



Ultrasound in Emergency Medicine

The Lipliner Sign: Potential Cause of a False Positive FAST Examination

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Abstract—Background: The focused assessment with sonography in trauma (FAST) examination plays an essential role in diagnosing hemoperitoneum in trauma patients to guide prompt operative management. The FAST examination is highly specific for hemoperitoneum in trauma patients, and has been adopted in nontrauma patients to identify intraperitoneal fluid as a cause of abdominal pain or distension. However, causes of false positive FAST examinations have been described and require prompt recognition to avoid diagnostic uncertainty and inappropriate procedures. Most causes of false positive FAST examinations are due to anatomic mimics such as perinephric fat or seminal vesicles, however, modern ultrasound machines use a variety of post-processing image enhancement techniques that can also lead to novel false positive artifacts. **Case Report:** We report cases where experienced clinicians incorrectly interpreted ultrasound findings caused by a novel mimic of hemoperitoneum: the “lipliner sign.” It appears most prominently at the edges of solid organs (such as the liver and the spleen), which is the same location most likely to show free fluid in FAST examination in trauma patients. **Why Should an Emergency Physician be Aware of This?** Clinicians who take care of trauma patients must be familiar with causes of false positive FAST examinations that could lead to a misdiagnosis of hemoperitoneum. © 2024 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Keywords—artifact; trauma; ultrasound

Introduction

The focused assessment with sonography in trauma (FAST) ultrasound examination is a vital diagnostic tool to identify intraperitoneal bleeding. Identification of hemoperitoneum in unstable hemodynamically unstable trauma patients is a direct indication for emergent operative intervention (1). In hemodynamically stable trauma patients, hemoperitoneum is associated with a high likelihood of subsequent urgent operative intervention (2). Past reports have reported high specificity of the FAST examination, however, several causes of false positive mimics have been reported (3–6). Because a positive FAST examination portends a high likelihood of resource-intensive and invasive interventions such as blood product transfusion, operative, or interventional radiology procedures, it is imperative that clinicians maximize examination specificity by accurately identifying potential false positive hemoperitoneum mimics.

Advanced signal processing techniques such as real-time adaptive filtering are commonly used by modern ultrasound technology to improve spatial resolution (7,8). Such postprocessing techniques may cause an outlining of an organ boundary, thereby making the image appear

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Table 1. Case Summary of FAST Examinations Where the Lipliner Sign Was Noted and Misinterpreted as Hemoperitoneum in Trauma Patients Negative by Abdominal CT for Hemoperitoneum or Was Noted in a Healthy Volunteer with No Known History of Liver, Cardiac, or Renal Disease

Case	Age (Years)	Sex	Trauma Type	Ultrasound Machine	Transducer	“Lipliner” Artifact Location
1	55	F	Blunt	Philips Lumify	Curvilinear	RUQ, Morison’s pouch
2	75	F	Blunt	Philips Lumify	Phased Array	RUQ, Morison’s pouch, liver tip
3	36	M	Penetrating	Mindray, TE7Max	Curvilinear	RUQ, liver tip
4	42	F	Healthy	GE Venue Sonosite PX	Phased Array Curvilinear	RUQ, Morison’s pouch liver tip

FAST = focused assessment with sonography for trauma; CT = computed tomography; RUQ = right upper quadrant.

more defined. In this report we describe how advanced signal processing can produce a hypoechoic outline, or lipliner, adjacent to the caudal tip of the liver and spleen, and thereby mimic a positive FAST examination.

Here we report a case series of three trauma patients in whom the hypoechoic artifact (lipliner sign) was misinterpreted as hemoperitoneum. We also present example images from a healthy individual who was scanned with ultrasound machines other than those used in our trauma resuscitation environment (Table 1). Informed written consent was obtained from all of the participants in the study prior to the conduct of study procedures. The trauma cases are derived from an institutional review board-approved ongoing prospective, observational study to acquire an image library of positive and negative FAST examinations for a machine learning training dataset. Images were reviewed by two ultrasound-trained physician annotators who were blinded to all clinical information. Each image’s review was compared with available clinical data including the original clinician’s interpretation, results of abdominopelvic computed tomography (CT), or operative report. Finally, we include images from a healthy volunteer to demonstrate the presence of the artifact in other machines used in areas of our hospital other than the trauma resuscitation environment.

