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PICTORIAL ESSAY

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Real-time, contrast-specific sonography imaging of acute splenic disorders: a pictorial review

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Abstract Real-time, contrast-specific ultrasonography (US) uses low-mechanical-index, harmonic software to stimulate echo emission from resounding second-generation contrast medium microbubbles. At our institution, contrast-enhanced US is increasingly being used in the evaluation of acute abnormalities of the spleen, mainly to overcome some limitations of conventional (basic) US. This pictorial essay illustrates the appearance of several acute splenic lesions, both traumatic and non-traumatic, on contrast-specific US.

Keywords Spleen · Acute disorders · Trauma · Infarct · Contrast-enhanced ultrasonography

Introduction

By using a low acoustic pressure (low mechanical index), real-time, contrast-specific ultrasonography (US) techniques produce images based on nondestructive, non-linear acoustic effects of sound interaction with microbubble contrast media [1, 2]. The high harmonic emission capability of stabilized microbubbles containing gases other than air (the so-called second-generation US contrast media) allows gray-scale display of tissue enhancement and continuous exploration of the spleen during circulation of these contrast agents. This is at the cost of a slight loss in spatial resolution and overall image quality.

The blood-pool, second-generation contrast agent SonoVue can be prepared in a few seconds and is immediately administrable. The overall time for contrast-enhanced US is 6 min at most. All these features make SonoVue optimal for use in emergency patients [3, 4].

Our technique

At our institution radiologists perform US studies directly [3, 4]. All patients first undergo baseline, conventional US examination. Thereafter, a contrast-enhanced study is obtained, employing the continuous-mode, low-mechanical-index technology called contrast-tuned-imaging (CnTI, Esaote, Italy). CnTI software allows selective tuning of the scanner with the contrast medium signal. A specific transmitting and receiving resonance frequency is used to avoid interference from tissue signals(lowered to minimum). We use an ultra-low acoustic power setting (40–50 kPa derated pressure, expressing a mechanical index of 0.06–0.07). The ultrasound beam is focused on the deepest portion of the region of interest.

We rapidly inject intravenously 2.4–4.8 ml of sulfurhexafluoride-filled, phospholipid-stabilized microbubbles (SonoVue, Bracco, Italy) [5, 6]. The contrast agent is administered through a peripheral vein and a 20G needle using a three-way stopcock, and is followed by 5–10 ml normal saline flush.

Real-time imaging starts immediately after injection and lasts 5–6 min. The spleen is scanned right through, exploring repeatedly the whole of the parenchymal portion. A timer is pushed at the moment of injection and the whole examination movie is archived on the scanner. Stored clips are subsequently sent to a personal computer and converted to *avi* files.

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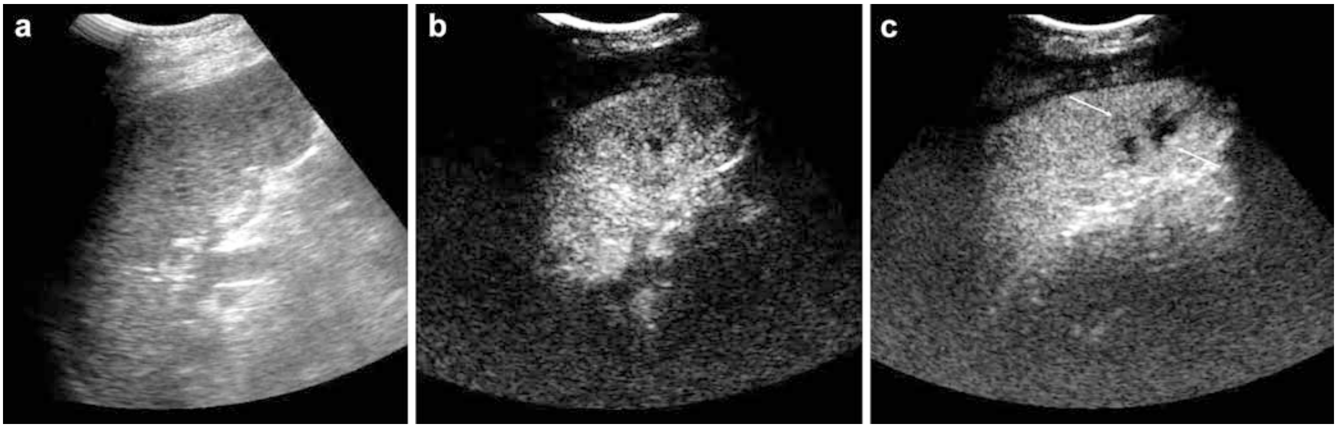


