypo- or unenhancing areas, as compared to the surrounding tissues.

Although the use of US contrast agents is still "off-label" for the assessment of BAT, recent studies have confirmed their utility for the diagnosis of posttraumatic lesions in parenchymal organs, both in adults and in children.

Key words: blunt abdominal trauma, ultrasonography, contrast agents

Rezumat

Din păcate, traumatismele abdominale sunt din ce în ce mai frecvente în practica de zi. Examenul computer tomografic cu substanţă de contrast este considerat a fi gold-standardul de evaluare al acestui tip de pacienţi, dar nu este întotdeauna disponibil şi, în plus, are dezavantajul de a fi iradiant. De asemenes, în majoritatea cazurilor, leziunile de la nivelul organelor parenchimatoase, secundare traumatismelor abdominale, sunt absente sau uşoare, majoritatea pacienţilor fiind tineri şi sănătoşi (frecvent copii şi adolescenţi). În aceste condiţii era nevoie de o nouă metodă performantă e evaluare, care să evite iradierea pacienţilor.

O astfel de metodă este ecografia cu substanţă de contrast, foarte sensibilă pentru vizualizarea unor cantităţi mici de agent de contrast, datorită unui software dedicat, capabil să detecteze şi să amplifice semnalul generat de acesta. Este cazul tipic al zonelor hipovasculare, cu flux sanguin lent, ce mărginesc laceraţiile secundare traumatismelor, precum şi al zonelor de contuzie, în care fluxul sanguin este stânjenit de edem.

Ficatul, splina şi rinichii sunt organe bogat vascularizate, ce se încarcă puternic după administrarea substanţei de contrast. Leziunile posttraumatice sunt hipovasculare (contuziile) sau avasculare (rupturile, hematoamele), deci vor fi bine definite după administrarea contrastului, apărând ca zone hipo sau anecogene în comparaţie cu ţesuturile înconjurătoare.

Deşi utilizarea substanţelor de contrast ecografic nu a fost încă oficial aprobată (este "off-label") pentru evaluarea pacienţilor cu traumatisme abdominale, studii recente au confirmat utilitatea acestora pentru diagnosticul leziunilor posttraumatice de la nivelul organelor parenchimatoase, atât la adulţi, cât şi la copii.

Cuvinte cheie: traumatism abdominal închis, ecografie, substanţe de contrast

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The incidence of blunt abdominal trauma (BAT) is, unfortunately, increasing in daily practice, being also a major emergency, with vital risks in some cases. Of course it is obvious that solely clinical evaluation is not sufficient to assess the extent and severity of injuries. The gold-standard assessment of a patient with abdominal trauma is contrast computer tomography (CT), preferably using a multislice machine with rapid image acquisition [1-3].

But CT assessment is not always available.

1. Why contrast enhanced ultrasound (CEUS) assessment in blunt abdominal trauma?

In many emergency units, abdominal ultrasound (US) in the first method to be used for the assessment of a patient with BAT, using either the conventional technique, or FAST examination (Focused Assessment with Sonography of Trauma) [4], both methods having approximately 90% sensitivity and 97-100 % specificity [5-7] for the detection of intraperitoneal liquid (fig 1).

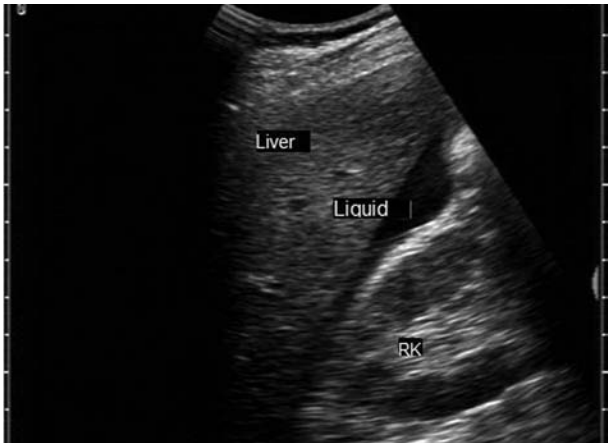

Fig 1. A small quantity of liquid is visible between the liver and the right kidney in a patient after blunt abdominal trauma (Conventional ultrasound).

Other advantages of US are that it can be used at the bedside, even without interrupting resuscitation maneuvers; in addition it is a fast, non-invasive, repetitive and non-irradiant procedure.

