Pediatric Blunt Abdominal Trauma and Point-of-Care Ultrasound

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Abstract: Blunt abdominal trauma (BAT) accounts for most trauma in children. Although the focused assessment with sonography in trauma (FAST) is considered standard of care in the evaluation of adults with traumatic injuries, there is limited evidence to support its use as an isolated evaluation tool for intra-abdominal injury as a result of BAT in children. Although a positive FAST examination could obviate the need for a computed tomography scan before OR evaluation in a hemodynamically unstable patient, a negative FAST examination cannot exclude intra-abdominal injury as a result of BAT in isolation. In this article, we review the evaluation of BAT in children, describe the evaluation for free intraperitoneal fluid and pericardial fluid using the FAST examination, and discuss the limitations of the FAST examination in pediatric patients.

Key Words: FAST, point-of-care ultrasound, trauma, intra-abdominal injury

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TARGET AUDIENCE

This CME activity is intended for healthcare providers who care for critically injured children in the emergency department.

LEARNING OBJECTIVES

After completion of this article, the reader should be better able to:

1. Describe the technique for completing a focused assessment with sonography for trauma (FAST) examination.
2. Determine FAST examination findings concerning for intraperitoneal fluid, pleural fluid/hemothorax, and pericardial effusion.
3. Identify limitations to using the FAST examination with pediatric trauma patients.

PEDIATRIC CONSIDERATIONS IN TRAUMA

Pediatric trauma is a leading cause of morbidity and mortality for children in the United States.[1] More than one third of pediatric emergency department (ED) visits annually are for injury-related visits,[2] and despite declining rates of childhood injuries, it is estimated that 1 in 5 child deaths is a result of an unintentional injury.[3] Blunt trauma accounts for most pediatric trauma.[4] Although blunt head and thoracic injuries have the highest rates of mortality, abdominal trauma is the leading cause of unrecognized fatal injury in children.[5] Most injured children are initially cared for in community EDs; thus, it is essential that all ED providers have the knowledge and skills to identify and manage pediatric traumatic injuries.[6]

There are anatomical differences that place pediatric patients at increased risk for intra-abdominal injury (IAI) as a result of trauma when compared with adults.[7] Children experience a greater degree of force per body surface area because of their smaller size. Their solid abdominal organs are relatively bigger compared with adults, which increases their risk of direct injury in blunt abdominal trauma (BAT). They also have underdeveloped abdominal muscles, leading to increased abdominal protuberance, and less abdominal fat to offer additional protection, putting the internal organs at increased risk for injury.

Children also have developmental and physiologic differences from adults that should be considered during the pediatric trauma evaluation. Younger children may not be able to accurately describe the mechanism of injury or communicate the location of their pain, limiting the clinical history. Fear and crying may lead to tachycardia. Although crying is a developmentally appropriate response to fear, it may lead to excess swallowing of air and increased abdominal distension, which can further complicate the examination.[8] Because of their small body size, there are often more systems injured during a trauma.[8] Compared with adults, children have a greater physiologic reserve, and as a result, hypotension from acute hemorrhage does not become evident until a child has lost approximately 25% to 45% of their blood volume.[9] Healthcare providers should maintain a high index of suspicion for IAIs when evaluating a child injured in a trauma.

In 2013, the Pediatric Emergency Care Applied Research Network proposed a prediction rule composed of 7 patient history and physical examination findings (Fig. 1) to identify children with BAT at very low risk for requiring IAI intervention (requiring therapeutic laparotomy, angiographic embolization, blood transfusion for abdominal hemorrhage, or intravenous fluids for ≥2 nights for pancreatic/gastrointestinal injuries).[10] This prediction rule was externally validated in 2018 and found to have a sensitivity of 99%, thus supporting its use to minimize the use of CTs in children presenting with potential IAI.[11]

RADIOLOGIC CONSIDERATIONS IN PEDIATRIC TRAUMA

Computed tomography (CT) is the criterion standard for diagnosing IAI in both children and adults. Although CT scans have the advantage of quickly providing detailed information about IAI, they are expensive and expose the patient to ionizing radiation, which increases the risk of future malignancy, particularly in children.[12] Diagnostic peritoneal lavage has fallen out of practice, whereas the focused assessment with sonography for trauma (FAST) examination has become standard practice for emergency medicine providers. The FAST examination is now incorporated in the Advanced Trauma Life Support algorithm,[13] and the American College of Graduate Medical Education and the American Board of Emergency Medicine consider the FAST examination a core skill for emergency medicine residents.[14] In adult patients, a positive FAST examination performed during