Fig. 1a–c Blunt spleen trauma. Subtle inhomogeneity of lower splenic pole on baseline US scan (**a**). Conspicuity of injured area increases on early-phase, contrast-enhanced US scan (**b**) and especially on 2-min-delay, contrast-enhanced US scan (**c**), where a lacerocontusive area becomes evident (*arrows*). No peritoneal effusion

Spectrum of findings

Spleen injury

US has recently become very popular in the evaluation of abdominal trauma, especially as a rapid way to rule out hemoperitoneum in unstable subjects (FAST technique) [7, 8, 9, 10]. The role of FAST technique in imaging stable patients is a matter of controversy [11, 12, 13] and many institutions, including our hospital, still prefer to obtain a complete US survey of abdomen and pelvis to detect combined organ injuries. In any case, it is known that US is less sensitive than CT in the evaluation of parenchymal lesions. The use of contrast enhancement may partially overcome this limitation [3,14, 15, 16, 17].

Spleen injuries appear as parenchymal portions lacking contrast enhancement (Figs. 1, 2, 3). Injury-to-parenchyma contrast increases progressively as spleen echogenicity rises, reaching its maximum at 2–3 min from injection. Lacerations are recognizable as hypoechoic bands, linear or branched, perpendicular to the spleen capsule, while lacerocontusive areas and parenchymal hematomas appear as inhomogeneous hypoechoic regions without mass effect or vessel displacement.

Contrast-enhanced US may also display findings that do not appear on conventional US imaging, including perfusion defects and contrast extravasation, as shown in experimental studies [18, 19, 20] and clinical series [3]. Partial hypoperfused areas (post-traumatic infarctions) appear as wedge-shaped or polar hypoechoic areas, whereas total or subtotal lack of enhancement is detectable in cases of pedicle avulsion or severe hypovolemia ("shock spleen"). In the latter case overall parenchymal enhancement is poor, clearly less than expected, and less than the adjacent left kidney.

Intrasplenic contrast pooling is recognizable as a small and persistent parenchymal area of hyperechogenicity, isoechoic to opacified parenchymal arteries. Extrasplenic contrast extravasation appears as a subcontinuous jet reaching the spleen capsule (possibly from the tip of an opacified artery) and spreading around the organ (Figs. 4, 5). Contrast medium leakage indicates ongoing bleeding and has been repeatedly

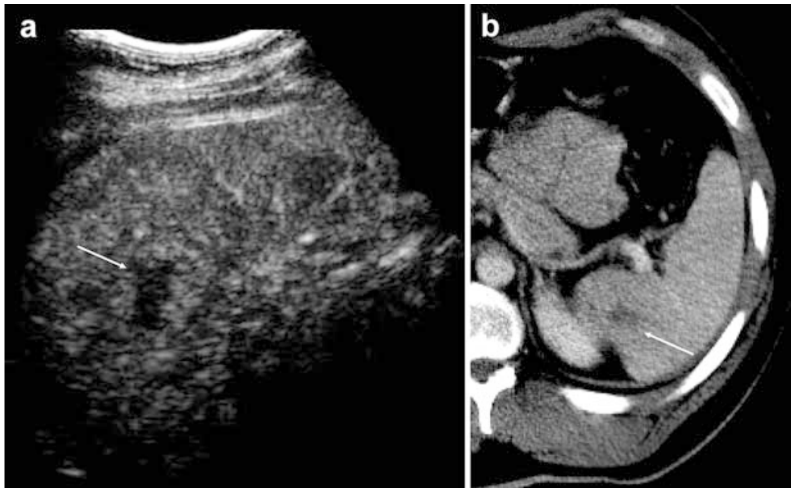


Fig. 2a, b Blunt spleen trauma. Contrast-enhanced US scan (**a**) showing a small peripheral laceration (*arrow*). Contrast-enhanced CT scan (**b**) confirms parahilar laceration (*arrow*). No peritoneal effusion

