Review

The technique and advantages of contrast-enhanced ultrasound in the diagnosis and follow-up of traumatic abdomen solid organ injuries.

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Abstract: Trauma is one of the most common causes of death or permanent disability in young people, so a timely diagnostic approach is crucial. In polytrauma patients, CEUS 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 sensitivity and specificity similar to those seen with MDCT. CEUS is recommended for the diagnostic evaluation of hemodynamically stable patients with isolated blunt moderate-energy abdominal traumas and for the diagnostic follow-up of conservatively managed abdominal traumas. In this pictorial review we illustrate the advantages and disadvantages of CEUS and the procedure details with tips and tricks during investigation of blunt moderate-energy abdominal trauma as well as during follow-up in non-operative management.

Keywords: CEUS; blunt trauma; non operative management; follow-up.

1. Introduction

Trauma is one of the most common causes of death or permanent disability in young people, so a timely diagnostic approach is crucial. Multidetector computed tomography (MDCT) with intravenous iodinated contrast is excellent at detecting and characterizing life-threatening injuries. Its use is crucial in the initial assessment of polytraumatized patients to determine whether a surgical, interventional, or non-operative treatment approach is best [1]. Given the need to reduce exposure to ionizing radiation and consider the risk of contrast-induced nephropathy associated with multiple administrations of iodinated contrast medium or single administrations in patients with renal insufficiency, the appropriate selection of trauma patients for MDCT is becoming more critical [2]. Furthermore, in recent years a more conservative approach for traumatic injuries of parenchymatous organs has been encouraged; at present, non-operative management is considered the standard treatment [3,4]. Consequently, this has led to an increased number of imaging studies to monitor the healing of lesions [5,6]. Due to the invasiveness associated with the use of intravenous contrast medium and ionizing radiation, MDCT is not the preferred follow-up imaging method for hemodynamically stable patients or isolated, blunt, moderate-energy abdominal trauma. Instead, at present, there is a trend toward the use of contrast-enhanced ultrasound (CEUS) [5]. In polytrauma patients, CEUS has been shown to be more sensitive than ultrasound (US) in the detection of solid organ injuries. CEUS is able to identify and grade traumatic abdominal lesions with sensitivity and specificity levels similar to those seen in MDCT, which reach up to 95% [7]. CEUS is a radiation-free technique with good diagnostic accuracy for identifying parenchymal lesions and vascular injuries [8,9]. According to EFSUMB (European Federation of Societies for

Ultrasound in Medicine and Biology) guidelines, CEUS can be used as an alternative to computer tomography (CT) scans for hemodynamically stable patients with isolated, blunt, moderate-energy abdominal traumas to evaluate solid organ injury, particularly for children and for follow-ups of conservatively managed abdominal trauma to reduce the number of CT examinations [10].

2. Findings and procedure details

2.1. Instrumentation

2.1.1. Ultrasound system with contrast imaging package software.

The US transducer should operate at a low mechanical index (MI), generally below 0.3. Additionally, it should be able to analyze the resonance signals originated by the contrast agent while avoiding the destruction of the bubble and reducing tissue harmonics and artifacts [10,11].

2.1.2. Ultrasound contrast agent.

SonoVue(TM) (Bracco, Milan, Italy) is the ultrasound contrast agent (UCA) currently used in Europe. It is a pure intravascular agent consisting of micro-bubbles (1-7 micron) that contain sulphur hexafluoride encapsulated by a phospholipid shell. Micro-bubbles are too large to pass through the vascular endothelium and stay intact for up to 7 minutes in the blood vessels. After they dissolve, the gas is exhaled through the lungs, and the phospholipid shell is metabolized, primarily in the liver. There is no need for blood tests prior to UCA injection as the agent is not excreted by the kidneys, rather through the lungs during breathing. Therefore, renal insufficiency is not a contraindication for UCA injection as there is no risk of contrast-related nephropathy or nephrogenic systemic fibrosis associated with their use [2,12]. Furthermore, there is no evidence of any effect on thyroid function as UCAs do not contain iodine. UCAs are generally well tolerated; the rate of adverse reactions is very low (1:7000 patients, 0.014%). This rate is significantly lower than the rate associated with iodinated state-of-the-art CT agents (35–95:100 000 patients, 0.035–0.095 %) [10,13]. The main contraindications for UCAs are a history of allergic reactions to the contrast agent, severe pulmonary hypertension, severe coronary artery disease, pulmonary hypertension, and unstable ischemic heart disease. The use of UCAs is not authorized for pregnant or breastfeeding women [10,13]. The use of UCAs is yet to be off-label for children; however, there is a large consensus on their safety [10,14]

2.1.3. Needle with a diameter of at least 32 gauge.

It is important to avoid the rupture of micro-bubbles under injection pressure [10,15].

2.2. Procedure details

Examination starts with a non-enhanced US. All parenchymatous organs and the peritoneal cavity are investigated to determine the presence of parenchymatous injuries that would need to be deeply studied following injection of the UCA. As there is limited time to scan each organ following the injection due to the timing of each vascular phase, it is important to find areas requiring further investigation before the injection is administered (Figure 1) [15].

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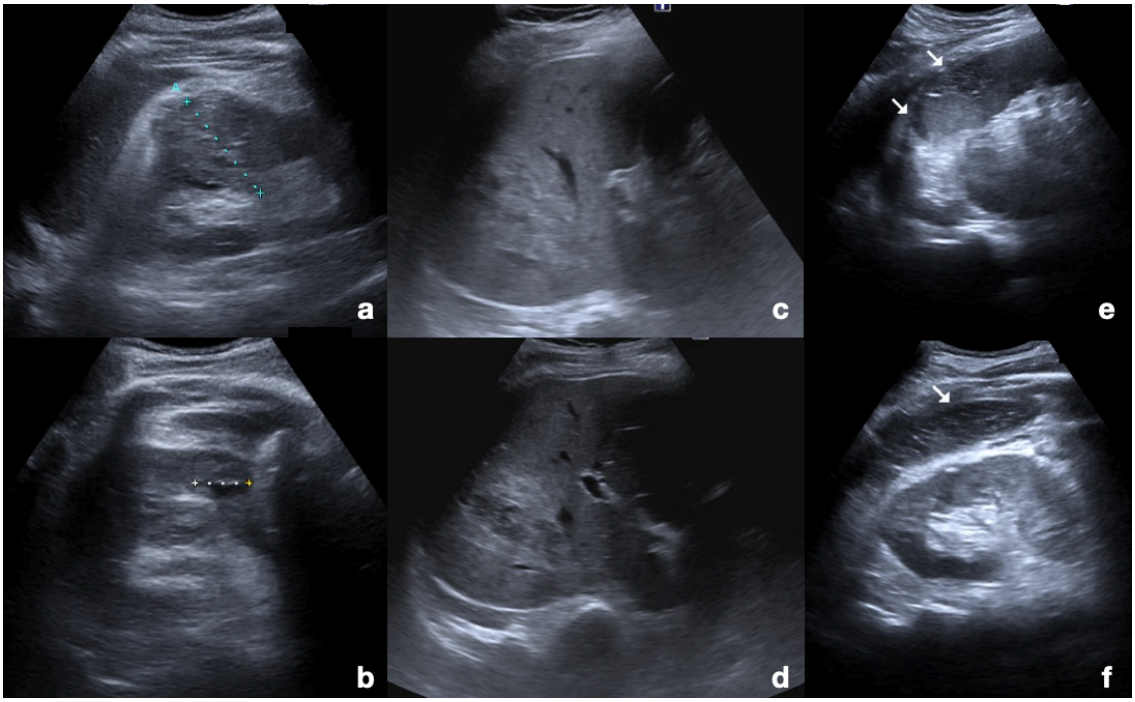

Figure 1. Non-enhanced US of parenchymal injuries. **(a)** Longitudinal view of the right kidney adequate to appreciate the renal parenchymal hematoma in its whole extension; **(b)** axial view of the same kidney showing another smaller hematoma. **(c,d)** Axial views of the liver showing a wide lacero-contusive area in the right lobe (arrows). **(e,f)** Multiple lacero-contusive areas of the spleen (arrows).

