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The focused ultrasound examination for trauma

La exploración ultrasonográfica dirigida en trauma

R. Stephen Smith M.D.

Resumen

Objetivo: Revisar el conocimiento actual acerca del papel de la exploración sonográfica en un servicio de trauma.

Obtención de la información: Revisión selecta de la literatura (26 artículos).

Selección de la información: Se seleccionaron los artículos más importantes relacionados con exploración ultrasonográfica para trauma.

Resultados: La evaluación oportuna y precisa de los pacientes con riesgo de lesiones abdominales es aún una de las metas primarias del cirujano involucrado en la atención del trauma. La búsqueda actual de un abordaje diagnóstico óptimo en el trauma abdominal recientemente ha puesto a la sonografía al frente de un campo que ya incluye la exploración física, lavado peritoneal diagnóstico (LPD), la tomografía computada (TC), la laparoscopia diagnóstica, y a la laparotomía exploradora. Antes de que los cirujanos y los urólogos acepten a la sonografía como un componente vital en la evaluación de pacientes agudamente lesionados, se deben dirigir y responder apropiada y satisfactoriamente algunas preguntas importantes. ¿Puede llevarse a cabo una exploración sonográfica con precisión y rapidez en la sala de reanimación de trauma? ¿Debería ser incorporada esta modalidad en el abordaje diagnóstico de rutina para trauma? ¿Quién debe practicar e interpretar el estudio? ¿Cuáles son las ventajas del ultrasonido comparado con los métodos de evaluación habituales incluyendo el LPD y la TC? y ¿Mediante qué proceso debe ser introducida la sonografía para trauma en las instituciones? Afortunadamente, recientes adiciones a la literatura han hecho mucho para responder estas incógnitas.

Conclusión: Es aparente que la sonografía puede ser practicada con una precisión aceptable en la evaluación temprana del paciente agudamente lesionado y es de gran valor en el diagnóstico temprano del hemoperitoneo.

Abstract

Objective: To review recent notions about the role of sonographic examination in the trauma setting.

Data collection: Selective review of the literature (26 articles).

Data selection: The most relevant papers dealing with ultrasound examination for trauma were selected.

Results: The accurate and timely evaluation of the patient at risk for abdominal injury remains one of the primary goals of the surgeon involved in trauma care. The ongoing quest for the optimal diagnostic approach for abdominal trauma has recently brought sonography to the fore of a field that already includes physical examination, diagnostic peritoneal lavage (DPL), computerized tomography (CT), diagnostic laparoscopy, and exploratory celiotomy. Before surgeons and emergency physicians accept sonography as a vital component of the evaluation of acutely injured patients, several salient questions must be properly addressed and satisfactorily answered. Can a rapid and accurate sonographic examination be performed in the setting of the trauma resuscitation room? Should this modality be incorporated into the routine diagnostic approach for trauma? Who should perform and interpret the study? How should the focused examination for trauma be performed? What are the advantages of ultrasound as compared with standard methods of evaluation including DPL and CT?, and by what process should sonography for trauma be introduced into the individual institution? Fortunately, recent additions to the literature have done much to address these questions.

Conclusions: It is apparent that sonography can be performed with acceptable accuracy in the setting of the early assessment of the acutely injured patient and is of great value in the early diagnosis of hemoperitoneum.



Department of Surgery, University of Kansas School of Medicine, Wichita, KS, USA.

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Correspondencia: R. Stephen Smith M.D. Suite 200-818, North Emporia, Wichita KS. 67214,

USA. Phone: (316) 2685-990. E-mail: rsmith3@kumc.edu

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Focused abdominal sonography for trauma

The accurate and timely evaluation of the patient at risk for abdominal injury remains one of the primary goals of the surgeon involved in trauma care. The ongoing quest for the optimal diagnostic approach for abdominal trauma has recently brought sonography to the fore of a field that already includes physical examination, diagnostic peritoneal lavage (DPL), CT, diagnostic laparoscopy, and exploratory celiotomy. Before surgeons and emergency physicians accept sonography as a vital component of the evaluation of acutely injured patients, several salient questions must be properly addressed and satisfactorily answered. Can a rapid and accurate sonographic examination be performed in the setting of the trauma resuscitation room? Should this modality be incorporated into the routine diagnostic approach for trauma? Who should perform and interpret the study? How should the focused examination for trauma be performed? What are the advantages of ultrasound as compared with standard methods of evaluation including DPL and CT?, and by what process should sonography for trauma be introduced into the individual institution? Fortunately, recent additions to the literature have done much to address these questions.