Case Reports

Case 1

A 55-year-old female patient (body mass index [BMI] 42 kg/m²) presented to the emergency department (ED) after a motor vehicle collision. On presentation, blood pressure was 167/121 mm Hg and heart rate was 75 beats/min. A FAST was performed with a portable Philips Lumify system (Eindhoven, Netherlands) using a curvilinear transducer (C5-2), which demonstrated a hypoechoic linear area near Morrison’s pouch tracking toward

the caudal edge of the liver (Figure 1A). During blinded case review of the images, two ultrasound-trained physician reviewers independently interpreted this ultrasound finding as positive for free fluid. CT of the abdomen and pelvis with intravenous contrast did not show free fluid or any traumatic abnormality. After unblinded review, the hypoechoic linear area was attributed to the lipliner artifact. The lipliner appears in a similar location as the previously described double-line sign (DLS), however, lipliner is present in the peritoneal location immediately adjacent to the liver, whereas DLS represents perinephric fat within the retroperitoneal space (6). This patient exhibited both the lipliner artifact (Figure 1A) and DLS (Figure 1B).

Case 2

A 75-year-old female patient (BMI 23 kg/m²) presented to the ED after a fall from a ladder. On presentation, blood pressure was 170/117 mm Hg and heart rate was 92 beats/min. A FAST was performed with a portable Philips Lumify system using a phased array transducer (S4-1). This demonstrated a hypoechoic linear area in the vicinity of the caudal liver edge (Figure 2). This region was again interpreted by two blinded ultrasound-trained physician reviewers as positive for free fluid, however, CT of the abdomen and pelvis with intravenous contrast did not reveal any abdominal injuries or intraperitoneal fluid. After unblinded review, the hypoechoic linear area was again attributed to the lipliner artifact.

Case 3

A 36-year-old male patient (BMI 37 kg/m²) presented to the ED after being found unresponsive with signs of both penetrating and blunt trauma. On presentation, his vital signs showed a blood pressure of 80/50 mm Hg and a heart rate of 99 beats/min. The clinical team performed