The administration of the UCA should be preceded by a preliminary study with a color-and power Doppler US (CD-US) of the injured parenchyma to identify any contained vascular lesions. This increases the diagnostic confidence in differentiating these lesions through their characteristic spectral pulsed-wave Doppler (Figure 2).

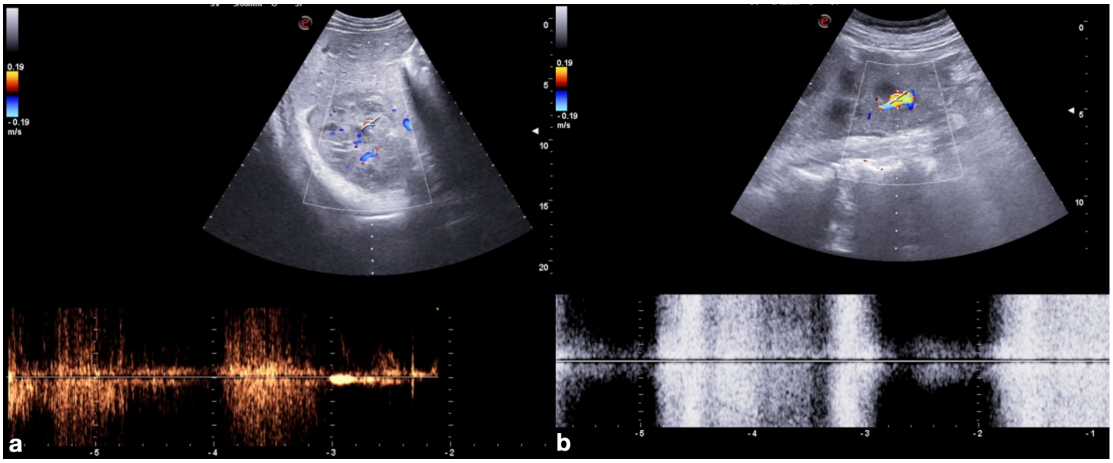

Figure 2. Role for color and spectral Doppler in the detection of post-traumatic vascular complications. Color (upper row) and spectral (bottom row) Doppler of right kidney shows post-traumatic pseudo-aneurysm in a 20 years-old man admitted at emergency department for hematuria after two weeks from car accident and previous CT diagnosis of traumatic right kidney contusion; **(a)** color Doppler shows turbulent flow in the false aneurysm, whereas spectral Doppler shows a "to and fro" spectrum. Color (upper row) and spectral (bottom row) Doppler of left kidney

post-traumatic arteriovenous fistula in a 45 years-old woman admitted at emergency department for penetrating injury; **(b)** color Doppler shows aliasing artifact due to the presence of a focus of increased blood flow, then confirmed at pulsed Doppler that showed high-velocity peak without a clear diastolic flow.

Indeed, after UCA administration these lesions could become indeterminate at CD-US evaluation due to the relative turbulence generated by the micro-bubbles; furthermore the relative destruction of the micro-bubbles due to high MI during the Doppler study may render the contrast study ineffective too (Figure 3).

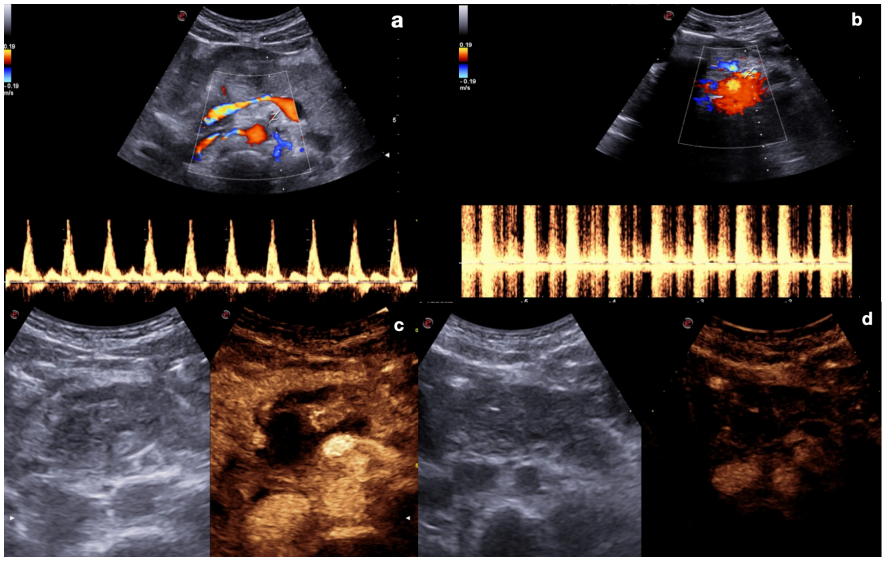

Figure 3. Artefacts in colour and spectral Doppler after CEUS (a-b), and in repeated CEUS after Doppler (c-d). Mesenteric artery colour and spectral Doppler before **(a)** and after **(b)** UCA administration showed alteration in the colour map (upper row) as well as in the wave form (bottom row) evaluation due to the relative turbulence generated by the micro-bubbles within the vessel. Upper abdomen CEUS in pancreatic trauma before **(c)** and after **(d)** Doppler study shows a relative destruction of the micro-bubbles due to high MI during the Doppler study, making the post-Doppler contrast study unable to properly visualize organs and tissues.

CEUS examination is performed after intravenous administration of a 2 mL bolus of UCA (90 μg of sulphur hexafluoride), followed by approximately 10 mL of saline solution administered through an antecubital vein.

The US software can host a split-screen to enable the baseline greyscale B-mode image to be used as reference images while the tissue enhancement is evaluated through the low MI CEUS [10]. Similar to MDCT, CEUS enables the evaluation of all contrastographic phases, in particular, the early arterial phase. CEUS is also capable of continuously scanning the region of interest during each contrast phase. The arterial phase starts 10–20 seconds and continues for up to 30–40 seconds following contrast injection. The advantage of scanning organs in the early arterial phase is obtaining the optimal depiction of contained vascular injuries, such as pseudoaneurysms and arteriovenous fistulas, that may appear days after the trauma occurred. Such injuries may be responsible for late organ rupture or, in later stages, the alteration of the systemic circulation.

During the venous and late phases, which occur 2–6 minutes following injection, the contrast agent is distributed to the entire capillary bed.

Flash mode, a technique specific to CEUS-capable US devices, emits a short US pulse with very high MI to destroy accumulated micro-bubbles within an area of interest. This enables the re-evaluation of dynamic post-contrast perfusion as long as the concentration of the UCA slowly decreases prior to its excretion through the lungs (Table 1) [10].

Table 1. US scanning time after UCAs administration and flash mode technique.

Time and Flash technique	Advantages
< 0 sec	Choose the best scan view in B-Mode and US Doppler studies (color, power and pulse Doppler).
0 sec	Injection of 2mL of UCA followed by 10mL of saline solution.
10-20 sec (early) 20-40 sec (late)	Arterial phase: best depiction of contained vascular injuries, such as pseudoaneurysms and arteriovenous fistulas in the early phase.
2-6 minutes	Venous-late phases: distribution of the contrast in the whole organ. Best time to depict parenchymal injuries.
Flash mode	Destruction of bubbles and possibility to re-evaluate an area of interest.

The timing of parenchymal enhancement after intravenous administration of the UCA is dependent on the vascular anatomical and physiological differences in each organ as well as the hemodynamic status of the patient. For example, this timing in elderly patients may be influenced by their cardiac function [15].

Kidneys show the most rapid parenchymal enhancement, followed by the liver, pancreas, and adrenal glands, which show intermediate enhancement patterns. The spleen has a later and more persistent enhancement compared to the kidneys. The timing of these enhancements is important if multiple organs require imaging during the same examination (Table 2).