Can sonography be performed in the trauma setting?

In the United States, the use of ultrasound technology for evaluation of trauma patients was essentially neglected until the past 5 years. Fortunately, our surgical colleagues in Asia and Europe, where sonographic competence is a requirement for surgical trainees, have used sonography as an integral component of the trauma evaluation for almost two decades. Over the past 10 years, numerous published series documenting the usefulness and accuracy of trauma sonography have appeared in the Japanese and European literature.¹⁻⁴ Recently, series from American, Asian, and European centers published in the American literature have confirmed the previous findings of our international colleagues and have introduced the concept of trauma sonography to North America. In an early experience, Kimura and Otsuka⁵ prospectively evaluated the use of sonography performed in the emergency department for the detection of hemoperitoneum in injured patients. Their initial favorable report provided the impetus for further investigations in North American trauma centers.⁵ Tso *et al.*⁶ evaluated the ability of trauma fellows (postgraduate year-6) with 2 hours of training to perform sonography in the trauma setting. Sonographic imaging was performed within 1 hour of patient arrival at a well-known trauma center. Sonographic findings were then correlated with DPL or CT. Sonograms performed by trauma fellows

were interpreted by staff radiologists who were unaware of the trauma fellows' interpretation to assure that adequate scanning techniques were used. Over an 8-month period of study, sensitivity, specificity, and accuracy were 69%, 99%, and 96%, respectively. Tso *et al.*⁶ concluded that emergency department sonography was a valuable adjunct in the evaluation of patients at risk for abdominal trauma.

Rothlin *et al.*⁷ assessed their experience with emergency sonography performed by surgeons for the assessment of significant abdominal or thoracic trauma between 1989 and 1991. They emphasized that sonography was a particularly useful diagnostic adjunct in patients with a negative or equivocal physical examination. They reported a sensitivity of 90% and specificity of 99.5%. Bode *et al.*⁸ retrospectively reviewed their ability to use ultrasound to predict a therapeutic laparotomy in 312 trauma patients with nontrivial abdominal injury. In their institution, sonography was a routine component of the standard trauma evaluation. They reported excellent results in this seriously injured group of patients: sensitivity, 93%; specificity 100%; accuracy, 99%; positive predictive value, 100%; and negative predictive value, 99%. More recently, Wherrett *et al.*⁹ assessed the role of emergency department sonography in the triage of 69 seriously injured (mean Injury Severity Score, 32) patients who presented with hypotension. In this group of patients, 22 were found to have a hemoperitoneum based on a rapid ultrasound examination. Nineteen of 22 patients with positive sonographic findings required urgent laparotomy, whereas none of the 47 patients with a negative sonographic examination required immediate abdominal exploration. Wherrett *et al.* concluded that emergency department sonography was an expedient method for determining the need for emergency celiotomy in the hypotensive injured patient. Furthermore, they concluded that a negative sonogram essentially eliminated the abdomen as a source of significant hemorrhage in the injured patient. Based on a significant body of literature, it is apparent that sonography can be performed with acceptable accuracy in the setting of the early assessment of the acutely injured patient and is of great value in the early diagnosis of hemoperitoneum.

Should sonography be performed in the trauma setting?

All of the current methods for the evaluation of abdominal trauma have advantages and pitfalls. Physical examination is not routinely accurate in the patient with multiple injuries, particularly if ethanol, pharmaceuticals, or brain injury have altered the patient's level of consciousness. Paracentesis is essentially obsolete due to a high

false-negative rate and lack of organ specificity. DPL, as initially described by Root *et al*,¹⁰ is extremely sensitive and will detect relatively small quantities (< 30 ml) of blood in the peritoneal cavity but is an invasive technique with a complication rate of 1% to 5%. Although this technique may be performed by a physician with rudimentary surgical skills, DPL has been associated with a high rate of negative and nontherapeutic laparotomies when traditional cell count criteria are used. CT, since its introduction in the late 1970's, has become the *de facto* gold standard for the nonoperative evaluation of abdominal trauma due to its ability to provide extensive organ-specific information concerning the peritoneal cavity, the pelvis, the retroperitoneum, and the thorax. Unfortunately, logistical problems involving patient transport, monitoring, and ongoing resuscitation still exist in most trauma centers, and this modality is clearly contraindicated in the unstable patient. Additionally, CT is expensive and requires exposure of the patient to ionizing radiation.