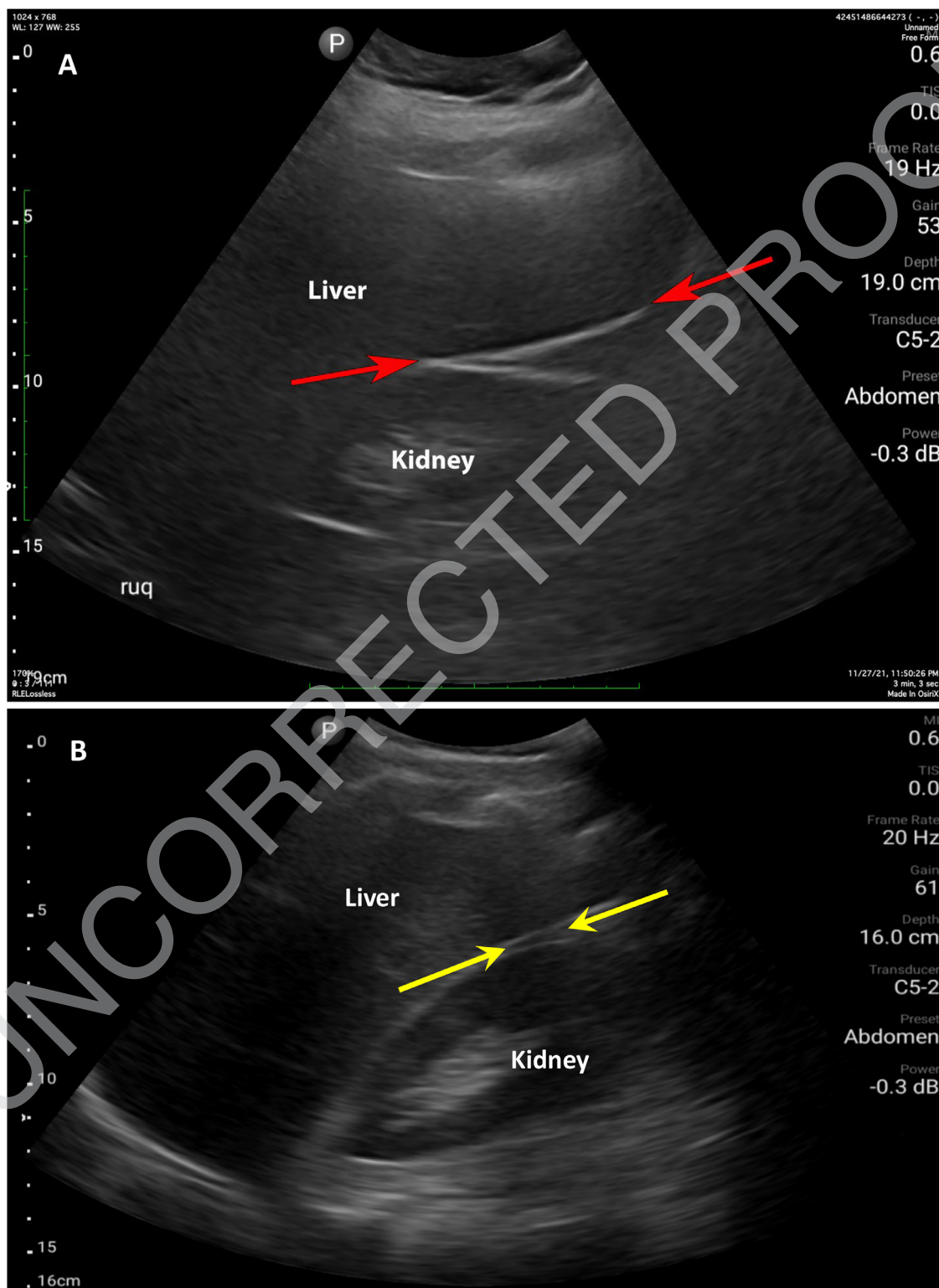


Figure 1. Right upper quadrant (RUQ) views acquired with a curvilinear transducer (C5-2) on a Philips Lumify device showing the lipliner sign (A), a thin hypoechoic line (indicated between two red arrows) tracking along the interface of the liver and kidney (Morison's pouch) toward the inferior border of the liver, and the double-line sign (B), a wedge-shaped hypoechoic region in Morison's pouch, outlined by two hyperechoic lines (indicated between two yellow arrows).

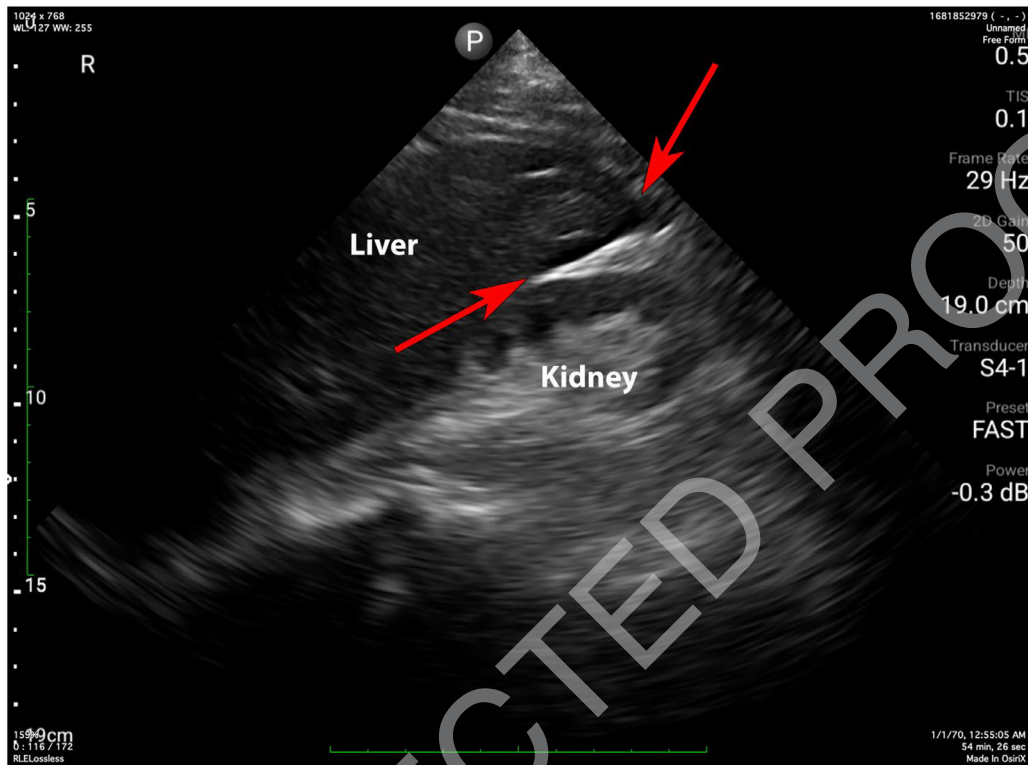


Figure 2. Right upper quadrant (RUQ) view acquired with a phased array transducer (S4-1) on a Philips Lumify device showing a thin hypoechoic line (indicated between two red arrows) tracking along the caudal edge of the liver.