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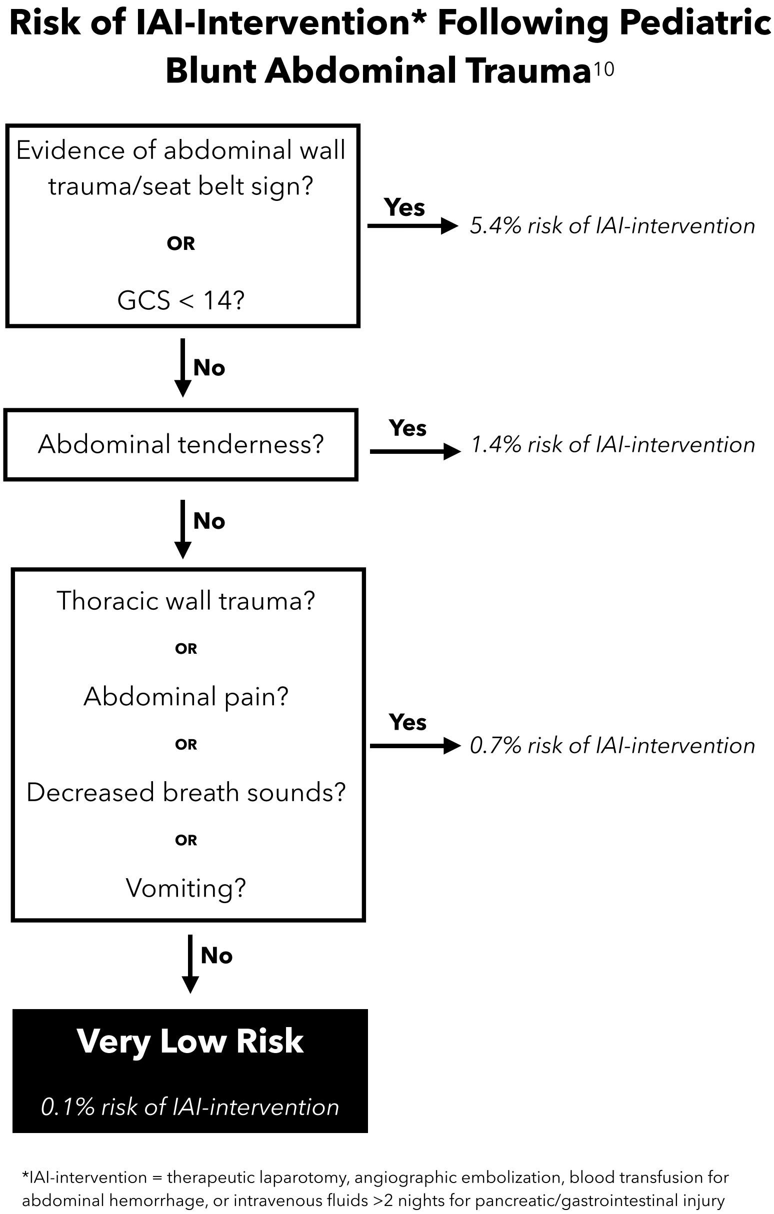

FIGURE 1. Risk of IAI intervention in pediatric BAT.

the initial trauma evaluation and resuscitation has proven useful for detection of IAI and accurate triage of hemodynamically unstable patients directly to therapeutic laparotomy.[15,16]

The FAST examination has several practical advantages as an imaging modality. It is inexpensive and can be repeated for real-time assessment of changes in clinical status. It is painless, and the study is not prohibitively time consuming. It is user dependent, so image quality may vary. Most importantly, it spares the patient from ionizing radiation.