Sonography is portable, noninvasive, and does not involve ionizing radiation. There are no complications that result from the use of sonography in the trauma setting. These factors make performance of serial examinations at the bedside either in the emergency department or the intensive care unit both practical and useful because there is no need to transport potentially unstable patients to the radiology suite. There are no absolute contraindications to sonography; it may be used in pregnant patients who are not candidates for CT or patients with a history of previous abdominal procedures in which peritoneal lavage is more difficult. Boulanger *et al*¹¹ developed and prospectively assessed an algorithm for the evaluation of patients with blunt trauma that used focused abdominal sonography for trauma (FAST) as the initial modality for the evaluation of the abdomen. This group reported that sonography was performed rapidly with the majority of examinations performed in less than 3 minutes and provided information that enhanced and expedited patient care. They report an accuracy of 95%, negative predictive value of 96%, and a positive predictive value of 82%. Based on this experience, they concluded that sonography was an essential component for the evaluation of blunt trauma victims and was the best initial study to screen the abdomen in the setting of acute trauma. The usefulness of sonography in screening mass casualties was assessed by Sarkisian *et al*¹² following the devastating Armenian earthquake of 1988. This group retrospectively reported their experience with sonography as the primary method for the abdominal evaluation of over 400 casualties brought to their tertiary care facility in the first 72 hours following the 1988 earthquake. Two ultrasound scanners were positioned in the initial triage area of their facility. The time required for the performance of sonography under these difficult conditions was approximately 4 minutes per patient. In most patients, a single screening examination was performed; however, in 130 patients serial sonographic evaluations were required. Sarkisian *et al* reported that 12.8% of the 400 patients initially screened were found to have signi-

ficant intraperitoneal or retroperitoneal injuries. They reported no false-positive examinations and found false-negative examinations in only 1% of patients. Based on their experience, they concluded that trauma sonography was particularly useful in the mass casualty scenario. Although FAST appears to be a major advance in the diagnostic evaluation of injured patients, there are some potential disadvantages associated with the technique. Sonography reliably detects only a significant hemoperitoneum (> 150 ml) and therefore, the early detection of hollow viscus injuries may be difficult. Branney *et al*¹³ attempted to determine the minimum volume of peritoneal fluid required before sonographic detection was probable. In this interesting and well-planned series, diagnostic peritoneal lavage was performed in 100 patients according to standard protocols. Sonography was used to continually scan Morison's pouch in real time as the lavage fluid was infused. Sonographers were blinded to the amount of fluid that had been infused into the peritoneal cavity as well as the rate of infusion. The mean volume of fluid required before sonographic detection was 619 ml. A fluid collection in Morison's pouch of less than 400 ml was detected in only 10% of cases. Branney *et al* concluded that the volume of fluid in the peritoneal cavity that was required to produce a positive FAST examination was greater than previously estimated. The findings of Branney *et al* would be more conclusive if sonographic imaging of the splenorenal recess and the pouch of Douglas had been performed in addition to assessment of Morison's pouch. Additionally it is to be expected that a few seconds will elapse before free fluid infused through a catheter placed through the anterior abdominal wall into the peritoneal cavity will gravitate to dependent areas such as Morison's pouch. Therefore, the study by Branney *et al* may overestimate the amount of intraperitoneal fluid required to produce sonographic detectability. Shih *et al*¹⁴ assessed the accuracy of sonography for the detection of hollow viscus injuries in 34 victims of blunt trauma. In this series, the initial sonographic evaluation failed to identify the presence of peritoneal fluid in 20% of patients with a bowel injury. Shih *et al* emphasized the importance of serial physical and sonographic examinations in patients with high potential for bowel injury and suggested that additional diagnostic modalities, such as DPL, are helpful in this group of patients. Kern *et al*¹⁵ also reported difficulty in the early diagnosis of isolated hollow viscus injury with FAST. In this retrospective study involving 518 patients, five of eight false-negative sonographic examinations were isolated hollow viscus injuries with luminal intraperitoneal fluid collections.