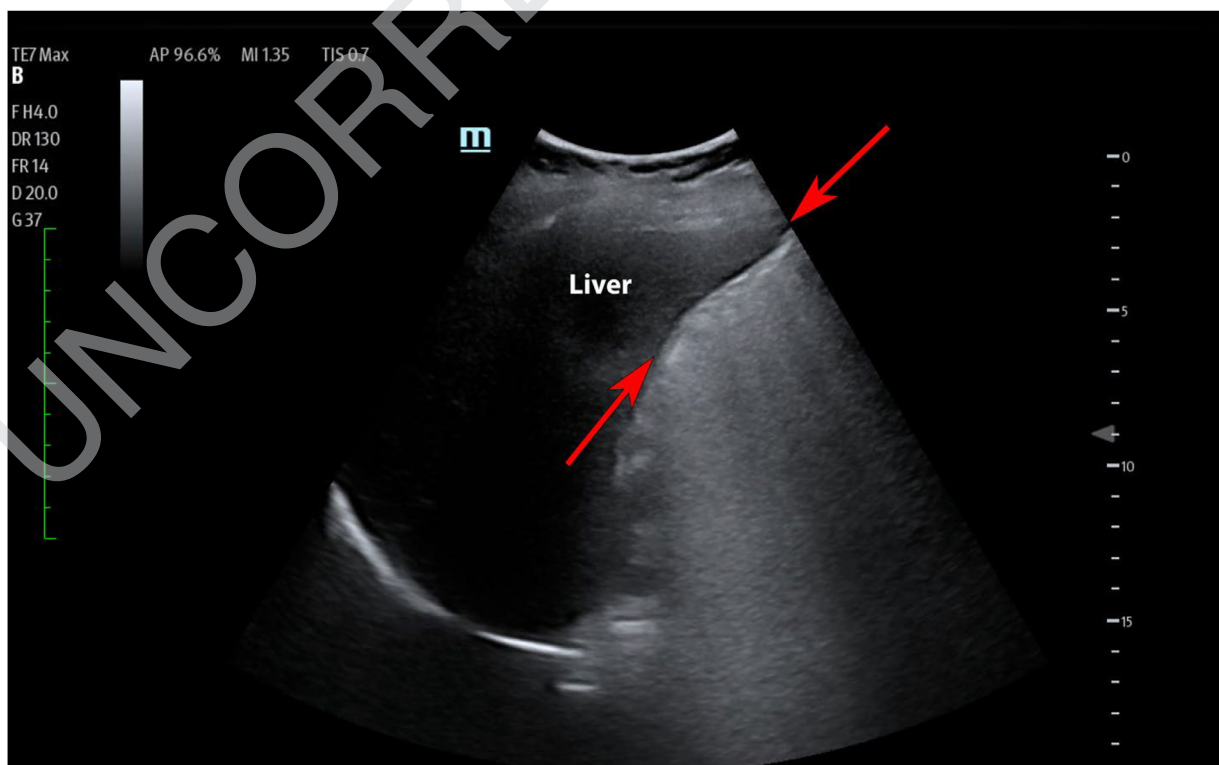


Figure 3. Right upper quadrant (RUQ) view acquired with a curvilinear transducer (SC5-1Ns) on a Mindray TE7Max device showing a thin hypoechoic line (indicated between two red arrows) tracking along the caudal edge of the liver.