Although the evidence for the FAST examination in the evaluation of adult trauma patients is compelling, and its advantages as an imaging modality are clear, there are limited data supporting its use in the assessment of pediatric patients with BAT.[17,18] There have been multiple systematic reviews, retrospective, and prospective studies surrounding the use of FAST in pediatric patients; however, the levels of sensitivity and specificity vary from 20% to 80% and 77% to 100%, respectively.[19–26]

While Sola et al[27] found that a negative FAST examination combined with normal liver enzymes was an effective screening tool to rule out IAI, eliminating the need for additional imaging, a systematic review and meta-analysis of prospective studies of point-of-care ultrasound (POCUS) FAST examinations determined that the FAST examination cannot be used in isolation to rule out IAI in children.[19] Review of recent data also suggests that a hemodynamically stable child with a positive FAST examination should receive a CT scan because of the high risk of IAI.[19,20] Approximately one third of children with IAI do not develop free intraperitoneal fluid, which contributes to the significantly high false-negative rate in some studies.[20,28,29] Furthermore, the addition of a FAST examination to standard care trauma assessment of pediatric patients does not improve clinical care, resource utilization, ED length of stay, missed intra-abdominal injuries, or hospital charges.[30]

FAST TECHNIQUE AND INTERPRETATION

The FAST examination evaluates for intraperitoneal and pericardial fluid using four standard views–the right upper quadrant (RUQ), left upper quadrant (LUQ), suprapubic, and pericardial views. Intraperitoneal fluid typically becomes visible in the suprapubic and RUQ views before it appears in the LUQ view.[31,32]

The preferred transducer for the FAST examination is generally the phased-array probe due to its low frequency and small footprint. The curvilinear probe may also be used, but its larger footprint may lead to obstruction from the ribs in the RUQ and LUQ views. Although pediatric patients often require less penetration due to their smaller size compared with adults, higher-frequency linear probes generally cannot assess for free fluid at an adequate depth for complete evaluation.

Patients should be examined in the supine position. The Trendelenburg and reverse Trendelenburg positions may also improve sensitivity for free intraperitoneal fluid in the upper quadrant and suprapubic views, respectively.[32–36] In adults, as little as 100-mL free fluid in the pelvis and 650 mL in the RUQ can be detected on FAST[37,38]; however, this value has not been quantified in pediatric studies. Fluid appears as dark, or anechoic, on ultrasound. If presentation for evaluation is delayed, the aging blood may appear hazy or gray and should not be overlooked. Fluid in any of the 4 views is considered a positive study. A negative FAST requires that all 4 areas have no free fluid.

Right Upper Quadrant View

The RUQ view allows operators to assess for intraperitoneal fluid in the right subphrenic space, hepatorenal recess (Morison's pouch), and at the inferior pole of the right kidney and the caudal liver edge (Fig. 2). This view also allows for evaluation for fluid in right pleural space, which can represent pleural effusion, or in the setting of trauma, hemothorax.

The transducer should be held on the right side of the patient's body with the probe marker oriented toward the patient's head and the beam angled slightly posteriorly, approximately 15 degrees. The intersection of the midaxillary line and an imaginary horizontal line extending from the xiphoid process can be used as a landmark to approximate optimal probe positioning.[39] The operator can then use the liver as an acoustic window to visualize the hemidiaphragm and hepatorenal recess. Sliding the transducer cephalad allows evaluation of the pleural space superior to the hemidiaphragm. Sliding the probe caudally allows visualization of the inferior pole of the kidney and the inferior edge of the liver (superior right paracolic gutter). Operators should ensure that they include evaluation of the caudal liver edge, as this has been shown to be the most commonly positive area of the RUQ view.[31,32]

Left Upper Quadrant View

The LUQ view allows operators to assess for free intraperitoneal fluid in the left subphrenic space, splenorenal recess, and surrounding the inferior pole of the left kidney and splenic tip (left paracolic gutter) as well as pathologic fluid in left pleural space (Fig. 3). The transducer is held on the left side of the patient's body with the probe marker oriented toward the patient's head. The intersection of the posterior axillary line and a horizontal line extending from the xiphoid process has been reported to predict proper localization of target structures (left hemidiaphragm, spleen, and left kidney) in more than 80% of adult FAST scans,[39] which is analogous to the often-taught "knuckles to the bed" approach when attempting to visualize the diaphragm on the LUQ view. The spleen is used as an acoustic window for visualization; however, its smaller size compared with the liver can make this view more challenging than the RUQ view. Sliding the transducer cephalad allows evaluation of the pleural space superior to the diaphragm, whereas sliding caudally allows visualization of the

