Digital Hand-held Sonography Utilised for the Focused Assessment with Sonography for Trauma: A Pilot Study‡

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Abstract

***Objective**: To evaluate the accuracy of the focused assessment with sonography for trauma (FAST) exam performed with a digital hand-held ultrasound machine in the emergency evaluation and resuscitation of trauma victims. **Introduction**: The FAST exam is a valuable screening tool in the evaluation of abdominal trauma. New digital ultrasound units have recently become available which can be hand-carried by clinicians responding to the earliest phases of trauma care. **Materials and Methods**: Forty-seven victims of blunt trauma and 3 victims of penetrating trauma underwent FAST examinations performed by an attending trauma surgeon. Scans were performed with a Sonosite™ 180, 2.4-kg machine utilising a 5-2 MHz curved array transducer. The results of the hand-held FAST were compared with formal sonographic examinations performed by radiology department personnel, computed tomographic (CT) studies, operative findings and ultimate hospital course. **Results**: In victims of blunt trauma, 7 of 8 true fluid collections were detected, and 38 out of 39 cases without the presence of fluid were correctly excluded. There was 1 false positive and 1 false negative determination, resulting in a sensitivity of 86%, specificity of 97%, positive predictive value of 88%, and a negative predictive value of 97%. The overall accuracy was 96% for victims of blunt trauma. The technique expediently detected intra-peritoneal bleeding in 2 victims of lateral penetrating abdominal trauma. Utilised as the initial component of a diagnostic protocol, no inappropriate management strategies were suggested. **Conclusions**: Digital hand-held sonography by clinicians can accurately allow the early performance of FAST exams. This exam may accurately and safely extend the physical senses of the examining physician.*

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Key words: Abdominal injuries, FAST, Hand-held ultrasound, Resuscitation, Sonography, Ultrasound

Introduction

On a global basis, the use of ultrasonography to assist clinicians in obtaining timely diagnoses in abdominal trauma is not particularly new. The first reported case of sonography to evaluate patients with splenic haematomas was in 1971,[1] and by 1976, series of up to 70 victims of blunt trauma were available.[2] Although initial North American interest in this technique was limited, there has been a veritable explosion in North American interest in the last decade. Although the first report by a North American surgeon was only in 1992,[3] the focused assessment with sonography for trauma (FAST) exam has replaced the diagnostic peritoneal lavage (DPL) as the initial abdominal screening test after blunt trauma in a majority of North American Trauma Centres.[4] A majority of US centres also use this technique to rapidly evaluate patients after penetrating injury.[4] The Australasian Trauma Society has issued a formal statement that the immediate availability of bedside ultrasound is a required standard in the assessment of injured patients.[5]

A recent international consensus conference developed recommendations to aid clinical sonographers, and to standardise the technique and nomenclature.[6] One of the topics suggested for future study was an examination of the potential role that smaller compact portable ultrasound machines might play in the early diagnosis of traumatic

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abdominal injury. Shock is synonymous with cellular hypoxia which is time-critical. Frequently, even with successful resuscitation and control of a haemorrhage, patients will succumb to the lethal after-effects of a prolonged oxygen debt.[7-9] Any device that has the ability to detect the source of haemorrhage quicker may have an impact on patient survival. To this end, the section of Trauma Services at the Vancouver Hospital and Health Sciences Centre (VHHSC) recently had the opportunity to use a digital, 2.4-kg hand-held ultrasound machine to rapidly examine multiply injured patients during the initial trauma resuscitation. This allowed us to evaluate the performance of a portable hand-held ultrasound machine in the emergency evaluation and resuscitation of trauma victims.