Despite its good performance for the detection of hemoperitoneum, US has poor results in the diagnosis of posttraumatic lesions of solid organs, with only 40% sensitivity [8,9], a fact to be considered since 30-40% of these injuries are not accompanied by hemoperitoneum [10-13]. Another disadvantage of US is the difficulty to obtain quality images in obese patients or in those who are unable to cooperate, mainly due to gas or bone interposition [14].

In high intensity abdominal trauma (such as in car accidents), the lesions are often severe, with hemodynamic instability requiring emergency surgery. In low intensity BATs (such as household accidents, playground accidents, sport injuries) the risk of severe injuries is smaller, but not zero. Often unilateral injuries occur, parenchymal organs (liver, spleen, kidneys), being the most commonly affected. The most frequent lesions are contusions, hematomas or ruptures, with potentially severe evolution, not obvious at the initial clinical and biological evaluation. Fortunately, most patients who suffered low intensity BAT do not develop severe injuries. Consequently, these patients should be evaluated by a performant imaging method, more as a precautionary measure, to exclude potentially serious injuries [14].

As noted above, contrast CT is the gold-standard method for assessing posttraumatic solid organ lesions. Considering that, in most cases, abdominal injuries secondary to BAT are absent or mild, and that most affected patients are young and healthy (often children or teenagers), the question arises whether their radiation exposure, sometimes repetitive, is justified [15]. The emergence of US contrast agents is a step forward, improving the performance of classical US evaluation for the detection of posttraumatic lesions in solid organs [16-18]. The liver, spleen and kidneys, organs most commonly affected by BAT, are richly vascularized, so they show intense enhancement following the injection of US contrast agents, similar to the enhancement following the administration of CT contrast agents. Their posttraumatic injuries are sometimes difficult to be seen by standard US, they can have hyper-, hypoechoic or mixed aspect [19-21] (fig 2, fig 3, fig 4).

Fig 2. In a patient with blunt abdominal trauma, a hypoechoic area is visible in the liver dome by conventional ultrasound – Hematoma?

Fig 3. In a patient with blunt abdominal trauma, a small anechoic area is visible in the spleen by conventional ultrasound – Hematoma?

Fig 4. In a patient with blunt abdominal trauma, the left kidney is surrounded by an anechoic area – subcapsular hematoma?

Even when visible, their size and extension are difficult to assess, making it difficult to predict their evolution. Being hypovascular (contusion) or avascular (ruptures, hematomas), they will be revealed after contrast, clearly appearing as hypo- or unenhancing areas, as compared to the surrounding tissues.

On the other hand, CEUS evaluation is very sensitive for the detection of small quantities of US contrast, due to the dedicated software of the US machine, able to detect and amplify the signal generated by a very small number of microbubbles. This is the typical case of hypovascular, slow blood flow areas, edging the lacerations caused by trauma, as well as the contusion areas where the blood flow is hampered by the presence of edema [14]. In the experience of Thorelius, one of the pioneers in the use of CEUS in BAT, CEUS is more sensitive than CT for the detection of these areas [14] and may be used to verify CT scans with inconclusive results, in which posttraumatic parenchymal lesions are suspected. In fact, this is one of the indications for the use of CEUS according to EFSUMB guidelines, even if the use of US contrast agents is "off-label" for BAT [15].

2. Particularities of CEUS in the evaluation of BAT.

Post-contrast appearance of traumatic lesions of the liver, spleen or kidney may vary, from completely unenhancing, with a clear demarcation from the surrounding tissues, as is the case of hematomas or organ ruptures; to hypoenhancing in the case of contusion areas that are hypovascular due to edema and vascular ruptures and to vaguely hypoenhancing as compared to the surrounding tissues, as is the case in some mild contusions, in which the hypovascular appearance is due more to edema than to tissue destruction [4].

The presence of microbubbles in an avascular area, suspected to be a hematoma or hemoperitoneum, is highly suggestive for active bleeding, and, depending on its intensity, may be an indication for surgery or percutaneous treatment.

Given the sensitivity of CEUS in detecting hypo- and avascular areas, and the fact that the liver, spleen and kidneys are highly vascular organs, their posttraumatic lesions are visible in all the vascular phases, with features depending on the circulating pattern of the concerned organ.