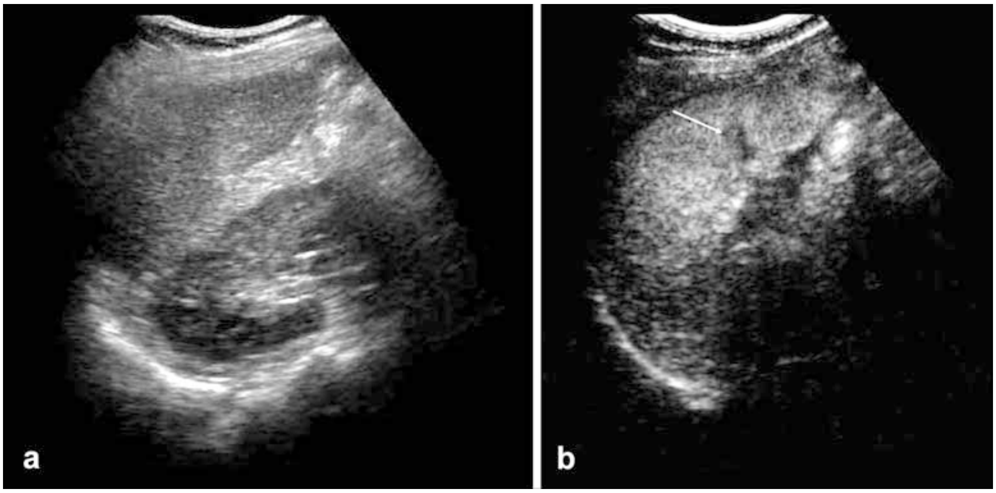


Fig. 3a, b Blunt spleen trauma. Baseline US scan (**a**) fails to show defined abnormalities. Contrast-enhanced US scan (**b**) identifies a small peripheral laceration (*arrow*). No peritoneal effusion

Fig. 4 Contrast extravasation. Contrast-enhanced US scan detects a large injury with an internal jet of contrast leakage abutting the external surface of the spleen (*arrows*). Perisplenic fluid and clots were also present

shown [21, 22, 23, 24, 25, 26, 27] to be a CT predictor of conservative management failure and an indicator of requirement for surgery. The new possibility of identifying this sign by using contrast-specific US opens new perspectives in blunt trauma sonographic evaluation and follow-up [3].

Contrast-enhanced US has been shown to be comparable to contrast-enhanced CT in detecting spleen trauma [3]. Small injuries may sometime be missed but, in our experience, this occurrence does not have practical consequences (Fig. 6).

Spleen infarction

Typical splenic infarctions appear as wedge-shaped or polar areas of persistent hypoechogenicity (opacification defect) (Fig. 7, 8). Absence of contrast enhancement and detection of a perihilar, truncated artery are the diagnostic landmarks. The texture can be homogeneous or inhomogeneous while infarction margins can be well- or ill-defined [4].

Atypical round-shaped infarcts, sometimes simulating focal lesions, are readily diagnosed because of total lack of enhancement.

Subtotal splenic infarction is seen as a lack of parenchymal opacification, with possible upper pole