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Table 2. Enhancement characteristic for organ with the best opacification times

Main organs to explore	Enhancement characteristic
Kidney	Quick enhancement of the cortex after injection. Pyramids enhancement after 30 seconds. No excretory phase. Good evaluation up to 2,5 minutes.
Liver	Arterial phase: 10–40 seconds Hepatic and portal phases: 40–120 seconds Sinusoidal phase: 120–300 seconds Dual vascular supply permits homogeneous enhancement.
Pancreas	Arterial phase: 15-30 seconds Venous phase: 30-120 seconds Best moment to detect organ injury: venous phase.
Adrenal glands	Arterial phase: 20-40 seconds Homogeneous enhancement up to 5 minutes.
Spleen	Arterial phase: 12-20 seconds. Venous phase: 40-60 seconds up to 5-7 minutes. Best moment to detect organ injury: venous phase.

Kidney: the cortex enhances very quickly and intensely after the injection, while the pyramids enhance from the periphery to the center in approximately 30 seconds [10,11]. The optimal time window for renal parenchymal injury assessment is up to 2.5 minutes following injection, as this is when maximum enhancement of the kidney can be observed [12,15] (Figure 4).

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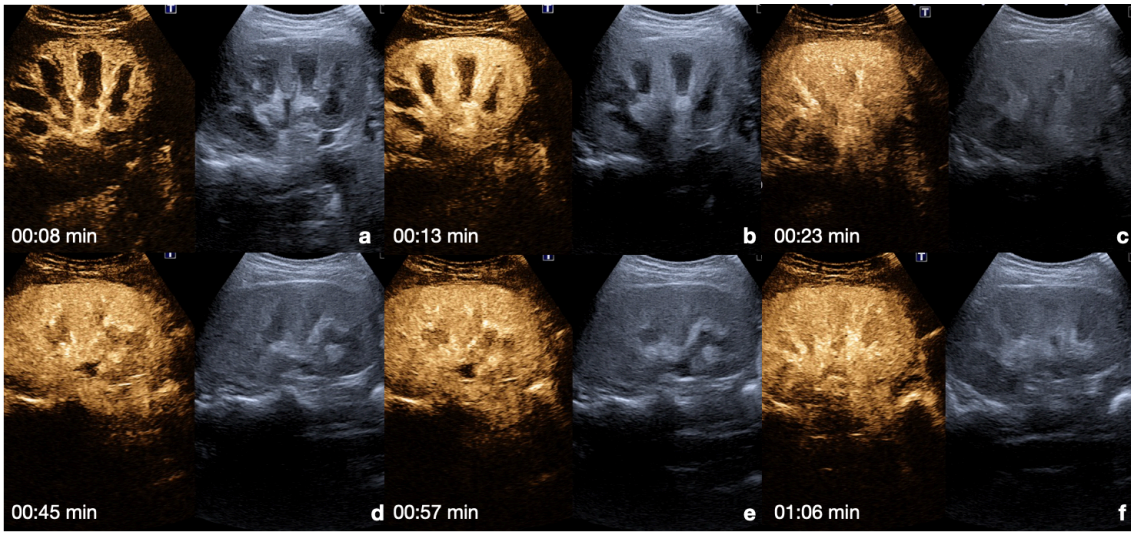

Figure 4. CEUS findings in a normal kidney; **(a, b, c, d, e, f)** Note the progressive physiological enhancement of the cortex and the medulla. *Figure 4 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

UCA does not accumulate in the pelvicalyceal system; therefore, no excretory phase will occur. Liver: the arterial phase starts between 10–40 seconds after the injection. The hepatic and portal phases start between 40–120 seconds after the injection, while the sinusoidal phase begins between 120–300 seconds after. Due to the dual vascular supply in the liver, a homogeneous parenchymal enhancement is shown that is adequate for the detection of organ injury (Figure 5) [10,11,15].

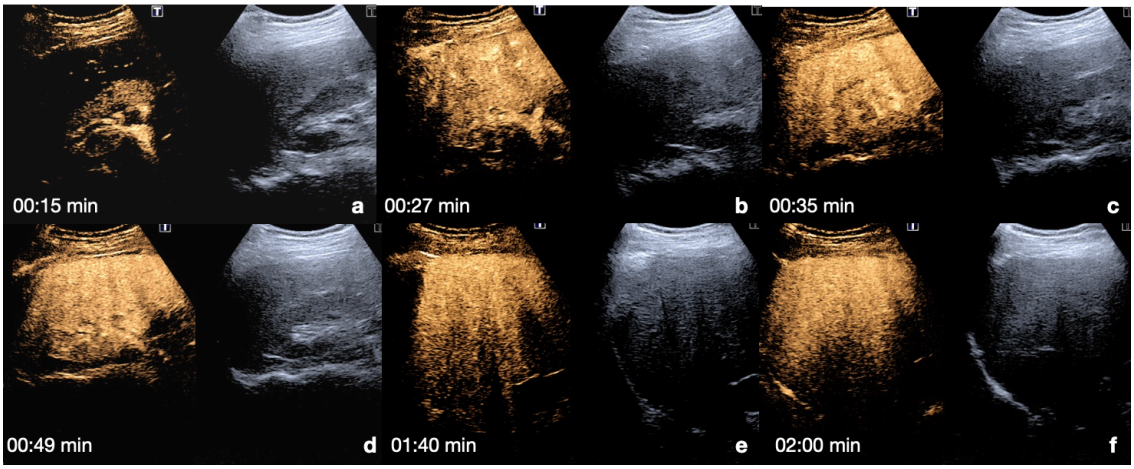

Figure 5. CEUS findings in a normal liver; **(a, b, c, d, e, f)** Note the progressive physiological enhancement of the liver in the different phases. *Figure 5 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

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Pancreas: the perfusion of the pancreas occurs early and intensely, with progressive wash-out. The arterial phase occurs 15–30 seconds following injection. This phase is recognizable by direct visualization of the aorta, celiac tripod, and superior mesenteric artery, which immediately precede the enhancement of the parenchymal gland. The venous phase occurs 30–120 seconds after injection and is associated with the visualization of the spleno-portal axis. This phase corresponds to the homogeneous enhancement of the parenchyma gland, which is adequate for the detection of organ injury [10,11,15,16] (Figure 6).

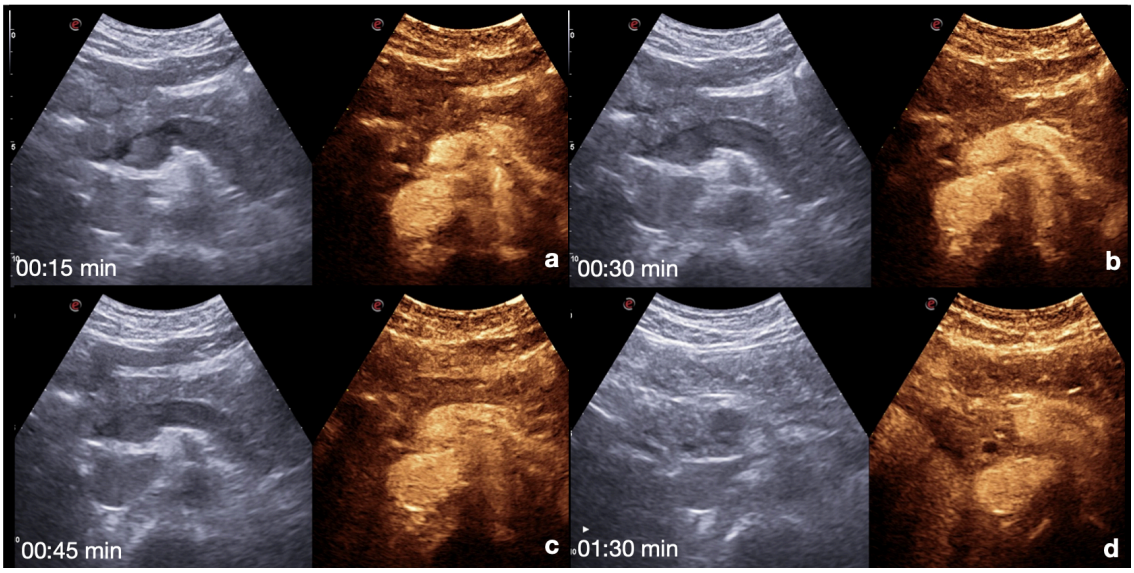

Figure 6. CEUS findings in a normal pancreas; **(a, b, c, d)** Note the enhancement of the pancreas in the late arterial phase.