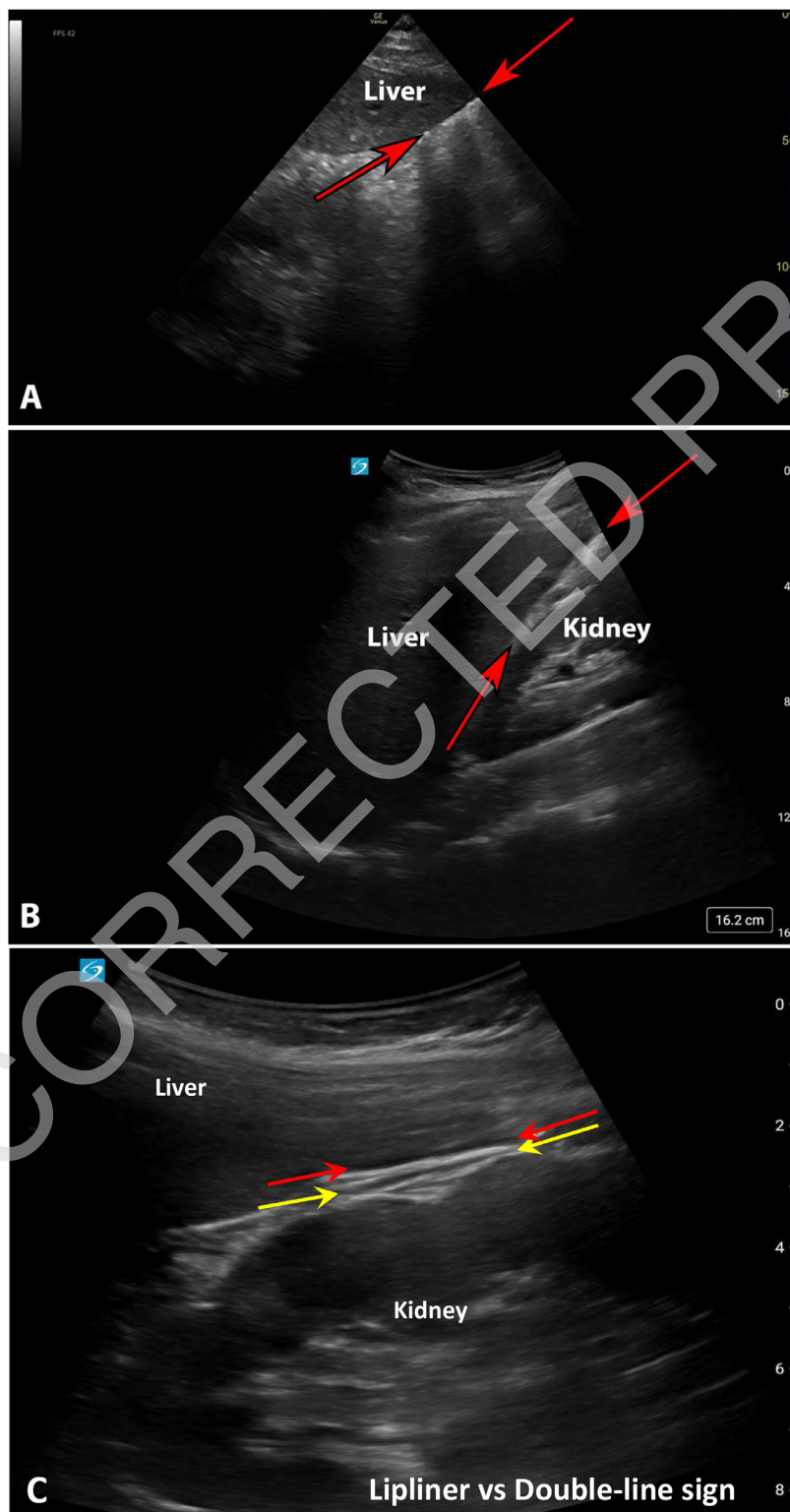


Figure 4. Right upper quadrant (RUQ) view acquired with a phased array transducer (3Sc-RS) on a GE Venue device (A) and a curvilinear transducer (C5-1) on a Sonosite PX device (B) showing a thin hypoechoic line (indicated between two red arrows) tracking along the caudal edge of the liver near the liver tip. RUQ zoomed-in view (C) acquired with a curvilinear transducer (C5-1) on a Sonosite PX device showing the lipliner sign (indicated between two red arrows) in comparison with the double-line sign (indicated between two yellow arrows).

94 a FAST examination with a Mindray TE7 Max system
 95 (Shenzen, China) using a curvilinear transducer (SC5-
 96 1Ns), which revealed a hypoechoic area near the liver tip
 97 (Figure 3). The clinical team interpreted this as positive
 98 for free fluid. The patient's initial hypotension improved
 99 after volume resuscitation, and a CT scan with i.v. con-
 100 trast of the abdomen and pelvis did not detect any signs
 101 of intraperitoneal free fluid or traumatic injuries. On inde-
 102 pendent quality review (performed routinely by members
 103 of the ultrasound section), the initial clinical ultrasound
 104 interpretation of free fluid was deemed to be due to the
 105 lipliner artifact.