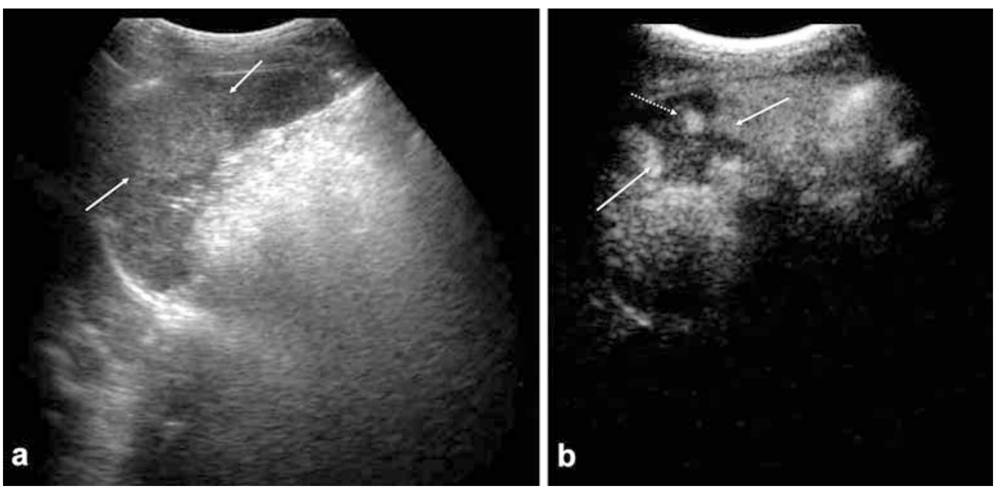


Fig. 5a, b Contrast extravasation. Baseline US scan (**a**) detects a large, middle-third area of subtle hyperechogenicity (*arrows*). Contrast-enhanced US scan (**b**) identifies the injured area better (*arrows*). Active bleeding is evident (*dotted arrow*). Hemoperitoneum was present

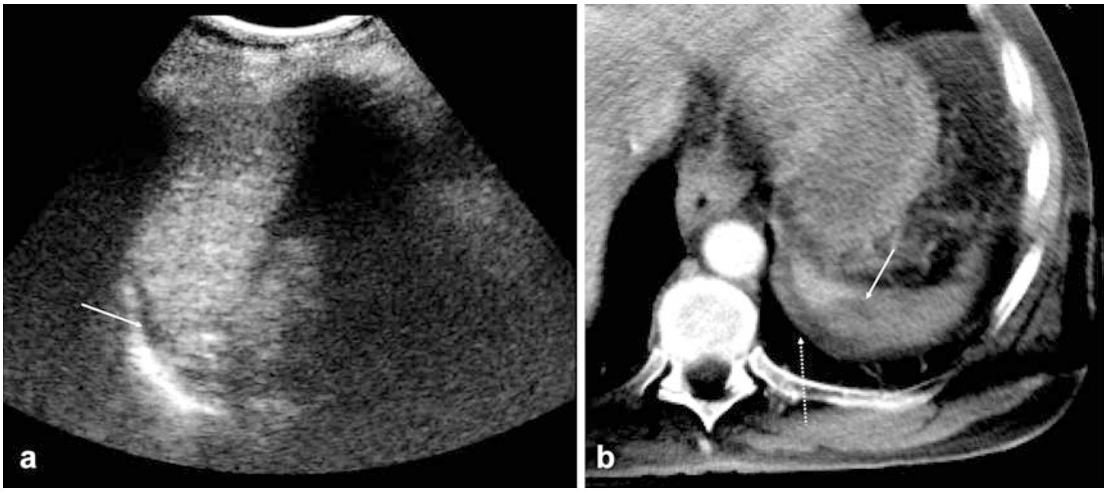


Fig. 6a, b Blunt splenic trauma: partial false-negative US study. Contrast-enhanced US scan (**a**) detects a small perisplenic effusion (*arrow*) but fails to show any parenchymal change. Contrast-enhanced CT (**b**) confirms perisplenic effusion (*dotted arrow*) but also identifies a small parenchymal laceration (*arrow*). Patient recovered with conservative treatment

peripheral areas of preserved perfusion. Comparison with the clearly enhancing left renal parenchyma allows immediate diagnosis.