Adrenal: the arterial phase starts 20–40 seconds after the injection, followed by a venous phase where a progressive enhancement of the parenchyma gland is observed for up to 5 minutes. This enhancement is adequate organ injury detection [10,11,15].

Spleen: the arterial phase starts 12–20 seconds after the injection. This phase shows irregular enhancement, similar to what is seen during MDCT, which makes it difficult to define any parenchymal injury. The venous phase starts 40–60 seconds after the injection. This phase provides adequate organ injury detection as the healthy parenchyma appears with homogeneous enhancement for 5–7 minutes (Figure 7) [10,11,15].

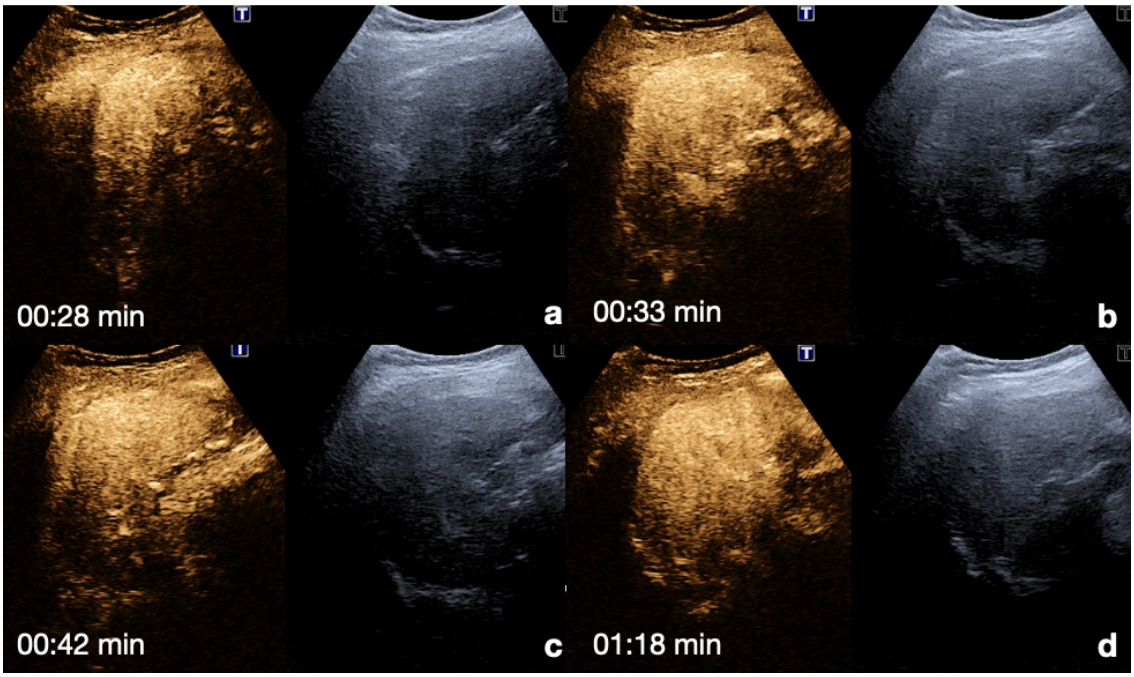

Figure 7. CEUS findings in a normal spleen; **(a, b, c, d)** Note the progressive physiological enhancement after contrast medium injection. *Figure 7 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

2.2.1. Haemodynamically stable patients with isolated blunt moderate-energy abdominal trauma.

The examination should begin with the kidneys during the arterial phase as their enhancement occurs quickly and is fleeting [10]. Following kidney examination, the adrenal glands, liver, pancreas and spleen should be evaluated during the venous phase of each, as the possible area of parenchymal laceration is better highlighted in this phase. The CEUS examination typically utilizes two split doses of intravenous UCA, one for each side of the body. More specifically, one dose is used to evaluate the right kidney, right adrenal gland, liver, and pancreas, while the second dose is used to evaluate the left kidney, left adrenal gland, and spleen [10]. Once exploration of all abdominal parenchyma and identification of areas containing parenchymal injuries is complete, injured areas should be re-evaluated under flash mode with the same dose of UCA. This is so the entire dynamic contrastographic study of the injured area can be observed, and any vascular lesions can be excluded. Any plurifocal or multi-organ parenchymal injuries, active bleeding, or contained vascular injuries still require diagnostic investigation with MDCT examination using intravenous iodinate contrast medium to understand the best therapeutic strategy to treat such injuries with greater study overview (Figure 8).

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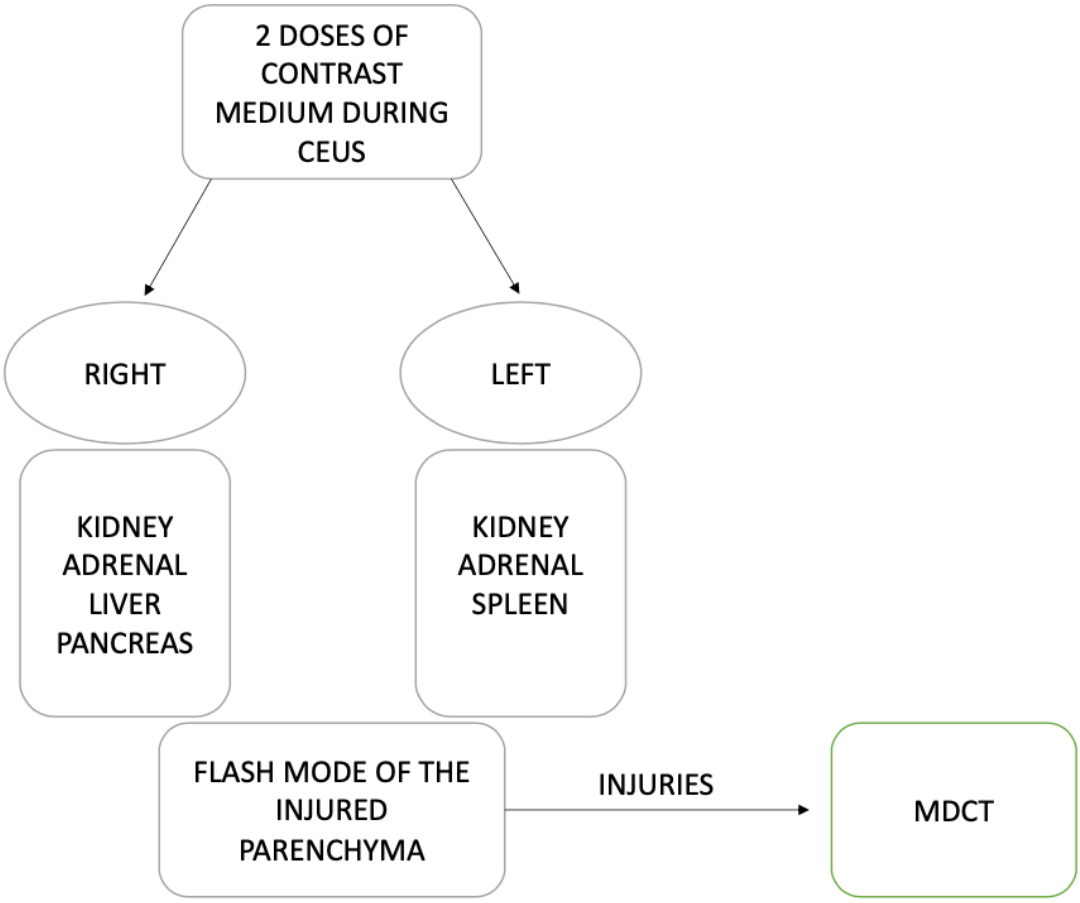

Figure 8. Low-grade trauma evaluated with CEUS.