Although FAST may not provide for the early diagnosis of hollow viscus injury in every case, this is a relative disadvantage. None of the currently available diagnostic modalities are 100% accurate in this difficult subset of patients. Sonography has many advantages as compared with other available methods of abdominal evaluation. As such, it appears to be the initial screening test of choice for blunt abdominal trauma in centers where it is immediately available.

Who should perform trauma sonography?

This question addresses the most controversial aspect of trauma sonography in North American centers. Interestingly, the answer to this question may actually lie in the economic rather than the clinical realm. German and Japanese surgeons have incorporated sonography into the surgical armamentarium for some time. In fact, surgical trainees in Germany are required to document a minimum number of sonographic examinations ($n = 500$) during training before they are eligible for certification examinations.

Unlike Japan and Germany, ultrasonography in the United States has remained primarily in the domain of radiology. Although obstetricians and some vascular surgeons have performed limited ultrasound examinations in the clinical setting, most clinicians have continued to depend on technologists or radiologists to perform specific sonographic evaluations. Recently, several American centers have documented that surgeons, surgical residents, emergency medicine practitioners, and others are capable of performing a focused ultrasound examination for trauma with sensitivity, specificity, accuracy, and predictive values equivalent to series performed by radiologists.¹⁶⁻¹⁸ Ma *et al*¹⁹ prospectively studied the ability of emergency physicians to perform the FAST examination in a level 1 trauma center. Ma *et al* sonographically examined 245 patients who then received a confirmatory study such as CT scan, DPL, exploration, or echocardiography. This group reported sensitivity of 90%, specificity of 99%, and accuracy of 99%. Kern *et al* reviewed the ability of senior surgical residents (postgraduate year-4, postgraduate year-5) to perform trauma sonography independently after an 8-hour introductory course that included a lecture component and practical session in which 10 practice examinations were performed on live models. Kern *et al* reported a sensitivity of 73%, specificity of 98%, and accuracy of 96.1%. This group concluded that the FAST examination is quickly learned by surgeons in training and may be introduced into the diagnostic armamentarium of surgeons rapidly. Additionally, this group documented that a surgeon-directed sonography program reduced the number of CT scans ordered by the trauma service thereby reducing charges to trauma patients. Therefore, sonography may be performed by a variety of physicians (or technologists). However, it is unlikely that any member of the trauma team would possess as much information concerning the minute-to-minute status of a trauma patient and the optimal timing of the ultrasound examination as the trauma surgeon. Furthermore, unlike the radiologist or sonographic technician, the surgeon is already present at the bedside during the evaluation and resuscitation of the trauma patient and can accomplish the sonographic assessment in a more timely fashion. Boulanger *et al*²⁰ documented that surgeon-performed trauma sonography was accomplished in 2.6 ± 1.4 minutes in a trauma center in which sonography was a standard component in the evaluation of injured patients. Conversely, Healey *et al*²¹ demonstrated that radiologist-performed sonography in the emergency

setting required a significantly longer time period. In the experience of Healey *et al*, radiologist-performed trauma sonography averaged approximately 35 minutes (average time for arrival of ultrasound machine in the emergency department, 17.3 minutes; average time from arrival of ultrasound machine in the emergency department until initiation of the FAST examination, 7.0 minutes; average length of examination, 10.6 minutes).

To provide ultrasound technologists or radiologists assigned to the trauma team on a 24-hour basis would require additional hospital expenses in the form of salaries or on-call fees. Thomas *et al*²² calculated that the introduction of a surgeon-performed sonography program into their level 1 trauma center produced a cost reduction of approximately \$100,000 per year in their institution. Therefore, surgeon-performed ultrasound appears to be cost effective. Ali *et al*²³ demonstrated that a concise workshop that included both a didactic session as well as a limited practical session greatly enhanced the ability of attending physicians and residents to perform the sonographic examination for trauma. During the practical session, hands-on experience with sonography was obtained by examining live models. Additionally, videotape of positive sonographic findings were available for review. This group concluded that such courses were useful in teaching basic sonographic skills and were an essential component of ultrasound training for trauma physicians.

