

Contrast-enhanced ultrasound performance in predicting blunt splenic injuries requiring only observation and monitoring

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Abstract

Aims: To assess contrast enhanced ultrasound (CEUS) performance in the prediction of non-operatively managed blunt spleen injuries requiring only observation and monitoring during follow-up and to evaluate if CEUS accuracy was higher than conventional ultrasound (US) in this field. **Material and methods:** In 112 hemodynamic stable blunt spleen trauma patients, CEUS was performed for follow-up after computed tomography evaluation in the emergency department. CEUS and US performance were assessed considering as true negative cases patients that had not underwent interventional or surgical treatment during follow-up and were assessed as negative for splenic complications respectively by CEUS or US examinations. **Results:** CEUS showed sensitivity of 100%, specificity of 96.1%, positive predictive value of 69.2%, negative predictive value of 100.0% and accuracy of 96.4%. CEUS showed a significantly higher accuracy than conventional US ($p=0.013$). **Conclusions:** CEUS is a very useful imaging modality during follow-up of blunt splenic trauma non-operatively managed, allowing an efficient prediction of splenic injuries requiring only observation and monitoring during follow-up.

Keywords: contrast-enhanced ultrasound; ultrasonography; spleen; blunt trauma

Introduction

After the liver the spleen is the second most commonly injured organ during blunt abdominal trauma [1]. When a trauma patient who is hemodynamically unstable or with diffuse peritoneal signs and free fluid is detected at Focused Assessment with Sonography for Trauma (FAST) examination, a laparotomy is usually performed. If the spleen is identified as the source of bleeding, a splenectomy is carried out. Stable patients undergo computed

tomography (CT) and, if required, they undergo interventional radiology (IR) procedures in the spleen. Non-operative management (NOM) is currently considered the best therapeutic option in stable patients in an optimal setting in which monitoring and frequent clinical evaluations are possible and an operating room is available for a possible urgent laparotomy [2]. NOM allows the preservation of the splenic role in the immune system, reducing the risk of future infections that could occur in the case of a splenectomy, the most serious of which are part of the overwhelming post-splenectomy infection (OPSI) syndromes. There is no consensus in the literature on how to follow-up patients under NOM. According to the World Society of Emergency Surgery (WSES) guidelines [3], reevaluation with CT should be considered in adult patients with the initial diagnosis of moderate lesions – hemodynamically stable American Association for the Surgery of Trauma (AAST)- spleen Injury Scale (SIS) grade III-IV-V lesions [4] - as well as when there is lowering hematocrit levels, vascular anomalies, underlying

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splenic pathology or coagulopathy and in neurologically impaired patients. In the last three situations, additional CT follow-up is suggested after discharge [3]. However, Leeper et al affirmed that reevaluation with CT at 48 hours following admission could be useful in all grades of injury, given the small but real risk of delayed rupture even in low-grade injuries [5]. Both the Western Trauma Association (WTA) algorithm and Muroya et al recommended to perform a routine follow-up CT after splenic injury also in patients with a relatively low-grade lesion (AAST-SIS grade II) [6,7].

When planning the use of CT for follow-up, however, radiation protection considerations must be taken into account. Furthermore, multiple injections of iodinated contrast medium in a short time can be contra-indicated in some patients. Therefore, the possible use of alternative imaging methods has to be considered.

The first aim of this study was to assess Contrast-Enhanced Ultrasound (CEUS) performance in predicting the evolution of blunt splenic injuries requiring only observation and monitoring during follow-up. The second end-point was to evaluate if CEUS accuracy were higher than conventional US in this field.

Material and methods

All consecutive hemodynamically stable patients without diffuse peritoneal signs undergoing conventional US and CT in the emergency department (ED) during a 2-year period (549 patients from January 2014 to December 2015) were registered prospectively. Among them, we included in our study only the patients in whom a splenic injury without surgery indication was detected by CT; pediatric population (<18 years-old) was excluded. Based on these criteria the patient cohort consisted of 112 patients (79 males; 33 females; mean age 45.7 years, range 18-89). All these patients underwent a CEUS follow-up protocol, consisting of serial CEUS examinations at pre-established intervals until the splenic injury was no more identifiable. Clinical follow-up lasted at least 6 months (mean 8.2; range 6-12 months). The study was approved by the Institutional Review Board and Ethics Committee of our institution. Informed consent was obtained from all individual participants included in the study.