2.2.1. Follow-up of conservatively managed abdominal trauma.

In follow-up CEUS examinations, the known injured organ is targeted, and all contrastographic phases are evaluated to exclude any contained vascular lesions in the arterial phase. Any regression of the parenchymal injured area is monitored during the venous and late phases [10]. In the event of any worsening changes in the post-traumatic findings, the use of MDCT with intravenous iodinated contrast medium administration is mandatory for the same reasons as above (Figure 9).

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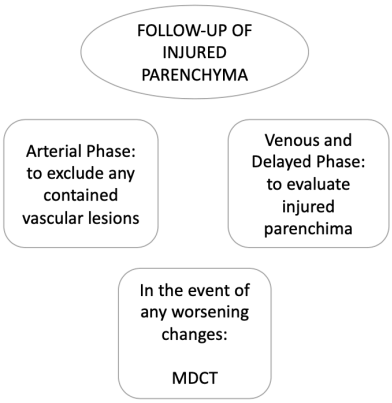

Figure 9. CEUS follow-up

2.3. Findings

Imaging findings depend on the contrast media distribution. In normal parenchyma, the distribution is homogeneous with a clear depiction of the vascular structures. CEUS may accurately define organ injuries, capsular extensions, and vascular injuries with accuracy similar to MDCT [9,10,15,17].

2.3.1. Solid organ injuries may involve the parenchyma and/or the vessel.

- Parenchymal injuries:

Intraparenchymal haematoma: the haematoma appears as a focal non-enhancing elliptic collection in the parenchyma with poorly defined irregular margins and no internal enhancing vessels. It does not involve interruption of the organ capsule and is particularly evident during the venous phase of study (Figures 10, 11) [10,15].

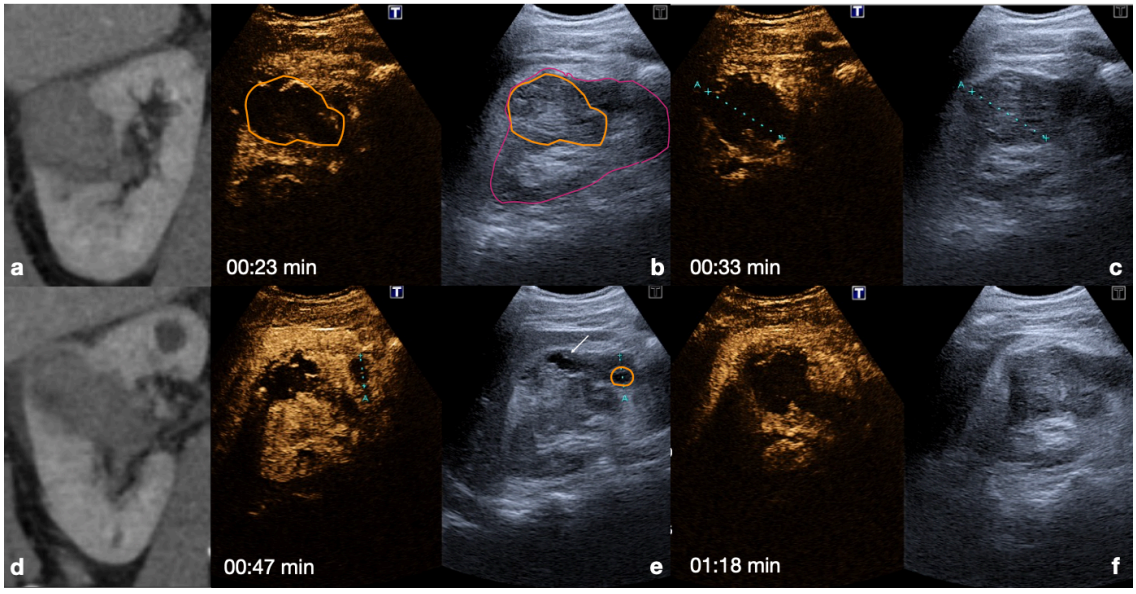

Figure 10. CT **(a, d)** and follow-up CEUS **(b, c, e, f)** of the right kidney in a 57-year-old patient fall from height. Follow-up CEUS was performed 4 days after the admission CT. Note at CEUS the

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progressive enhancement, at different time points, of the renal cortex in about 30 seconds **(b, c)** and of the medulla, up to 2.5 minutes **(e, f).** The parenchymal hematomas appear as non-enhancing collections **(b,e orange lines)** contained in the organ capsule **(b, pink lines),** without internal enhancing vessel neither associated vascular injuries. Due to the physiological evolution of the hematoma, at the follow-up it shows small fluid anechoic areas related with the progressive resorption **(e, arrow)**. *Figure 10 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

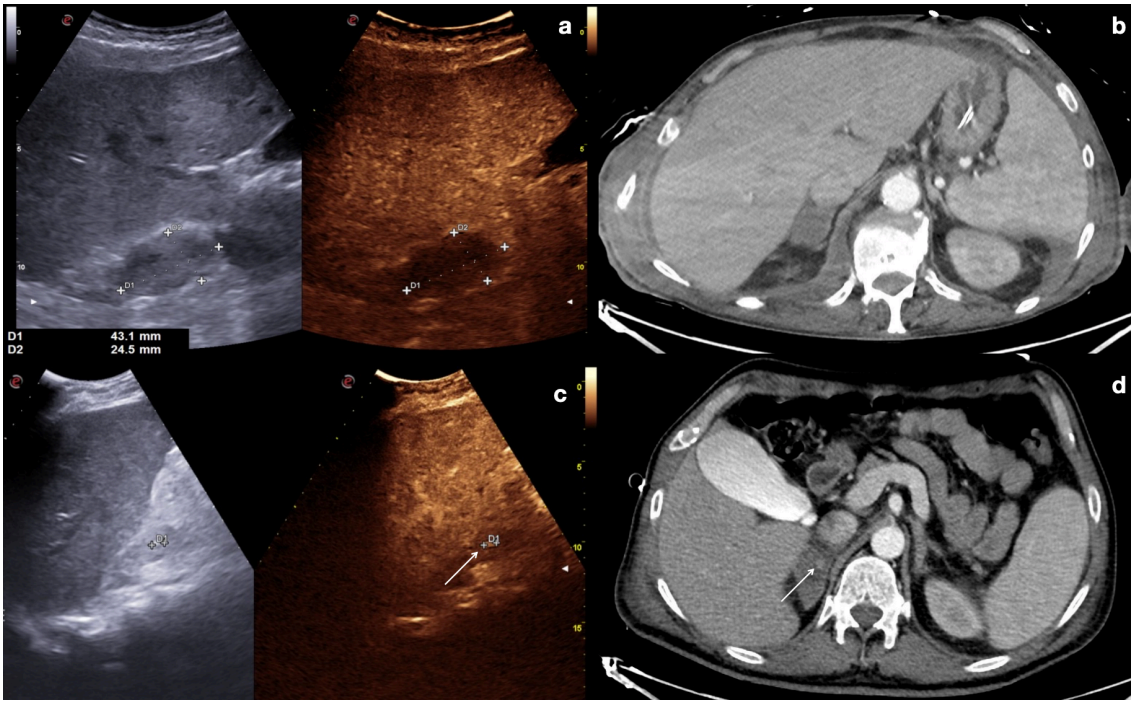

Figure 11. This Adrenal gland hematomas. CEUS **(a)** and contrast-enhanced CT **(b)** of a 44 years-old male patient after motor vehicle accident, showing right adrenal gland hematoma with no vascular complication. CEUS **(c)** and contrast-enhanced CT **(d)** follow up of a 36 years-old male patient at day 3 after car accident; a pseudo-aneurysm within the right adrenal gland hematoma is visible (white arrows).

