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Contrast enhanced ultrasound for the evaluation of blunt pediatric abdominal trauma

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ABSTRACT

Introduction: Blunt abdominal trauma is a common problem in children. Computed tomography (CT) is the gold standard for imaging in pediatric blunt abdominal trauma, however up to 50% of CTs are normal and CT carries a risk of radiation-induced cancer. Contrast enhanced ultrasound (CEUS) may allow accurate detection of abdominal organ injuries while eliminating exposure to ionizing radiation.

Methods: Children aged 7–18 years with a CT-diagnosed abdominal solid organ injury underwent grayscale/power Doppler ultrasound (conventional US) and CEUS within 48 h of injury. Two blinded radiologists underwent a brief training in CEUS and then interpreted the CEUS images without patient interaction. Conventional US and CEUS images were compared to CT for the presence of injury and, if present, the injury grade. Patients were monitored for contrast-related adverse reactions.

Results: Twenty one injured organs were identified by CT in eighteen children. Conventional US identified the injuries with a sensitivity of 45.2%, which increased to 85.7% using CEUS. The specificity of conventional US was 96.4% and increased to 98.6% using CEUS. The positive predictive value increased from 79.2% to 94.7% and the negative predictive value from 85.3% to 95.8%.

Two patients had injuries that were missed by both radiologists on CEUS. In a 100 kg, 17 year old female, a grade III liver injury was not seen by either radiologist on CEUS. Her accompanying grade I kidney injury was not seen by one of the radiologist on CEUS. The second patient, a 16 year old female, had a grade III splenic injury that was missed by both radiologists on CEUS. She also had an adjacent grade II kidney injury that was seen by both.

Injuries, when noted, were graded within 1 grade of CT 33/35 times with CEUS.

There were no adverse reactions to the contrast.

Conclusion: CEUS is a promising imaging modality that can detect most abdominal solid organ injuries in children while eliminating exposure to ionizing radiation. A multicenter trial is warranted before widespread use can be recommended.

Level of evidence: Level II; Diagnostic Prospective Study.

Injury is the most common cause of morbidity and mortality among children. Computed tomography (CT) with intravenous (IV) contrast is the gold standard imaging study for evaluating the abdomen in children with suspected injury. CT is used liberally since abdominal injuries are often suspected and are difficult to rule out with history and physical examination alone, leading to a greater than 50% rate of normal abdominal CT for trauma in the pediatric population, even at a pediatric trauma center [1]. Children have an increased risk of cancer related to the radiation exposure required to perform an abdominal CT, possibly as high as 1 in 300 in children younger than 5 years [2,3]. In addition there is a greater than 1 in 200 incidences of reaction to the IV contrast agent used [4], as well as a potential for renal insufficiency [5,6].

Sonography has been evaluated as a modality to replace CT for the evaluation of the potentially injured abdomen. Several studies in Europe utilizing contrast enhanced ultrasound (CEUS) for trauma evaluation are reported in the literature with variable results as outlined in Table 1 [7–13]. Clinical experience with the use of CEUS has been limited in the United States. The contrast agent Optison™ (GE Healthcare, Princeton, NJ) is FDA approved for use in adult echocardiography. Optison™ is an injectable suspension of perflutren gas encased in microspheres of human albumin. Perflutren is a stable gas that is not metabolized by the body and is eliminated through the lungs. The contrast agent acts as a marker of organ perfusion [14]. Recent reports describe the use of CEUS for the evaluation and monitoring of pediatric abdominal and pelvic solid tumors [15,16]. These prospective studies

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Table 1
Literature review of conventional US and CEUS vs CT in the evaluation of abdominal solid organ injury.

Author	Year	*N*	Study type	Subject age	Conventional US		CEUS	
					Sens/Spec	PPV/NPV	Sens/Spec	PPV/NPV
Armstrong	2017	18	P	Ped	45.2/96.4	79.2/85.3	85.7/98.6	94.7/95.8
Menichini et al. [7]	2015	73	R	Ped	38.8/100	100/12.8	100/100	100/100
Sessa et al. [8]	2015	256	R	Both	59/99	98/83	96/99	98/98
Mihalik et al. [9]	2012	20	P	Adult	n/a	n/a	79/100	100/20
Valentino et al. [10]	2010	133	P	Adult	70.2/59.2	74.7/53.7	96.4/98	98.8/94.1
Catalano et al. [11]	2009	156	P	Adult	79/82	89/69	94/89	94/89
Valentino et al. [12]	2008	27	P	Ped	57.1/86.7	80/68.4	92.9/100	100/93.8
Valentino et al. [13]	2006	32	P	Adult	45.7/91.8	84.2/64.1	91.4/100	100/92.5

Legend: *N* = number; Study Type: R = retrospective or P = prospective, Subject age: adult, pediatric (Ped) or both; Conventional US = grayscale/Doppler ultrasound, CEUS = contrast enhanced ultrasound, Sens/Spec = sensitivity/specificity, PPV/NPV = positive predictive value/negative predictive value.

demonstrated safety and efficacy in the pediatric oncologic population. Their use of CEUS allowed decreased exposure to the radiation required for CT imaging and decreased use of sedation that is usually required for magnetic resonance imaging in the high risk pediatric oncology patient [15–17]. Safety and efficacy of the contrast agent has also been reported in pediatric echocardiography evaluation [18].