How is the trauma ultrasound examination performed?

The purpose of the bedside ultrasound evaluation in injured patients is to detect the presence of a clinically significant amount of fluid (blood) in the peritoneal cavity or pericardial space. When the patient is supine, free peritoneal fluid accumulates first in the most dependent regions of the abdomen; therefore, the sonographic examination is directed at these areas. Detailed organ-specific information is not sought nor routinely obtained during the FAST examination. The technique of the FAST for blunt trauma patients has been well established in several previous articles.¹⁶⁻¹⁸ To perform the ultrasound examination, four specific areas of the abdomen and thorax are assessed: Morison's pouch, the splenorenal recess and the left subdiaphragmatic space, the pouch of Douglas, and the pericardial space. Some authors²⁴ have reported scanning other areas such as the pericolic gutters and the midabdomen to detect loops of bowel floating in blood, but we have not found these additional areas of significant benefit. The smallest amount of free fluid in the peritoneum that can be detected with sonography depends on the volume of the individual patient's peritoneal cavity as well as other factors such as the presence of adhesions. In the average adult, a minimum of 150 ml of fluid must be present before sonographic findings will occur. Therefore, isolated hollow viscus injuries may be very difficult to detect immediately following injury. When 250 ml to 500 ml of blood or fluid is present, the sonographic examination should reliably demonstrate

the typical anechoic appearance of blood in at least one of the areas evaluated with sonography.¹³ If blood is detected in two of the three regions of the peritoneum, 1 l of blood is usually present. The sensitivity of the ultrasound examination for trauma is improved if a second examination is performed 30 minutes to 6 hours after the initial study.¹⁶⁻¹⁸

Although not a component of the basic FAST examination, sonography has been successfully used to detect the presence of hemothorax and pleural penetration in thoracic injury. Ma *et al*²⁵ retrospectively compared emergency department sonography with standard chest radiographs for the identification of hemothorax. A third diagnostic test (CT scan) or tube thoracostomy placement was performed in each case to confirm the findings of sonography or chest radiograph. Sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for both diagnostic modalities were found to be identical. Ma *et al* concluded that sonography was equal to routine radiographs for the detection of hemothorax and suggested that the use of sonography could expedite this diagnosis. Fry *et al*²⁶ in an innovative study, assessed the ability of experienced surgical sonographers to use high resolution B-mode sonography to determine the course of tangential penetrating wounds of the abdomen or thorax. Fry *et al* used a 7 MHz transducer to trace wound tracts and to determine whether peritoneal or pleural penetration had occurred. Sonographic findings were confirmed by operative exploration, laparoscopy, chest radiography, or serial physical examination. Fry *et al* reported positive and negative predictive values of 100%. Fry *et al* suggested that the use of sonography in this group of patients may replace other modalities such as wound exploration and serial chest radiography.

What are the advantages of trauma ultrasound?

Sonography is portable and can easily be performed at the bedside in the emergency department.¹⁻²⁶ Because no ionizing radiation is involved, serial examinations may be performed as often as desired.¹⁶⁻¹⁸ Because sonography is a noninvasive technique, there are no complications. There are no contraindications to the use of sonography; the technique may be used in pregnant patients and patients with previous abdominal operations. As compared with other diagnostic modalities, such as CT and DPL, sonography performed by surgeons is cost effective.^{15,22}

How do I introduce ultrasound for trauma into my institution?

The introduction of the ultrasound examination for trauma into a hospital is best accomplished when a spirit of cooperation exists between surgeons, radiologists, ultrasound technologists, and emergency medicine physicians. Unfortunately, turf battles have prevailed over improved patient care in many trauma centers. The surgeon or emergency medicine physician interested in performing trauma sonography gains credibility by attending a well organized ultrasound course that provides both didactic lectures and extensive hands-on experien-

ce.^{15,22,23} Each department of surgery or emergency medicine should develop and adhere to specific criteria for privileges in trauma sonography. A brief period of proctoring seems appropriate for the neophyte sonographer, but the number of cases required before proficiency is achieved remains controversial.^{6,15-29} Ultrasound experience should be documented, and results of sonographic examinations should be confirmed by other diagnostic modalities until the trauma physician develops significant expertise in trauma sonography.

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