Lacerations: these are identifiable as irregular linear or branched non-enhancing bands, frequently perpendicular to the organ capsule, and can be associated with capsular discontinuity. Lacerations can be classified as superficial (≤ 3 cm in depth) or deep (> 3 cm in depth) (Figures 12,13, 14, 15) [10].

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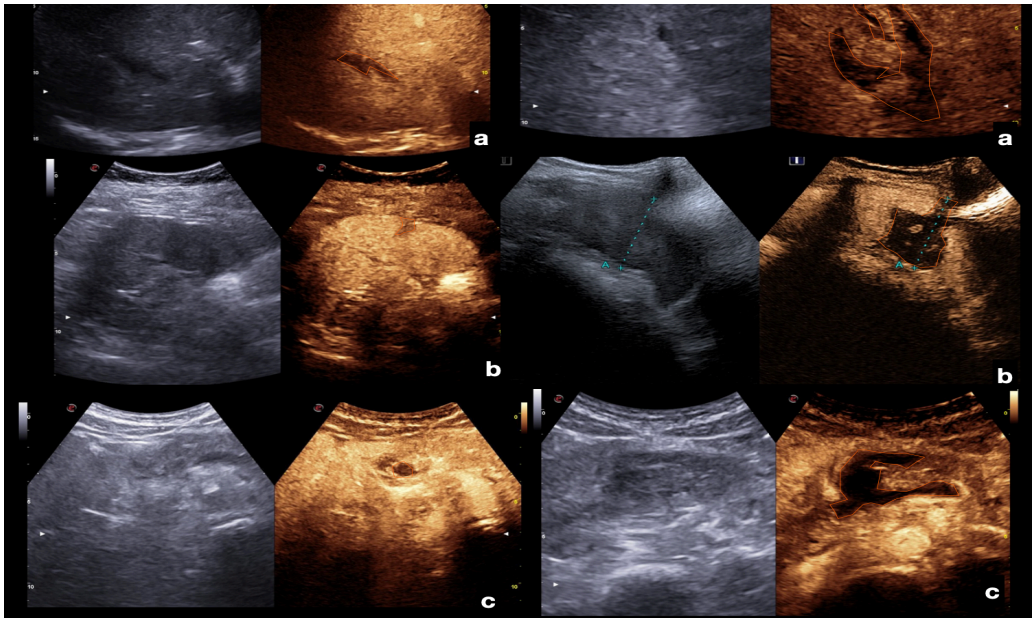

Figure 12. Example of CEUS imaging of low grade (first column) and high grade (second column) injuries in liver **(a)** and spleen **(b)** after moderate energy blunt trauma. Parenchymal lacerations/haematomas are indicated by orange lines.

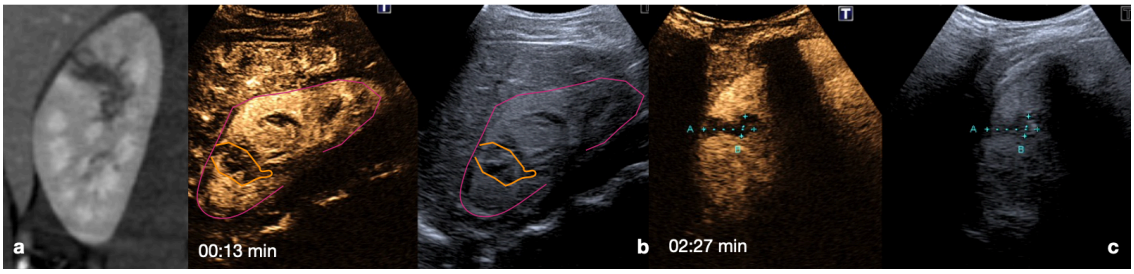

Figure 13. CT **(a)** and follow-up CEUS **(b,c)** of the right kidney in a 16-year-old patient with blunt trauma. At the admission CT is detected a kidney laceration reaching the organ capsule **(a, arrow).** CEUS was performed 10 days after trauma **(b,c),** showing a minimal healing of the laceration without the presence of vascular injuries. *Figure 13 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

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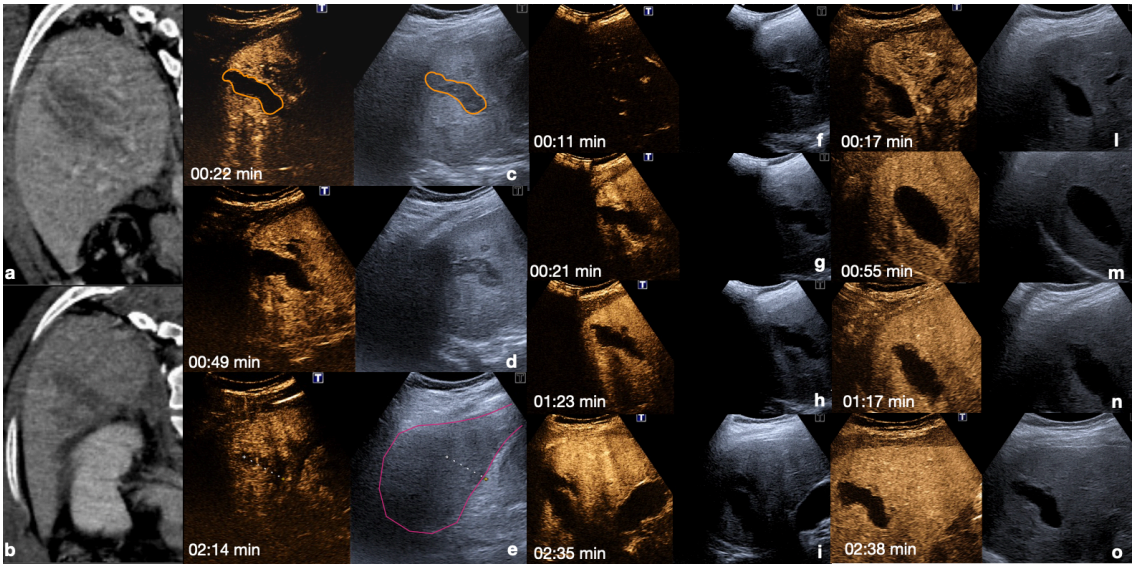

Figure 14. Admission CT **(a,b)** and follow-up CEUS **(c-o)** of a 35-year-old blunt trauma patient with multiple hepatic lacerations. Follow-up CEUS was performed 3 days **(c,d,e),** 11 days **(f,g,h,i),** and 20 days **(l,m,n,o)** after the admission CT. Note at CEUS the progressive enhancement of the liver parenchyma in the different phases. The parenchymal lacerations appear as non-enhancing bands (c, **orange line),** some of them reaching the liver capsule (pink line) **(e, i).** In the follow-up it is important to look for possible vascular injuries (absent in this case) in the early arterial phase **(f,l).** Parenchymal lacerations appear progressively better demarcated, and more hypoechoic. *Figure 14 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