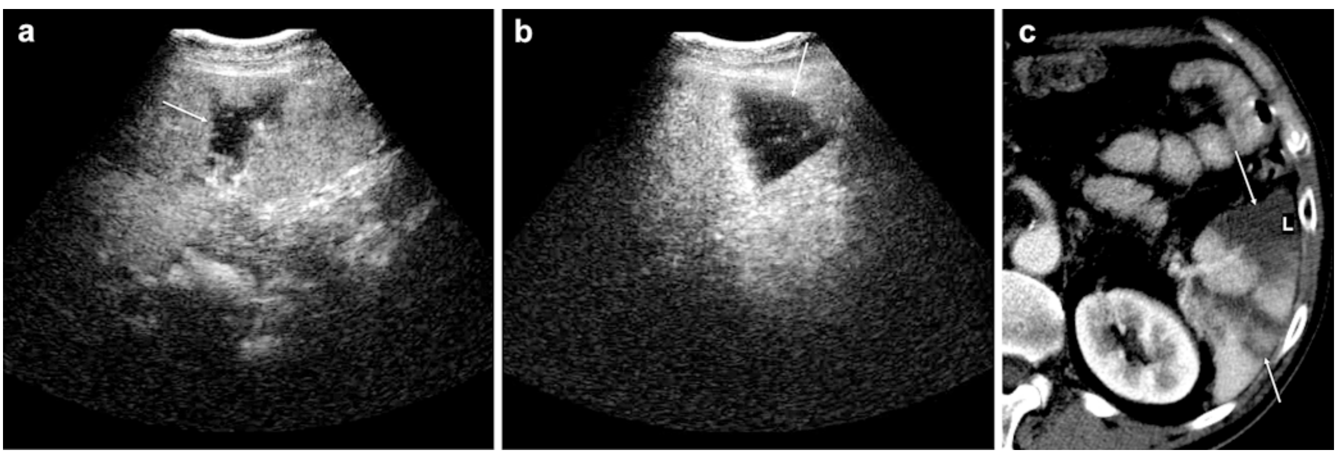
Other acute disorders

Less commonly seen disorders of the spleen include spontaneous hematomas and abscesses. Both are recognizable as hypoechoic areas surrounded by enhancing normal parenchyma (Fig. 9). Abscess collections are surrounded by opacified vessels and may show peripheral enhancing rim and enhancing septa [4].

Fig. 7a–c Splenic infarction. Contrast-enhanced US scans (**a, b**) detect clearly hypoechoic, avascular areas within the lower third of the spleen (*arrows*). Contrast-enhanced CT scan (**c**) confirms the infarction (*arrows*)

Pitfalls and limitations

There are a few potential causes of misinterpretation to be aware of [3]. During the early phase of parenchymal opacification the spleen may appear inhomogeneous (a finding similar to the well-known zebra pattern of dynamic CT and MRI). However, the transient nature of pseudolesions distinguishes them from real disorders (Fig. 10). At about 2–3 min from injection the densely opacified superficial parenchyma may cause transient obscuration of deeply located portions. Large hemangiomas may also opacify densely and thus obscure the deeply located parenchyma. Splenic lobulation, incisures, and accessory tissue may be mistaken for traumatic lesions, an well-known occurrence on conventional US imaging (Fig. 11). Opacified parenchymal arteries may mimic intrasplenic contrast extravasation and vice versa. Finally, it should be noted that regions difficult to explore using conventional US, such as the deep pole of the spleen or subphrenic regions, are still hard to image using contrast-specific US. The same applies to cases where a meteoric left colonic angle partially overshadows the spleen: this limitation clearly persists on contrast-enhanced images.



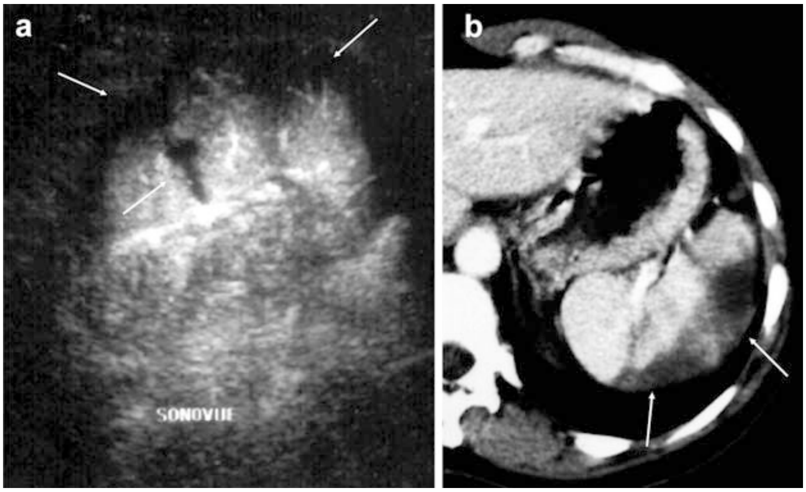


Fig. 8a, b Splenic infarction. Splenic external third hypoechogenicity (*arrows*) is visible on contrast-enhanced US scan (**a**). Contrast-enhanced CT scan (**b**) confirms the infarction (*arrows*)