In the CEUS assessment of the liver, three classic phases are described: arterial, portal and late, parenchymal [15]. Thorelius proposes another description of the postcontrast behavior of the liver in assessing posttraumatic lesions, depending on the parenchymal homogeneity, in order to better explain the management of contrast agents [14]. This description takes into consideration only the parenchyma, irrespective of what happens in US identifiable large vessels, and can be applied to any parenchymal organ (including the kidney and spleen). Thus, three phases can be described: the first starts with the enhancement of small arterioles and ends with the disappearance of enhancement variations of the parenchyma, when the second phase begins, the homogeneous one. This lasts until the microbubbles begin to be destroyed (recurrence of the inhomogenous phase), or until the early phase of the wash-out. Finally, the third phase lasts until the contrast agent is eliminated from the organ [14]. Avascular and marked hypovascular lesions (such as the posttraumatic ones) are visible in all the three phases described above, but they are better seen in the second, homogeneous phase.

In the liver, the homogeneous phase begins early after contrast injection, approximately after 40 seconds, sometimes slightly earlier, and lasts until about 4 minutes after injection (14, 15). Spleen enhances intensely, inhomogeneously in the first phase, the homogenous phase beginning approximately 1 minute after injection and lasting until about 5 minutes after contrast. Often a rapid wash-out of the tissue surrounding the splenic veins occurs, which may mimic posttraumatic lesions [14,15]. This phenomenon can be explained by the efficient filtration of the microbubbles in the spleen [14]. Diagnostic errors can be avoided by careful pre- and postcontrast examination, knowing that this behavior may occur, and in case of doubt, by CEUS reassessment after a second dose of contrast.

In the kidney the postcontrast enhancement is intense, beginning from the cortical area, followed by the pyramids that enhance starting from the periphery to the center, so that they become homogeneous 30-40 seconds after contrast injection, when the homogeneous phase begins. In the kidney the homogenous phase is short, the wash-out occurring less than 3 minutes after contrast injection.

Even if the pyramids enhance less than the cortical, their posttraumatic lesions (hypo- or avascular) are clearly visible. In a study published by Valentino, CEUS assessment had 80% sensitivity and 100% specificity for the diagnosis of posttraumatic renal lesions as compared with contrast CT, detecting 8 of the 10 lesions visualized by CT [22].

3. Recommended doses of US contrast agents for the evaluation of BAT.

When establishing the optimal dose of US contrast needed to evaluate a patient with BAT, several factors should be taken into consideration, including age, patient conformation, obesity and, also, the organ that should be evaluated.

In non obese adults, the recommended doses of US contrast are smaller than those used for the CEUS assessment of focal lesions. Thus, for the evaluation of the liver, the recommended dose is 1.2-1.6 ml SonoVue, and for kidney and spleen assessment, the recommended dose is 0.6 ml [14]. Thorelius recommended these small doses in order to avoid the "drowning" phenomenon of hypo- or avascular areas that characterize lacerations, hematomas and contusions, in the hyperintense signal of the surrounding tissues. Sometimes ruptures may be only 1-2 mm in diameter, but can spread from one side of the organ to the other. Also, high doses of contrast can make the small depth parenchyma, with hyperintense enhancement, to reflect a large part of the US waves, thus masking deep lesions [14].

Although SonoVue was not officially approved for the use in children, there are studies that demonstrated the effectiveness and safety of CEUS evaluation of BAT in this age group [23-25]. Thorelius recommended that the following formula should be used in order to calculate the dose of contrast needed to assess BAT of the liver in children:

Dose (ml SonoVue) = patient's age/10, but not less than 0.1 ml.

To assess the spleen and kidney doses should be reduced by half [14].

4. Technique of CEUS assessment of patients with BAT.

a) General recommendations.

Before CEUS evaluation, BAT patients should be clinically and biologically assessed. CEUS assessment must be made only by experienced ultrasonographists in the use of contrast US. If such an operator is not available, CT evaluation is recommended. In no circumstances should only conventional US be used for the diagnosis of BAT patients [14].

The examination should start with FAST assessment of intraperitonel liquid, followed by conventional US [15] in order to try to localize possible posttraumatic lesions. The examination should focalize on the organ (organs) alleged to be harmed. The optimal patient position, as well as the respiratory position offering maximum accessibility to the target lesion should be evaluated on the same occasion. If they can not be properly viewed (in patients with poor US window, or who are not able to cooperate with the examiner), CEUS evaluation should not be performed, and the patient will be evaluated by CT [14,15]. In order to evaluate the liver, a good subcostal US window is mandatory (it can not be replaced by intercostal examination). If the subcostal assessment is not accessible, the patient will be referred to CT scan [14].