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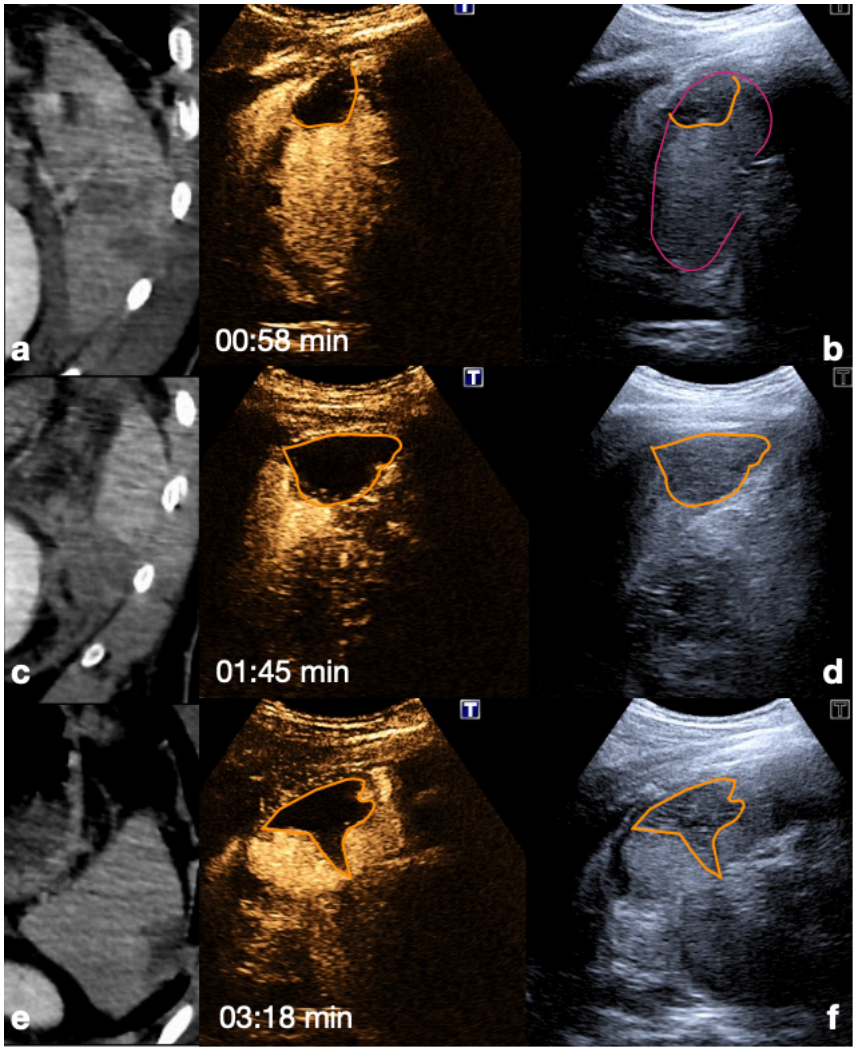

Figure 15. Admission CT **(a,c,e)** and follow-up CEUS **(b,d,f)** of the spleen in a 35-year-old patient fall from height. Follow-up CEUS was performed 7 days after the CT. Note at CEUS the progressive enhancement, at different time points, of the healthy spleen parenchyma in venous phase, clear demarcated from the subcapsular hematomas (b, orange line), from the contusion of the inferior-pole **(d, orange line)** and from a sub-capsular laceration **(f, orange line)** *Figure 15 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

2.3.2. Vascular injuries

- Active bleeding:

Active bleeding can be observed as micro-bubble extravasation outside blood vessels within the peritoneal or retroperitoneal space (Figure 16) [1,15].

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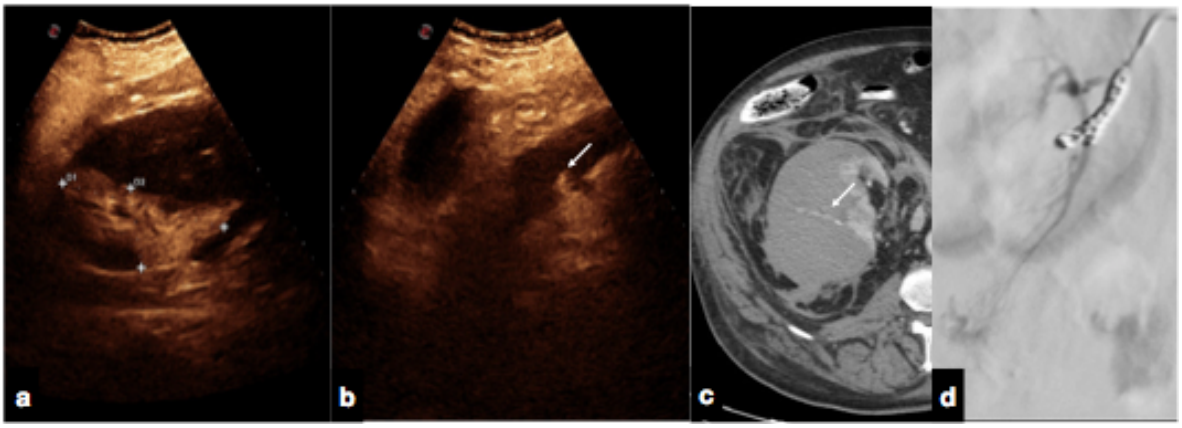

Figure 16. Follow-up CEUS of a 52-year-old blunt trauma patient with high grade right kidney injury and extensive ischemia complication. Venous **(a)** phase CEUS examination shows multiple kidney laceration with extensive ischemia complication and a small amount of perfused renal (caliper). At the same venous phase **(b)** CEUS active venous hemorrhage is well appreciated (arrow) confirmed at contrast-enhanced venous phase CT scan (**c,** arrow) and subsequent at angiography too **(d).**

- Contained vascular injuries:

Contained vascular injuries include pseudoaneurysms and arteriovenous fistulas. Pseudoaneurysms are focal outpouchings of the external vessel contour due to the partial disruption of the wall, which is contained by the tissue around the vessel (Figure 17, 18, 19) [1,15].

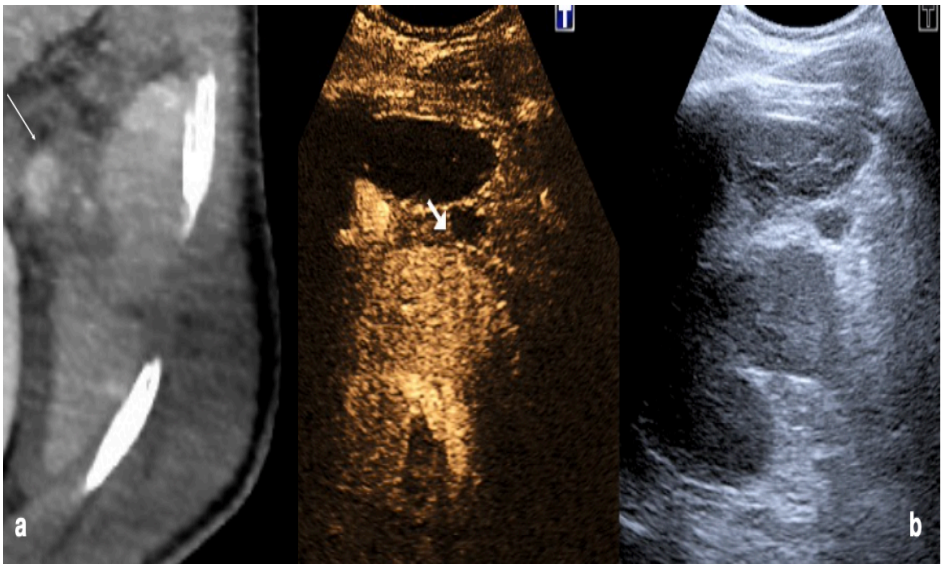

Figure 17. Admission CT **(a)** and follow-up CEUS **(b)** of the spleen of the same patient of Figure 14. At the admission CT in arterial phase, was noticed a small hilar pseudoaneurysm (a, arrow). CEUS was performed after the embolization, showing the lack of vascular enhancement in the site of the pseudoaneurysm (b, arrow). *Figure 16 is reprinted with permission from Iacobellis F, Acampora C, Ponticiello C, Stavolo C, Scuderi MG, Cinque T, Pinto A, Gagliardi N, Romano L. Technique and advantages of contrast-enhanced ultrasound versus MDCT in the follow-up of solid organ injuries. Electronic Presentation Online System (EPOSTM) Educational Exhibit ECR 2018 Iacobellis et Al. doi: 10.1594/ecr2018/C-2010.*