All patients underwent a conventional US in the ED and a few minutes/hours later a CT of the abdomen and pelvis. CT diagnosed splenic injuries were classified according to the AAST-SIS [4]. The patients underwent between 1 and 8 CEUS follow-up examinations at pre-established intervals until the splenic lesion became no more identifiable (at day 1, 3, 7, 15, 30, 60, 90 and 180 days after trauma; mean CEUS 4.6; mean CEUS

follow-up 24 days) with a iU22 scanner (Philips, The Netherlands) using a 1-5 MHz curved-array multi-frequency probe. CEUS examinations were performed with a low-mechanical-index (MI=0.08) after an intravenous bolus injection of a second-generation blood-pool contrast agent (Sonovue®, 2.4 mL, Bracco SpA, Milan, Italy) followed by flushing with 10 ml of saline. The first CEUS examination was performed 24±4 hours after CT performed in the ED; subsequent studies were carried out on the scheduled day (±1 day). Each CEUS was preceded by a conventional US examination using the same scanner. All scans were performed by one member of a group of four radiologists with more than 10 years of experience in abdominal CT, US and CEUS. Each US, CT and CEUS report described the injury presence, its location and size; an opinion on the need for IR/splenectomy was provided. No patient had an inappropriate echoic window during follow-up and it was possible to perform CEUS examinations in all patients. In four patients it was not possible to fully evaluate the upper pole of the spleen in the first conventional US performed in the ED due to a non-optimal echoic window but this did not affect the evaluation of CEUS performance and its accuracy compared to conventional US in this field. During follow-up, whenever CEUS examination raised the suspicion of a delayed splenic injury complication – a pseudoaneurysm (PSA) or an active bleeding – the splenic injury was considered worthy of IR or surgical intervention; CT was always performed to confirm CEUS findings before treatment.

In order to evaluate CEUS and US performance, imaging evaluation results were considered as positive for suspected delayed splenic injury complication (PSA or active bleeding) or negative for it (no suspected delayed complication showed by CEUS or US).

Active bleeding was suspected when CEUS evidenced an irregular or round spot or fountain-like jet of contrast enhancement in or adjacent to the spleen that persisted in being evident in the late parenchymal phase. PSA was suspected whenever CEUS showed a round or oval area of contrast enhancement with distinct margins in the arterial phase and isochogeneity and isodensity in the delayed phase.

When conventional US showed splenic or perisplenic inhomogeneity with irregular hyperechoic areas not identified in previous US examinations, active bleeding was suspected; whereas, when US showed a regular shaped hypoechoic area within the spleen parenchyma with arterial internal blood flow observed at color Doppler ultrasonography, PSA was suspected.

The absence of IR procedures or surgical treatment performed in the spleen during follow-up was used in or-

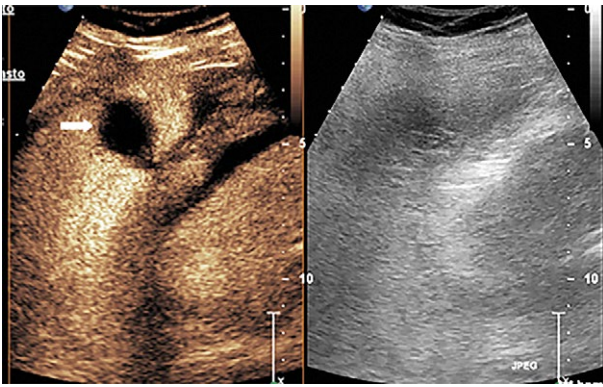


Fig 1. A 57-year-old man with an AAST-SIS grade II spleen injury. Seven days after blunt abdominal trauma CEUS did not show active bleeding or delayed splenic vascular injury (arrow). The patient underwent CEUS follow-up only.