Materials and Methods

The VHHSC is the provincial trauma referral centre. Critically-injured patients are resuscitated by a trauma team approach led by both an attending emergency physician and a trauma surgeon. A timely sonographic abdominal assessment following international guidelines has been the initial screening test for blunt abdominal trauma since 1996 at the VHHSC.[6] Radiology residents in training, with a later staff review, have and continue to routinely carry out this examination. An excellent report on the results of this service has recently been published.[10]

To evaluate the potential of the digital hand-held ultrasound unit used by clinicians in the earliest phases of a trauma resuscitation, FAST scans were performed prior to any other abdominal imaging investigations by an attending staff trauma surgeon. A Sonosite™ 180 (Sonosite, Inc., Bothell, WA), 2.4-kg ultrasound machine with a 5-2 MHz curved array transducer was used. Forty-seven victims of blunt trauma and 3 victims of penetrating trauma were examined in either the emergency department (48) or a critical care unit of Vancouver General Hospital (2). The results of the hand-held FAST (HHFAST) were compared with formal sonographic examinations performed by radiology department staff (formal (F)FAST), computed tomographic (CT) studies, operative findings and the ultimate hospital course. Although the next appropriate management strategy was recorded, the HHFAST examinations were not intended to influence the patients' clinical care, except when a positive HHFAST in a hypotensive patient suggested immediate operative intervention. The ultimate hospital course was determined by collating demographic information recorded in the British Columbia Trauma Registry with a complete chart review. The study was approved by both the University of British Columbia Ethics Approval and the VHHSC Research Affairs Committees.

Results

The study comprised 41 male and 9 female patients, with an average Injury Severity Score (ISS) of 24 (SD = 16) indicating a severely injured cohort of patients. Three patients (6%) were victims of penetrating trauma, 2 from handguns, and 1 from a stab wound. Twenty-seven (54%) patients were injured as a result of being occupants involved in motor vehicle crashes (MVCs), 4 (8%) from being struck by vehicles, 6 (12%) from falls, 4 from motorcycle crashes (8%), 2 (4%) from skiing or snow-boarding crashes and 4 (8%) from personal assaults. The average length of stay was 19 days (SD = 21 days), with 28 (56%) patients being admitted to an intensive care unit. Eight patients (16%) died: 2 (4%) in the operating room due to shock, 1 unexpectedly in the ward from a pulmonary embolus, and 5 after having aggressive supportive care withdrawn due to devastating head injuries. Of the survivors, 30 (60%) were discharged home or were capable of leaving hospital against medical advice, 4 (8%) were transferred back to the original referring hospital and 8 (16%) were transferred to a rehabilitation hospital.

A subsequent positive diagnosis of intra-peritoneal free fluid by any other radiological technique was considered the gold standard comparison for the purposes of this study. At initial analysis of the victims of blunt trauma, 7 out of 8 true fluid collections were detected and 1 false positive determination made. This resulted in both a sensitivity of 88% and a positive predictive value of 88% (Table I). There was 1 false negative determination by the hand-held ultrasound, with a diagnosis of free intra-peritoneal fluid being made later by a formal radiological survey performed by the radiological resident utilising a standard ultrasound machine. A CT scan, which revealed a small amount of free intra-peritoneal fluid, confirmed this and this patient ultimately underwent a non-therapeutic laparotomy. There were 38 correct negative determinations that were corroborated by the radiological studies, giving a specificity of 97%. With 1 false negative, this gave a negative predictive value of 97%. The overall accuracy of the hand-held technique was 96% (Table I).

For victims of penetrating trauma, 2 patients with gunshot wounds to the flank had the immediate identification of

TABLE I: PERFORMANCE OF THE HHFAST EXAM

	True status of intra-peritoneal fluid		
Sonosite™	Fluid present	Fluid absent	Total
Positive determination	7	1	8
Negative determination	1	38	39
Total	8	39	47

HHFAST: hand-held focused assessment with sonography for trauma

intra-peritoneal fluid, which expedited operative planning. The third patient suffered a stab wound to the anterior abdominal wall, and did not have intra-peritoneal fluid detected at the initial examination. Free fluid was seen on a CT scan done 120 minutes after the initial HHFAST scan and the patient had a therapeutic laparotomy.