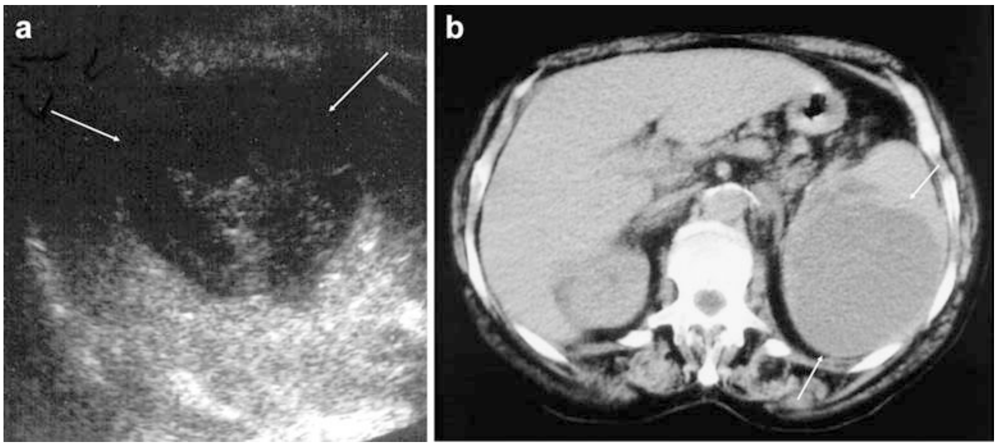


Fig. 9a, b Splenic infected hematoma. Large, hypoechoic, inhomogeneous collection (*arrows*) is visible on contrast-enhanced US scan (**a**). Unenhanced CT scan (**b**) confirms diagnosis (*arrows*)

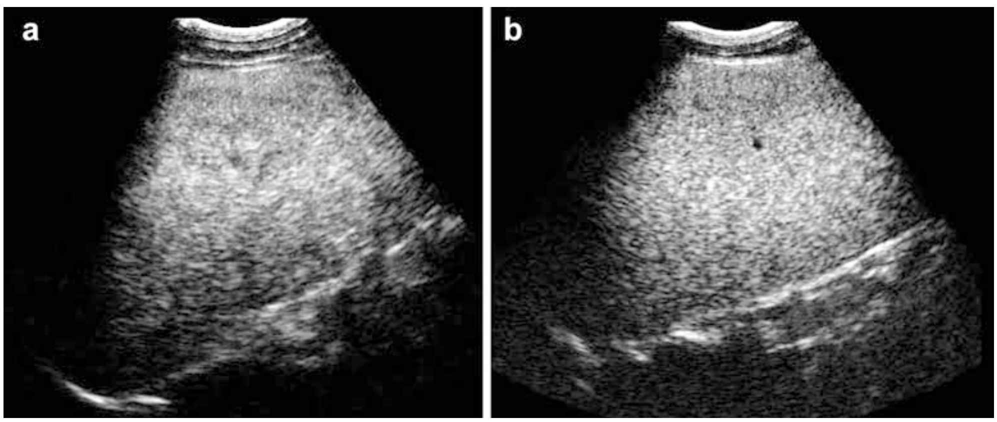


Fig. 10a, b Pseudolesions. Inhomogeneous parenchymal enhancement, simulating abnormal changes, on early-phase, contrast-enhanced US scan (**a**). Three-minute-delay scan shows a homogeneous texture (**b**)

Conclusion

The spleen is a superficial organ in the abdomen, with an almost homogeneous echotexture and dense and persistent contrast enhancement. These features make the spleen an optimal organ to be study with contrast-specific US [4].