This study aims to determine the sensitivity and specificity of CEUS compared to CT in the evaluation of children with blunt abdominal trauma.

1. Materials and methods

1.1. Patients

A prospective observational study was performed between July 2013 and October 2015 at Boston Children's Hospital, a level one pediatric trauma center. Hemodynamically stable children, aged 7–18 years and able to assent, who were admitted to our institution for the care of an abdominal solid organ injury identified on CT scan, were eligible for inclusion, regardless of body habitus. Written informed consent was obtained from the parents/guardians. Patients were excluded for: known cardiac or pulmonary injury/abnormalities, albumin or blood product sensitivity, pregnancy, inability to provide assent or inability to roll over for the exam. The study was approved by our institutional review board and was conducted under the United States Food and Drug Administration (FDA) Investigational New Drug (IND) 117,660.

1.2. Imaging technique

CTs performed at a referring institution were reinterpreted by pediatric radiologists at our hospital to confirm the presence and grade of any abdominal solid organ injuries. Study ultrasounds were performed within 48 h of injury, allotting sufficient time for thoughtful consent for this pilot study during a traumatic event. Grayscale and Doppler ultrasounds were performed by ultrasound technologists. Contrast-enhanced sonography was performed by one of two pediatric attending sonographers experienced in the technique and blinded to the results of the CTs. All images, including cineloops, were recorded and stored in a separate research file, which was deidentified. Ultrasound results were not reported to the trauma service and were not used to guide clinical care. Two separate radiologists underwent a brief tutorial in the interpretation of CEUS prior to interpreting the stored images and did not interact with the patients.

1.3. Conventional ultrasound

Grayscale and power Doppler ultrasound (conventional US) images were obtained before ultrasound contrast administration. Ultrasound (US) examinations were performed on a LOGIQ E9 machine (GE Healthcare, Milwaukee, WI) using a curved 1–5 MHz probe. Conventional grayscale images of the abdomen were obtained by ultrasound technologists according to standard departmental protocol, including transverse and sagittal views of the liver and biliary tree, gallbladder, kidneys and adrenal areas, spleen and bladder; and sagittal images of the pancreas, aorta and inferior vena cava. Transverse and sagittal power Doppler images of the liver, kidneys and spleen were also acquired. Approximately 15 min was required to perform the US examinations.

1.4. Optison™ administration and contrast enhanced ultrasound

Immediately following conventional grayscale and Doppler abdominal US, a CEUS was performed, using Optison™ as the contrast agent. Optison™ is a sterile, nonpyrogenic suspension of microspheres of human serum albumin with perflutren, approximately 1–10 μm in size. The perfluorocarbon undergoes pulmonary elimination. The vial requires resuspension by gentle mixing to produce a homogeneous, opaque white suspension that is used for peripheral intravenous injection [14]. Optison™ suspension was administered by syringe bolus using an existing peripheral IV in 0.5 ml aliquots for children weighing ≥20 kg and 0.3 ml for children weighing <20 kg. This was followed by a 10 ml normal saline flush. The Optison™ suspension was redosed once in 10 min as needed to survey all 5 solid organs including the liver, spleen, pancreas and kidneys. CEUSs were completed within minutes (mins) as each contrast bolus resulted in organ enhancement for only 1–2 mins, allowing sonography of up to 3 organs per dose.

CEUS was performed using a curved 1–5 MHz probe and contrast-specific software. Sequential cineloops of the liver, right kidney and pancreas were obtained following the first injection, with cineloops of the spleen and left kidney acquired after the second injection. Vital signs including blood pressure, heart rate, respiratory rate, and oxygen saturation were monitored at 5 min intervals during the study and 30 mins after completion of each contrast injection. An adverse reaction symptom questionnaire was completed before contrast injection, after each contrast bolus, and 30 mins after the final contrast infusion (Table 2).

1.5. Image interpretation

All conventional US, CEUS and CT studies were deidentified and stored in a research database within the Radiology Departmental Picture Archiving and Communication (PACS) system (Synapse®, Fujifilm

Table 2
Patient side effects questionnaire

Headache	Chest pain	Pruritus
Warm sensation/flush	Nausea/vomiting	Rash
Chills/fever	Wheezing	Palpitations
Flu-like symptoms	Dyspnea	Paresthesia
Fatigue/weakness	Pain at injection site	Dry mouth
Dizziness	Altered taste	Photophobia
Tremor	Burning eye sensation	Tinnitus
Visual blurring	Urticarial	Other

Administered precontrast, after each contrast bolus, and 30 mins after last contrast injection.