Ultimately, 5 of the blunt trauma victims and all 3 of the penetrating trauma patients had laparotomies, with 1 non-therapeutic laparotomy occurring in the blunt trauma group. Considering the hospital course, the HHFAST quickly and correctly identified obvious free intra-peritoneal fluid in all 5 haemodynamically unstable patients who required a therapeutic laparotomy. There were 5 haemodynamically stable patients with free fluid, 3 of whom were successfully managed non-operatively. There were 2 failures of non-operative management. One patient had multiple splenic artery pseudo-aneurysms that were not amenable to angio-embolisation. Another patient underwent a laparotomy based on the clinical examination despite the absence of any abnormal imaging studies. Despite negative ultrasound examinations, 18 abdominal CT examinations (46% of the group) were done with the identification of 1 renal laceration that was not associated with free fluid and was managed non-operatively.

Discussion

This study evaluated the performance of a digital hand-held ultrasound system for expedited clinician-performed FAST examinations in the course of a critical care-trauma surgical practice. In addition to comparing one device against another, it also examined the philosophy of enabling early clinician-performed sonography. The acutely traumatised patient is an excellent proving ground for clinician-performed sonography, as radiologists will not always be immediately available. Physical findings in the multiply injured are often unreliable because of the neurologic status, the presence of analgesic, sedative and other psychotropic medications, and other distracting injuries.[11,12] With these confounders, a quick non-invasive and repeatable screening test is immensely valuable.[13,14] The accurate utilisation of sonography for this purpose has been repeatedly documented. The published evidence reflects the fact that any discipline or individual that undertakes the commitment to learn, practise, and review their results can benefit patients, be they radiologists,[10,15] emergency physicians,[16-18] or surgeons[3,13,19-24] either trained or in training.

This study was an effectiveness rather than an efficacy study. There were both conservative and time biases built into the study that potentially acted against the HHFAST. In cases where no other imaging was obtained, the formal ultrasound scan obtained by the radiology resident was considered the gold standard investigation. This is a conservative bias against the HHFAST approach, as there was at least 1 case where the HHFAST yielded a true but conflicting result compared to the FFAST. For example, 1 patient was examined after a serious MVC and the clinician-performed HHFAST scan was positive. The formal examination obtained by the radiology resident was considered negative, but when a CT scan confirmed the presence of free fluid, this case was considered a true positive HHFAST for comparison purposes. There was also a sequence bias with the HHFAST being performed prior to any other investigations. In the acute trauma situation, it is recognised that initial negative examinations may become positive with time due to the accumulation of intra-peritoneal fluid, from either ongoing bleeding, or from third spacing after resuscitation.[13,15,17,25]

The fact that 47% of the patients with negative exams had an abdominal CT scan illustrates that despite a primary reliance on sonography, our institution practises the liberal use of CT. CT scans were obtained for clinical indications, despite the negative findings on the FFAST. Recognised causes of an indeterminate FAST exam include subcutaneous emphysema and obesity.[26] It has been noted that the FAST exam will not detect all abdominal visceral injuries, especially hollow viscus, or those without a haemoperitoneum,[13] potentially missing up to 29% of injuries in certain situations if there is no emphasis on combining the FAST results with the clinical picture.[27,28] This remains a concern with the HHFAST in less seriously injured patients in whom large amounts of fluid may not have had time to accumulate. The risk of false negative determinations, based on one examination only, may be greater in the less seriously injured as the exams are done earlier after injury. It will be imperative for safety that users without great sonographic experience not rely on negative exams without further correlative studies. A strength of the FAST technique, however, is that there is no interference with further testing, be it formal repeat sonography or CT scanning.

We believe that there is tremendous potential for digital hand-held sonographic investigations. Truly hand-held sonography would also make it much simpler to re-image patients. We believe it is probable that in the future, most clinicians will utilise sonography whenever they interact with a patient as a simple extension of the physical examination. On an individual patient level, with a greater availability and portability in equipment, as well as a greater number of clinicians comfortable in its use, repeat sonography should be logistically easier to provide. Numerous authors have either shown or predicted better test performance, with potentially fewer false negatives with the routine re-examination of injured patients despite

an initial negative FAST.[13,16,17,29,30] Early in typical trauma care, it might even be feasible to dedicate 1 sonographic unit to each patient for frequent, standardised re-imaging much like the current bedside foetal heart monitor now used, especially in those patients with unstable or uncertain haemodynamic status.