US contrast media injection allows a significant increase in lesion-to-parenchyma conspicuity, with hypovascular abnormalities becoming clearly evident in comparison with the undamaged hyperechoic parenchyma. Parenchymal changes that were very subtle on baseline US became evident after contrast administration. Moreover, the true size of parenchymal

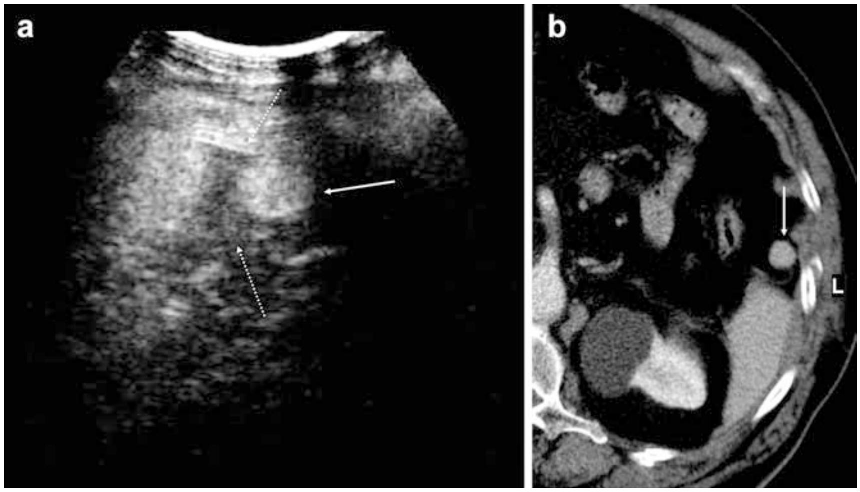


Fig. 11a, b Accessory spleen simulating parenchymal abnormality in a trauma patient. On contrast-enhanced US scan (**a**) a splenula (*arrow*) adjacent to the lower splenic pole (*dotted arrows*) simulates splenic injury (*arrows)* due to interposed fat. Contrast-enhanced CT scan (**b**) demonstrates the accessory spleen (*arrow*) and rules out splenic trauma

abnormalities is better defined on contrast-enhanced US, showing greater correlation with CT findings than conventional US.

Traumatic injuries, infarctions, and other acute disorders of the spleen can be optimally evaluated using real-time, contrast-specific US. Radiologists should be aware of the related findings, since this technique is expected to be increasingly used in clinical practice.