It is recommended that CEUS assessment should be made according to standard protocols, respecting certain sequences. Documentation of the assessment by recorded images is mandatory, so that they can be reviewed after the procedure, thus avoiding reinjection in cases of unclear lesions [14].

b) Evaluation of right flank trauma [14]

Following conventional US, CEUS assessment will begin by a 0.6 ml SonoVue injection, and *right kidney* examination as soon as possible thereafter, considering that cortical lesions are still visible in the early arterial phase. It is recommended that the kidney should be examined by continuous scans throughout the homogeneous phase, until about 3 minutes after contrast.

It is important that the kidney should be assessed both in the longitudinal and transverse axes, so that the scanning covers the transverse plane in 7-10 seconds and the longitudinal plane in 5-7 seconds, alternating the intercostal spaces when the ribs cannot be avoided. Ideally, the transducer is placed in the longitudinal axis of the kidney.

Approximately 3 minutes after the injection, the wash-out of the kidney starts and the examination of the *liver* can begin immediately. A bolus of 1.2 ml of SonoVue is injected, which can be divided into 2 doses of 0.6 ml each, at 1-2 minutes interval, in order to prolong the homogeneous phase, for a better visualization of the right liver lobe, most frequently affected by right flank trauma.

It is preferable that the liver examination begins in the left side decubitus, for a better subcostal approach to the right liver lobe, including the fourth segment. With good cooperation of the patient, who will be invited to inspire, lateral and ventral segments of the liver in which the chance of missing a lesion is higher will be viewed. After evaluating the right liver lobe, the patient will be invited to lie into dorsal decubitus for further evaluation of the left liver lobe.

c) Evaluation of left flank trauma [14]

As in the trauma of the right flank, following conventional US, the CEUS assessment will begin by a 0.6 ml SonoVue injection and the examination of left kidney immediately afterwards, according to the above outlined protocol.

The left kidney assessment is followed by spleen evaluation, without needing a new contrast administration, given that in the spleen the homogeneous phase has the longest duration, approximately 2 minutes longer than in the kidney. Spleen assessment will be made both in the longitudinal and transverse axes, by repetitive scans in the intercostal or subcostal spaces, inviting the patient to deeply inspire, so as the spleen is viewed in its entirety, sometimes difficult to achieve in patients with small spleen, placed deeply subcostal.

5. Instead of conclusions

Although the use of US contrast agents is still "off-label" for the assessment of BAT, recent studies have confirmed their utility for the diagnosis of posttraumatic lesions in parenchymal organs, both in adults and in children. A study in 2006 which compared CEUS with contrast CT in the evaluation of 35 posttraumatic lesions (of the liver, spleen, kidney and adrenal glands), demonstrated a 91.4% sensitivity, a 100% specificity, with positive and negative predictive values of 100% and 92.5%, respectively (22). The same authors evaluated 14 posttraumatic lesions in children with CEUS and contrast CT, demonstrating similar performances of CEUS, with a 92.2% sensitivity, a 100% specificity, 100% positive and 93.8% negative predictive values [25].

In a study published in 2008 by Clevert [26], a 100% overlap was also demonstrated between multislice CT and CEUS in the diagnosis of 18 posttraumatic lesions of the liver, spleen and kidney, the CEUS examination being used for the elucidation of unclear CT images.

Starting from these initial promising data, further studies are required, on a larger number of cases, in order to establish a standard protocol for CEUS examination in BAT patients. Also, the training of highly skilled, , experienced ultrasonographists is mandatory in order to be able to perform this exploration.

In the guidelines of good practice for the use of contrast agents, EFSUMB recommends that CEUS should be used for the assessment of posttraumatic liver, kidney and splenic lesions, in addition to FAST and conventional US, as well as to clarify doubtful lesions on contrast CT. CEUS assessment should be considered for the initial diagnosis of organ lacerations and ruptures, of subcapsular hematomas and intraperitoneal collections. It is also useful for the follow-up of detected parenchymal lesions, thus avoiding repetitive CT-scans and induced irradiation [15].

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