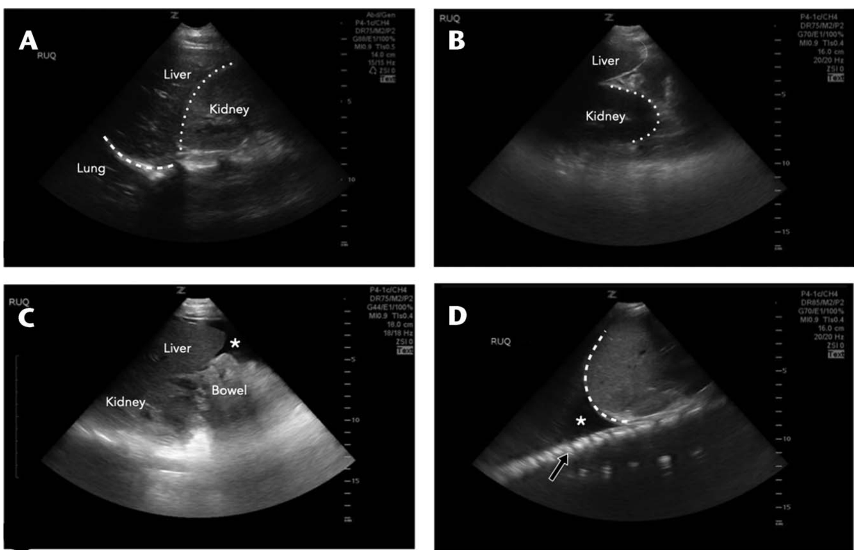

FIGURE 2. Right upper quadrant view. A, Standard RUQ view showing the diaphragm (dashed line) and hepatorenal recess (Morison's pouch, dotted line). B, Caudal RUQ view showing the inferior pole of the right kidney (dotted line) and the inferior edge of the liver (solid line). C, Positive RUQ view demonstrating anechoic free fluid at the inferior liver edge (black area marked by an asterisk). Of note, this patient had no visible free fluid in the subphrenic space or the hepatorenal recess, which illustrates the importance of scanning inferiorly for a complete evaluation. D, Positive RUQ view demonstrating fluid (black area marked by an asterisk) above the diaphragm within the pleural space. In the setting of trauma, this finding is concerning for hemothorax. Note that the spine (arrow) is visible above the diaphragm (dashed line) as a result of this fluid. Normally, the spine is not seen above the diaphragm because air in the lung prevents its visualization with ultrasound.

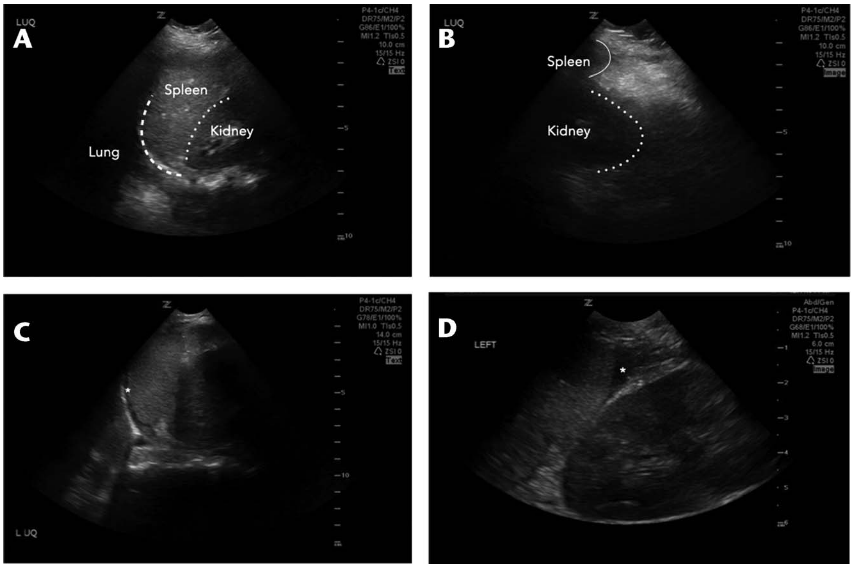

FIGURE 3. Left upper quadrant view. A, Standard LUQ view showing the diaphragm (dashed line) and splenorenal recess (dotted line). B, Caudal LUQ view showing the inferior pole of the left kidney (dotted line) and the inferior edge of the liver (solid line). Clear visualization of this area can be difficult because the spleen's smaller size (relative to the liver in the RUQ view) limits its function as an acoustic window. Bowel gas can also impede clear visualization of structures. C, Positive LUQ view showing anechoic fluid in the subphrenic space (black stripe marked with an asterisk). D, Positive LUQ view showing anechoic fluid at the inferior edge of the spleen (black area with asterisk).