References

1. Bauer A, Solbiati L, Wessman N (2002) Ultrasound imaging with SonoVue: low mechanical index real-time imaging. Acad Radiol 9(Suppl 1):282–284
2. Lencioni R, Cioni D, Bartolozzi C (2002) Tissue harmonic and contrast-specific imaging: back to gray scale in ultrasound. Eur Radiol 12:151–165
3. Catalano O, Lobianco R, Sandomenico F, Siani A (2003) Splenic trauma: evaluation with contrast-specific sonography and a second-generation contrast medium: preliminary experience. J Ultrasound Med 22:467–477
4. Catalano O, Lobianco R, Sandomenico F, D'Elia G, Siani A (2003) Real-time, contrast-enhanced sonography of the spleen: examination technique and preliminary clinical experience. Radiol Med 106:338–356
5. Schneider M (1999) SonoVue, a new ultrasound contrast agent. Eur Radiol 9(Suppl 3): 347–348
6. Morel DR, Schwieger I, Hohn L, Terrettaz J, Llull JB, Cornioley YA, Schneider M (2000) Human pharmacokinetics and safety evaluation of SonoVue, a new contrast agent for ultrasound imaging. Invest Radiol 35:80–85
7. Bode PJ, Edwards MJ, Kruit MC, van Vugt AB (1999) Sonography in a clinical algorithm for early evaluation of 1671 patients with blunt abdominal trauma. AJR Am J Roentgenol 172:905–911
8. Dolich MO, McKenney MG, Varela JE, Compton RP, McKenney KL, Cohn SM (2001) 2,576 ultrasounds for blunt abdominal trauma. J Trauma 50:108–112
9. Brown MA, Casola G, Sirlin CB, Patel NY, Hoyt DB (2001) Blunt abdominal trauma: screening US in 2,693 patients. Radiology 218:352–358
10. Richards JR, McGahan JP, Jones CD, Zhan S, Gerscovich EO (2001) Ultrasound detection of blunt splenic injury. Injury 32:95–103
11. Shanmuganathan K, Mirvis SE, Sherbourne CD, Chiu WC, Rodriguez A (1999) Hemoperitoneum as the sole indicator of abdominal visceral injuries: a potential limitation for screening abdominal US for trauma. Radiology 212:423–430
12. Chiu WC, Cushing BM, Rodriguez A, Ho SM, Mirvis SE, Shanmuganathan K et al (1997) Abdominal injuries without hemoperitoneum: a potential limitation of focused abdominal sonography for trauma (FAST). J Trauma 42:617–623
13. Poletti P-A, Kinkel K, Vermeulen B, Irmay F, Unger P-F, Terrier F (2003) Blunt abdominal trauma: should US be used to detect both free fluid and organ injuries? Radiology 227:95–103
14. Beckman M (2003) Ultrasound with contrast enhancement as a means to assess trauma patients—an initial experience. Digital Imagery (ASER 14th Annual Scientific Meeting book):84–85
15. Poletti P-A (2003) Contrast-enhanced ultrasound in blunt abdominal trauma: the Geneva experience. Digital Imagery (ASER 14th Annual Scientific Meeting book):85–86
16. Martegani A, Cosgrove DO, Del Favero C, Aiani L, Harvey CJ (2002) Contrast enhanced abdominal ultrasound in trauma using Sonovue. Radiology 225(p): 358 (Radiological Society of North America, oral presentation)
17. Poletti P-A, Platon A, Becker C, Terrier F (2003) The value of contrast-enhanced sonography to improve detection of liver and spleen traumatic injuries: a comparison with contrast enhanced CT. Oral presentation, Radiological Society of North America, Radiology (p):45
18. Brown JM, Quedens-Case C, Alderman JL, Greener Y, Taylor KJ (1997) Contrast enhanced sonography of visceral perfusion defects in dogs. J Ultrasound Med 16:493–499
19. Goldberg BB, Merton DA, Liu J-B, Forsberg F (1998) Evaluation of bleeding sites with a tissue-specific sonographic contrast agent: preliminary experiences in an animal model. J Ultrasound Med 17:609–616
20. Liu J-B, Merton DA, Goldberg BB, Rawool NM, Shi WT, Forsberg F (2000) Contrast-enhanced two- and three-dimensional sonography for evaluation of intra-abdominal hemorrhage. J Ultrasound Med 21:161–169
21. Schurr MJ, Fabian TC, Gavant M, Croce MA, Kudsk KA, Minard G, et al (1995) Management of blunt splenic trauma: computed tomography contrast blush predicts failure of non-operative management. J Trauma 39:507–513
22. Gavant ML, Schurr M, Flick PA, Croce MA, Fabian TC, Gold RE (1997) Predicting clinical outcome of nonsurgical management of blunt splenic injury: using CT to reveal abnormalities of splenic vasculature. AJR Am J Roentgenol 168:207–212
23. Federle MP, Courcoulas AP, Powell M, Ferris J, Peitzman AB (1998) Blunt splenic injury in adults: clinical and CT criteria for management, with emphasis on active extravasation. Radiology 206:137–142
24. Shanmuganathan K, Mirvis SE, Boyd-Kranis R, Takada T, Scalea TM (2000) Nonsurgical management of blunt splenic injury: use of CT criteria to select patients for splenic arteriography and potential endovascular therapy. Radiology 217:75–82

25. Omert LA, Salyer D, Dunham CM, Porter J, Silva A, Protetch J (2001) Implications of the “contrast blush” findings on computed tomographic scan of the spleen in trauma. J Trauma 51:272–27
26. Yao DC, Jeffrey RB, Mirvis SE, Weejes A, Federle MP, Kim C, et al (2002) Using contrast-enhanced helical CT to visualize arterial extravasation after blunt abdominal trauma. AJR Am J Roentgenol 178:17–20
27. Willmann JK, Roos JE, Platz A, Pfammatter T, Hilfiker PR, Marincek B, et al (2002) Multidetector CT: detection of active hemorrhage in patients with blunt abdominal trauma. AJR Am J Roentgenol 179:437–444