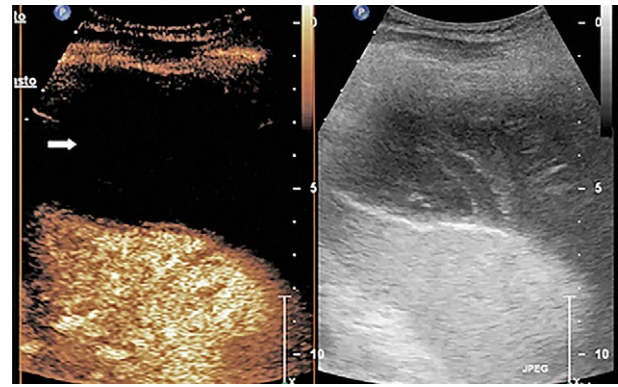


Fig 3. A 48-year-old man with AAST-SIS grade III subcapsular hematoma (arrow). Three days after blunt abdominal trauma CEUS did not show active bleeding or delayed splenic vascular injury. The patient underwent CEUS follow-up only.

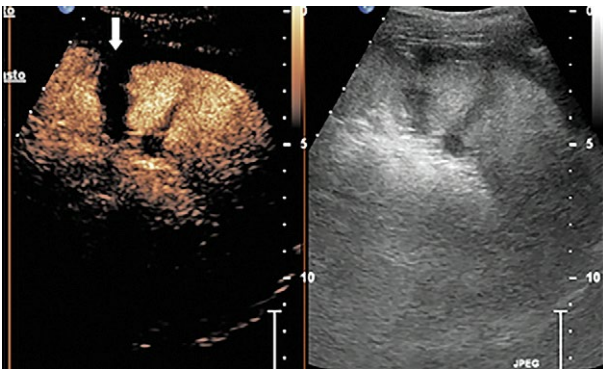


Fig 2. A 19-year-old man with an AAST-SIS grade III spleen injury. Three days after blunt abdominal trauma CEUS did not show delayed splenic complications (arrow). The patient underwent CEUS follow-up only.

der to evaluate CEUS and US performance in predicting patients requiring only observation and monitoring during follow-up. Among the patients that underwent IR or surgical treatment during follow-up, those whose CEUS or US examinations were assessed as positive were considered respectively CEUS or US true-positive cases, whereas those whose examinations were evaluated as repeatedly negative were considered false-negative ones. Among the patients that did not undergo IR or surgical treatment during follow-up, those whose CEUS or US examinations were assessed as persistently negative were considered respectively CEUS or US true-negative cases, whereas those whose examinations were assessed at least once as positive were considered false-positive ones.

Statistical analysis

CEUS and US accuracy were compared using the non-parametric Mann-Whitney U-test. The statistical significance level was set at $p < 0.05$. All statistical analy-

ses were performed using MedCalc Software v. 15.8 (Ostend, BEL).

Results

Patients and lesions characteristics are detailed in Table I and in Table II CEUS and US imaging results are summarized. We exemplified some of these cases in figures 1-5.

Table I. Patients' and lesions' characteristics

Number of patients	112
Mean age, years	45.7
AAST-SIS grade, first CT performed in the ED, patients, %	
I	41 (36.6)
II	35 (31.2)
III	32 (28.6)
IV	4 (3.6)
V	0
AE immediately after the first CT performed in the ED, patients, %	28/112 (25)
NOM success rate, patients, %	109/112 (97.3)
Patient died from splenic injury-related complications, patients, %	0/112 (0)

AAST-SIS, American Association for the Surgery of Trauma - spleen Injury Scale; CT, computed tomography; ED, emergency department; AE, splenic artery angioembolization; NOM, non-operative management.