inferior pole of the kidney and the inferior edge of the spleen for evaluation of the left paracolic gutter. In adults, LUQ free fluid is most commonly visualized in the subphrenic space, and contrary to the RUQ view, left-sided free fluid is least likely to be seen at the inferior pole of the left kidney.[31] However, a similar pattern of fluid distribution was not demonstrated in a single-center retrospective review of pediatric trauma patients; LUQ fluid was most often visualized caudal to the splenic tip. Only 1 patient in this study had fluid isolated to the LUQ, which was localized to the left subphrenic space.[32]

Suprapubic View

The suprapubic view assesses for free fluid in pelvis, the most dependent space in the peritoneum (Fig. 4). This area is evaluated in both the transverse and sagittal planes, ideally through a

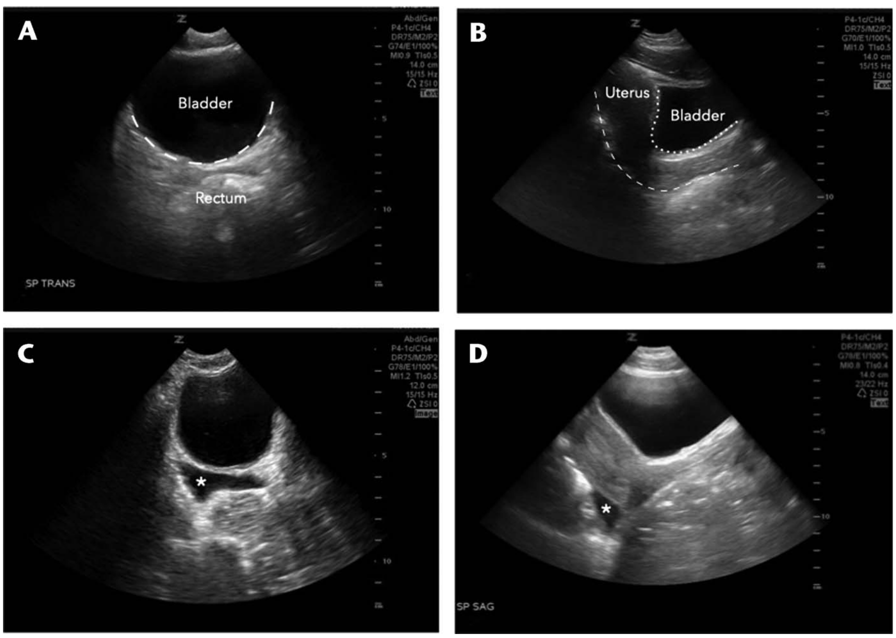

FIGURE 4. Suprapubic view. A, Transverse view (male) showing the bladder, rectum, and rectovesicular space (dashed line). B, Sagittal view (female) showing the bladder, uterus, vesicouterine space (dotted line), and rectouterine space (dashed line). C, Positive transverse view showing anechoic fluid in the rectovesicular space (black area with an asterisk). D, Positive sagittal view showing anechoic fluid in the rectouterine space (black area with asterisk).