106 Case 4

107 The presence of lipliner sign was then confirmed using
 108 machines from two different manufacturers. These ma-
 109 chines are not commonly used in the ED, but are used
 110 elsewhere in our institution. A FAST examination was
 111 performed in a healthy 42-year-old individual (BMI 24
 112 kg/m²) with no known history of liver, cardiac, or renal
 113 disease. The lipliner artifact was demonstrated in the right
 114 upper quadrant using a phased array transducer (3Sc-RS)
 115 on a GE Venue Go (GE HealthCare, Chicago, IL) and a
 116 curvilinear transducer (C5-1) on a Sonosite PX system
 117 (Bothell, WA) (Figures 4A, B). The DLS was also noticed
 118 in the right upper quadrant with a curvilinear transducer
 119 (C5-1) on a Sonosite PX device (Figure 4C).

120 Discussion

121 We present four cases; in each case image adaptive filter-
 122 ing resulted in a possible false positive FAST examina-
 123 tion. A false positive FAST examination has the potential
 124 to triage patients inappropriately to a higher level of
 125 care, exposing them to unnecessary resource-intensive
 126 interventions while also delaying diagnosis of alternate
 127 injuries. To the best of our knowledge, this lipliner sign of
 128 image-adaptive filtering artifact has not been previously
 129 described and has the potential to mislead the clinical
 130 team caring for trauma patients. Although relatively sub-
 131 tle, lipliner sign appears most prominently at the edges of
 132 solid organs (liver and spleen), which is the same location
 133 most likely to show free fluid in the FAST examination
 134 (9).

135 Clinicians must be aware of the “lipliner sign” and be
 136 able to distinguish it from true free fluid. Free fluid forms a
 137 wedge shape, decreasing in width as it dissects into depen-
 138 dent tissue planes, whereas the lipliner sign presents as a
 139 simple linear feature that serves to outline an organ. This
 140 is similar to the previously reported “double-line sign”:
 141 a hypoechoic region (perinephric fat) between the liver
 142 and kidney outlined by hyperechoic lines (Gerota's fas-
 143 cia) (4,6). The lipliner sign described here differs from

the DLS in that it is not outlined by hyperechoic lines and
 is a postprocessing nonanatomic artifact seen adjacent to
 the solid organ itself. In the case of either sign, where
 a sonologist encounters a thin anechoic strip of uncer-
 tain etiology, it may be best to report the examination as
 “indeterminate” rather than “positive” or “negative.” Al-
 though this may result in mildly decreased sensitivity for
 hemoperitoneum, such small stripes are unlikely to corre-
 late with a need for operative management (10). Treating
 such results as “indeterminate” may be helpful to avoid
 team anchoring on an incorrect diagnosis of hemoperi-
 toneum.

In addition to clinicians, our findings ought to be of
 interest to ultrasound manufacturers. We have identified
 the lipliner sign with all the machine manufacturers used
 at our institution (Philips, Sonosite, Mindray, and GE
 HealthCare). There is a wide array of speckle reduc-
 tion techniques described in the engineering literature,
 which are based on mathematical modeling to achieve
 post hoc noise reduction (11). The exact mechanisms used
 to achieve such filtering are proprietary and likely vary
 by manufacturer (7). Adjusting advanced signal process-
 ing in point-of-care devices geared for free fluid detection
 may help improve clinician confidence in a positive FAST
 examination. Future work must focus on machine- and
 transducer-specific factors affecting the frequency of the
 lipliner sign, its incidence in clinical FAST examinations,
 and its impact on results reporting and clinical decision-
 making.

173 Why Should an Emergency Physician be Aware of 174 This?

The goal of this report is to make clinicians aware of
 this lipliner sign as a potential cause of a false positive
 hemoperitoneum mimic. This artifact is likely ubiqui-
 tous on modern ultrasound machines. Prompt recognition
 and appropriate interpretation by clinician sonologists is
 imperative to report accurately the results of the FAST ex-
 amination.

182 Declaration of competing interest

The authors declare that they have no known competing fi-
 nancial interests or personal relationships that could have
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186 CRediT authorship contribution statement

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