Table II. The ultrasonography (conventional and contrast-enhanced) results

	CEUS	US
True positive	9	4
True negative	99	96
False positive	4	7
False negative	0	5

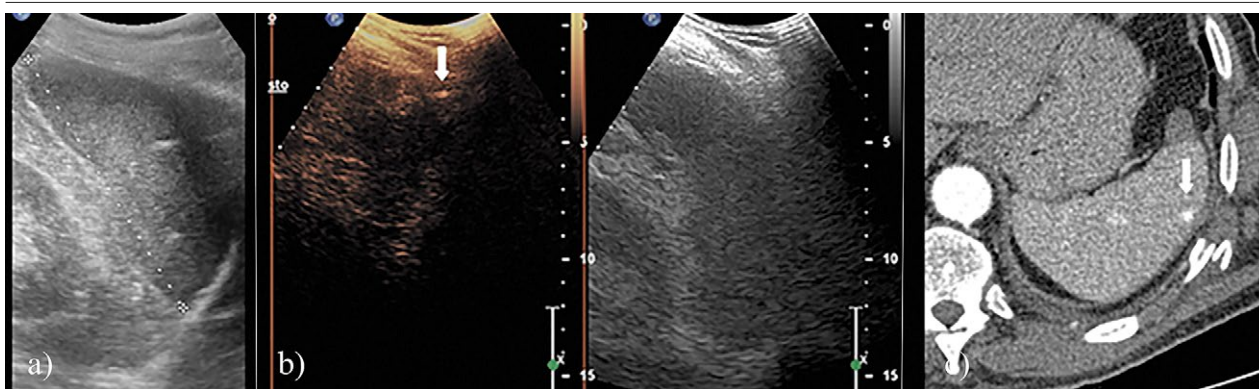


Fig 4. A 35-year-old man with a false negative conventional US (a) three days after trauma. CEUS examination, in the early arterial phase, raised the suspicion of a little pseudoaneurysm (arrow) (b) that was confirmed by subsequent CT scan (c).

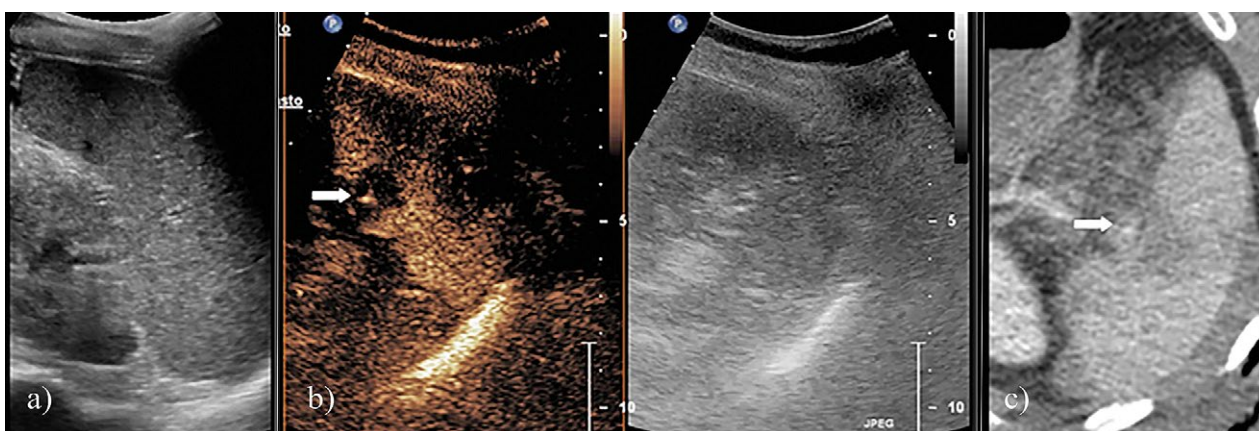


Fig 5. A 82-year-old woman with AAST-SIS grade II splenic injury. Seven days after blunt abdominal trauma conventional US (a) did not evidence the splenic lesions. CEUS showed the splenic injury and a small pseudoaneurysm (arrow) was suspected (b). CT (c) did not confirm the latter and demonstrated that it was a small para-hilar arterial vessel (arrow).

CEUS showed a sensitivity of 100%, specificity of 96.1%, positive predictive value of 69.2%, negative predictive value of 100.0% and accuracy of 96.4%. Conventional US showed a sensitivity of 44.4%, specificity of 93.2%, positive predictive value of 36.4%, negative predictive value of 95.0% and accuracy of 89.3%. CEUS accuracy was significantly higher than the US one ($p=0.013$).