Trauma sonography has taken on two congruous yet distinct roles. One is the early localisation of the major site of injury in unstable trauma victims requiring urgent surgical interventions, and the other newer role is that of definitively excluding stable patients from further abdominal imaging procedures. It is likely that the HHFAST technique will save the most lives in the former role. The most critical target population is those unstable patients with massive intra-peritoneal haemorrhage. This is a select group, as it has been reported that only 10% of patients with blunt abdominal trauma, with haemoperitoneum from intra-abdominal injury, remain hypotensive despite aggressive fluid resuscitation, and thus require an urgent life-saving laparotomy.[23,31] Every second counts in this group though, and it is in this group wherein an early FAST exam might most expedite management. Is this realistic? Pre-hospital physicians and paramedics are typically very busy and cannot devote a large amount of time to pre-hospital imaging even if they have sonographic training. Fortunately, it has been shown that massive haemoperitoneum can quickly be detected with a single view of Morrison's Pouch. There are studies demonstrating this in 82% to 90% of hypotensive patients with an abdominal source.[21,32] With some experience, this can also be done very quickly. The detection of a massive haemoperitoneum by viewing only Morrison's Pouch required an average of 19 seconds when a massive haemoperitoneum was present in one study.[21] The performance of bedside echocardiography with this same hand-held unit was also found to fall short of standard echocardiography in critically-ill patients.[33] Echocardiography is a technique that is many degrees more demanding than a simple appreciation of gross free fluid. Presumably, one simple sonographic image from the MP location might differentiate a patient with a massive haemoperitoneum who might respond to a damage control intervention, from one with a severe retro-peritoneal haemorrhage that will require angiography at a referral centre. Such an image might also be easily remotely interpreted, yet be critically important in triage and transport decisions.

Clinical medicine, as we know it, is undergoing a paradigm shift as our entire society embraces the information age.[34-37] Every day our routine interactions with patients become more abstract and physically removed as clinicians rely more and more on numerical results rather than physical findings. Physicians dealing with critically-ill patients have become essentially "digital physicians".[38] Most decisions regarding patient care in a modern intensive care unit are made on the basis of numerical information represented as "bytes" rather than "atoms". Intensive care rounds in many respected institutions take place in conference rooms remote from the patients. Acute trauma care still very much requires an up-front clinical presence as interacting and resuscitating the patient in real time, as the human information processing capacity is still felt to be the best means of integrating all the clues required to detect immediately life-threatening conditions. Sonography is a technology that enhances the clinicians' ability beyond usual human limitations, essentially adding a further digital sense to our physical capabilities. Digital sonographic examinations have the potential to confer the added digital information that allows information enhancement, decision support, digital transmission, documentation, remote consultation, manipulation, and data fusion, without delaying or distancing the clinician from the clinical interaction. The information age is a revolution. Hand-held sonography is one facet of that revolution that is in our hands now.

Conclusions

Digital hand-held portable ultrasound units can be used effectively by appropriately trained clinicians involved in trauma care under real-life conditions to quickly detect intra-peritoneal fluid with a high degree of accuracy. No single technique or device will always perform flawlessly in all situations but the hand-held ultrasound is a safe, relatively cheap and dependable device that does not compromise the patients' future examinations, nor carry the risks of ionising radiation. As long as a negative examination is not accepted as the final determination of the patients' clinical status *without* initiating at a minimum appropriate clinical follow-up, or ideally further radiological investigations, the authors see no potential adverse affects on patient care. Conversely, this examination rapidly directs the treating physicians to the source of haemorrhage, and may save time in providing appropriate operative therapy. Further, this technique can provide early digital information regarding the status of the peritoneal cavity in any environment. Further studies with these devices in the hands of appropriately trained medical personnel should continue in both hospital and pre-hospital settings.

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