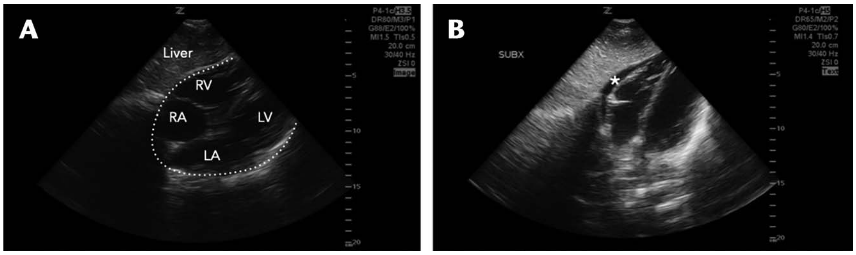

FIGURE 5. Pericardial view. A, Subxiphoid view of the heart showing the pericardium (dotted line) and 4 chambers of the heart. LA indicates left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle. B, A pericardial effusion appears as anechoic fluid (black stripe between the heart and liver noted by an asterisk).

full bladder for optimal visualization of the retrovesicular space (the rectovesicular pouch in males and the rectouterine pouch, or pouch of Douglas in female patients). For the transverse view, the transducer is placed at the midline of the abdomen just superior to pubic symphysis aimed toward the spine with the probe marker pointed to the patient's right. The bladder will appear as a round or "toast-shaped" anechoic structure. Aiming the transducer toward the head then slowly fanning caudally toward the feet and sweeping through the bladder allows visualization of the entire bladder. The sagittal view can be captured by rotating the transducer 90 degrees clockwise so that the probe marker is oriented toward the patient's head. In this orientation, the bladder will appear as a curved or triangular shaped anechoic structure, and aiming toward the right anterior iliac spine and fanning toward the left anterior iliac spine provides a complete view of the retrovesicular space.

Although the bladder is used as an anatomic landmark, it is the retrovesicular space that is the area of focus. When free fluid is present, it tends to collect lateral to the bladder, or in females, posterior to the uterus.[31] While the RUQ view is most commonly positive in adults with free intraperitoneal fluid,[31] the pelvis is the most common location of free fluid for pediatric patients.[32] This may be due the dependent position of the peritoneum or that many children have a small amount of physiologic pelvic free fluid.[40]

Pericardial View

In addition to free intraperitoneal fluid, the FAST examination evaluates for cardiac function and detects pericardial fluid and possible resulting tamponade (Fig. 5). This view is classically evaluated using the subxiphoid approach. With the probe marker pointing to the patient's right, the ultrasound probe is placed 1 to 2 cm beneath the xiphoid process aiming toward the patient's left shoulder using the liver edge as an acoustic window for visualization of the heart.[36] Fluid between the visceral and parietal layers of the pericardium appears as a black, anechoic layer beneath the white, echogenic pericardium.

Common Pitfalls and Limitations of the FAST Examination

Approximately 10% of children have a small amount of physiologic free fluid in the pelvis, which can be mistaken for pathologic free fluid, resulting in a falsely positive interpretation.[41] The FAST examination also cannot distinguish blood from other intraperitoneal fluid such as ascites. In addition, hypoechoic fat in the perinephric space, anterior abdominal wall, and pericardium can be mistaken for free fluid, resulting in unnecessary additional evaluation.[41–43] Another common pitfall is mistaking fluid in the bowel, stomach, or gallbladder for hemoperitoneum. The IVC may also be mistaken for free fluid in the RUQ view.

Because the bladder is the acoustic window used to evaluate the retrovesicular space, an empty bladder limits the evaluation of this space, resulting in an indeterminate FAST examination. Free fluid behind the bladder may also be missed because of posterior acoustic enhancement, an artifact where the posterior bladder wall appears excessively hyperechoic, which can impede the visualization of small amounts of fluid behind the bladder.

One of the limitations of the FAST examination is that it does not evaluate for hollow viscous injury. Although this is a rare consequence of BAT, there is significant mortality associated with these injuries.[44] It also does not evaluate for solid organ injuries, which are the most common injuries in pediatric BAT.[45] Oftentimes, solid organ injuries do not result in free intraperitoneal fluid due to the strength of the organ capsule. Finally, the FAST cannot evaluate for retroperitoneal hemorrhage. In each of these cases, a negative FAST examination would not exclude injury.

Summary

The FAST examination is a ubiquitous POCUS study and can be used to evaluate patients presenting after BAT. It is important to recognize that there are significant limitations of the FAST for diagnosing IAI. It should be interpreted in conjunction with the patient's clinical presentation and other available information, such as laboratory evaluation. In a low-risk patient, a negative FAST can help providers avoid the cost and risk of additional studies. However, patients with a positive FAST who do not meet very low-risk criteria should be evaluated further.

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