No splenic injury complication was suspected by CEUS in patients with AAST-SIS grade I; 13 out of 13 (100%) CEUS suspected splenic injury complications were identified during the first week after trauma; 25.2% of CEUS and US follow-up examinations were performed in intensive care unit (ICU).

Discussions

CEUS is a useful imaging modality during the follow-up of patients with splenic injuries: it is effective in

predicting blunt spleen injuries requiring only observation and monitoring during follow-up and it is more accurate than conventional US.

The two end-points were successfully achieved and this occurred most likely because serial CEUS examinations permitted the understanding of the modifications over time of each specific splenic injury and correctly assessing when a finding merited IR/surgical treatment or only observation and monitoring was required. Conversely, conventional US could not evaluate these changes as well as CEUS, therefore its performance in this field is lower.

Splenic injury follow-up after trauma in adult patients is currently a matter of debate. To our knowledge, this study is the only one which continued the splenic injuries evaluation for such a long period and with very short time intervals using CEUS in order to predict blunt spleen injuries requiring only observation and monitoring during follow-up. According to recent guidelines and studies, CEUS could be used in order to detect splenic

injuries, particularly in hemodynamically stable patients with isolated blunt low or moderate-energy abdominal trauma [8-11]. Some previous studies showed that CEUS can detect active bleeding [12,13] and that performing one or two CEUS during follow-up is useful [14,15]. In another study serial CEUS follow-up examinations in a few patients with mild liver and spleen trauma were performed and CEUS was considered to be particularly suited to the follow-up of this kind of lesion [16]. As in some other previous studies, we reported a very low NOM failure rate [14,15,17] and this could be related to the high rate of blunt abdominal trauma with splenic injury that underwent splenic angioembolization after the CT performed in the ED in our cohort. In fact, a previous study demonstrated that high splenic angioembolization rates could reduce NOM failure [18].

Previous studies reported the usefulness of repeating the CT scan for follow-up in patients with a splenic injury: on the third day after admission in patients with AAST-SIS grade III and IV injuries, with the aim of showing a possible PSA development [15]; 48 hours after admission in patients with grade \geq II in order to diagnose delayed splenic vascular injuries after nonoperative management [19]; or 48 hours to rule out a possible PSA development in patients with splenic injuries grade \geq III managed non-operatively without angioembolization [20].

This study demonstrates that CEUS is a valuable imaging modality that can be used during splenic injury follow-up. We agree that CT is the best initial imaging modality in adult patients with blunt abdominal trauma in order to diagnose all possible abdominal complications and offer guidelines for the best treatment or suggest when a follow-up is necessary. However, CEUS could replace CT as a follow-up imaging modality. In fact, all the patients without abnormal CEUS findings who underwent only observation and monitoring did not show clinical complications that prompted performing an IR/surgical treatment during follow-up. Therefore, we strongly advise the use of CEUS as a follow-up radiation free imaging modality of splenic injury. In fact, CEUS can be repeated at short time intervals without radiation exposure and this is especially important taking into account that spleen injury often occurs in young and middle-aged adults. CEUS allows a quick, safe and relatively cheap serial splenic evaluation and could be also performed in critically-ill patients, such as those in intensive care units (ICU), because CEUS can be performed at the patient's bedside. We also agree with the possibility to avoid follow-up in patients with grade I splenic injury, but we think that repeated imaging evaluations at short time intervals during follow-up could be worth doing in patients with grade II or higher injury.

The authors think that serial CEUS examinations could be performed at least in the first seven-fifteen days after trauma in patients with AAST-SIS grade \geq II in order to predict non-operatively managed blunt spleen injuries requiring only observation and monitoring during follow-up.

This study has some limitations. First of all, it is a single-institution analysis. Moreover, the patient cohort consisted of a relatively small number of patients, particularly of those with high grade splenic injuries. Therefore, we cannot know if the study results could have been different in a series of cases with more severe lesions which have an intrinsic higher risk of complication.

Conclusions

CEUS is an effective imaging modality in order to predict which lesions require only observation and monitoring during follow-up of patients with blunt splenic injuries and it is more accurate than conventional US. Therefore, the authors believe that CEUS could represent the reference follow-up imaging modality in these patients.

Conflict of interest: None

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