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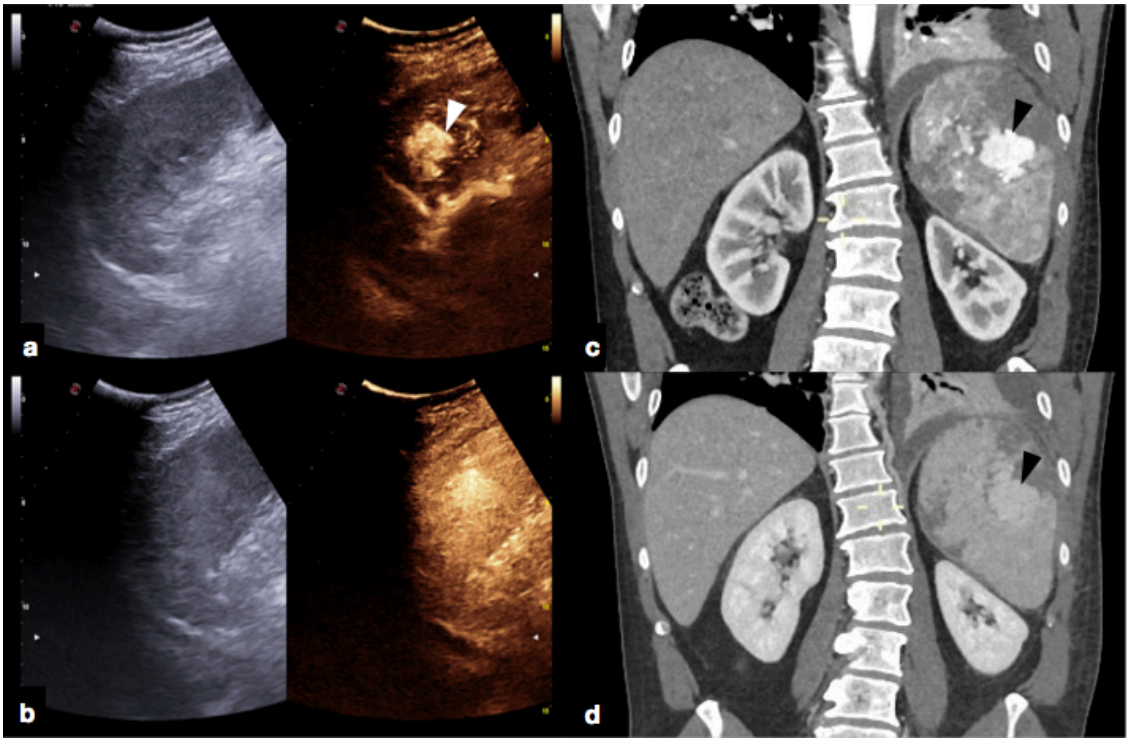

Figure 18. High grade traumatic splenic injury with vascular complication. Arterial **(a)** and venous **(b)** phase CEUS examination in a 25 years-old patient admitted at emergency department for blunt abdominal trauma, showing multiple splenic lacerations and a voluminous arteriovenous fistula (white arrowhead). Subsequent arterial **(c)** and portal vein **(d)** phase contrast-enhanced CT scan further confirmed the diagnosis (black arrowhead).

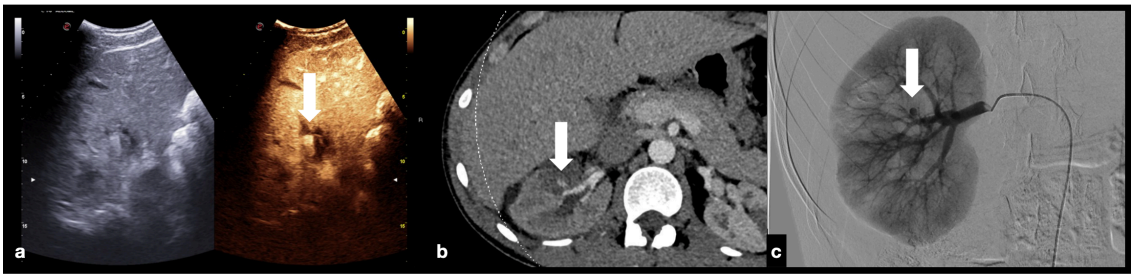

Figure 19. CEUS **(a)** of 23 years-old man referring to emergency department for direct blunt trauma to the right flank showed the presence of a small pseudoaneurysm (white arrow) inside contusion area of the right kidney; the diagnosis was then confirmed at axial arterial phase contrast-enhanced CT scan **(b),** as well as at angiography performed for treatment purposes **(c,d).**

Arteriovenous fistulas consist of traumatic communication between the arterial and venous systems [1,15]. Fistulas are characterized as asymmetrical, early contrast opacification of a vein during the early arterial phase of study (Figure 19).

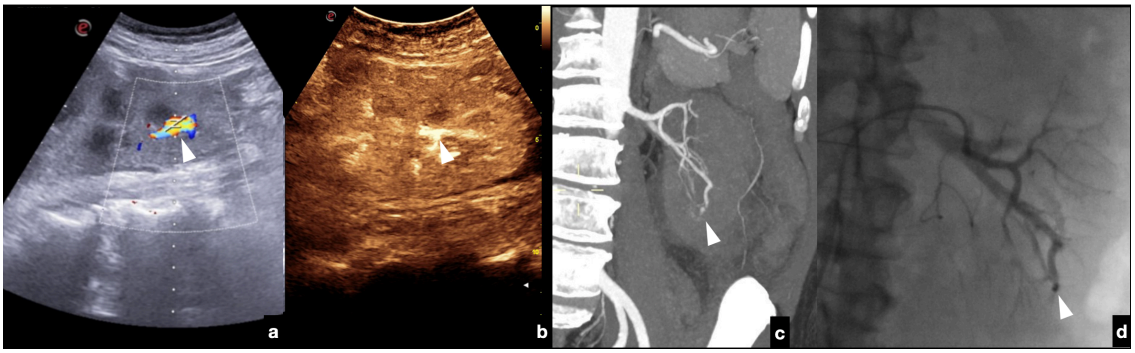

Figure 20. Companion case of Figure 2. Renal A-V fistula (white arrowhead) at color –Doppler US **(a)** and CEUS **(b),** confirmed **(c)** at contrast-enhanced CT scan (arterial phase, coronal MIP reconstruction) and subsequent angiography **(d).**

3. Advantages and disadvantages

MDCT with intravenous iodinated contrast medium is the primary imaging method used for total body evaluation in patients with high energy blunt trauma. MDCT can provide precise delineation of a parenchymal laceration or contusion, indicating the presence of devascularised segments and vascular lesions [18]. However, the use of ionizing radiation and intravenous iodinate contrast medium are limiting factors, particularly for injuries with a moderate risk mechanism and for follow-ups of conservatively managed abdominal traumas. For the latter, recourse to CEUS is strongly recommended as CEUS can achieve 99% sensitivity and specificity, which avoids overutilization of CT [10].

CEUS is fast, cheap, simple to perform, and can be performed bedside. It does not use ionizing radiation, and USCAs are well tolerated; anaphylactoid reactions to these agents are rare. Furthermore, there are few contraindications for its use [15,19–21].

The limitations of CEUS are the possibility that adequate exploration of organs of interest may be obscured by bowel gas interposition or due to the body habitus. For example, the pancreas can be obscured due to its deep retroperitoneal location. CEUS cannot diagnose traumatic lesions of the pelvicalyceal system as micro-bubbles are not excreted by the kidneys. Likewise, CEUS cannot diagnose bile duct injuries with bile leakage as micro-bubbles are also not excreted by the biliary tract [5,10,15]. Furthermore, patients with bowel injuries, high-energy blunt traumas, multi-organ trauma, or who are hemodynamically unstable should undergo MDCT examination rather than CEUS examination.

4. Conclusions

In polytrauma patients, CEUS 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 sensitivity and specificity similar to those seen with MDCT. CEUS is recommended for the diagnostic evaluation of hemodynamically stable patients with isolated blunt moderate-energy abdominal traumas and for the diagnostic follow-up of conservatively managed abdominal traumas. Using CEUS minimizes inappropriate or further exposure to ionizing radiation and multiple intravenous iodinate contrast medium administration.

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