Diagnostic value of a hand-carried ultrasound device for free intra-abdominal fluid and organ lacerations in major trauma patients

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ABSTRACT

Background Technological progress has led to the introduction of hand-carried ultrasound (HCU) imagers in clinical workflow. The aim of this study is to analyse whether examination with a HCU device is a rapid and reliable alternative to contrast-enhanced multidetector CT (MDCT) scans in diagnosis of free intra-abdominal fluid and organ lacerations in major trauma patients.

Methods 31 major trauma patients with an injury severity score >15 and the necessity of a MDCT scan (standard of reference) were enrolled prospectively to this study, and additionally examined with a HCU, according to 'focused assessment with sonography for trauma' principles for the assessment of organ lacerations and free intra-abdominal fluid. The HCU device employed was of the latest generation. Statistical analysis was performed using PASW V.18.

Results Four patients were diagnosed with free intra-abdominal fluid (prevalence 12.9%). HCU showed a sensitivity and specificity of 75% and 100%, respectively. Positive predictive value and negative predictive value were 100% and 96%, respectively. Five patients had organ lacerations (prevalence 16.1%). In these cases, the HCU was able to detect organ lacerations with a sensitivity and specificity of 80% and 100%, respectively. Therefore, a positive predictive value and negative predictive value of 100% and 96%, respectively, were calculated.

Conclusion In major trauma patients, examination with HCU according to the 'focused assessment with sonography for trauma' principles for the diagnosis of organ lacerations and free intra-abdominal fluid is a reliable and rapid alternative to MDCT scans and can help save precious time in emergency situations, and should, additionally, be evaluated in the pre-clinical workflow.

INTRODUCTION

Over the past few years, the frequency of intra-abdominal injuries from blunt abdominal trauma continues to increase worldwide.[1] This entity is life-threatening and a major cause of death within the first 24 h after trauma, requiring immediate action by all physicians involved.[2 3] The organs being most frequently involved are the spleen and liver.[4 5]

Abdominal injuries have historically been difficult to detect, and a delayed diagnosis increases the length of hospitalisation, morbidity and mortality.[6 7] Diagnostic peritoneal lavage has a high sensitivity for the detection of abdominal injuries, but as an invasive procedure, it is associated with complications and, consequently, disadvantageous for haemodynamically unstable trauma patients.[8 9] CT is considered as a sensitive testing method for blunt abdominal trauma. Especially, the multidetector CT (MDCT) represents state-of-the-art technology for major trauma patients. Still, this modality is not available 24 h and 7 days a week, and even less so in rural regions. Moreover, it is considered to be time-consuming and expensive, as the patient needs transportation and trained personnel are required.[10]

However, ultrasound provides a quick and standardised overview of the abdomen with a high sensitivity for free intra-abdominal fluid collections, but cannot distinguish between blood, urine, ascites or bile.[7 11] However, it is an excellent screening method. In 1997, the International Consensus Conference Committee defined the acronym 'FAST', which stands for 'focused assessment with sonography for trauma'. Since the late 1990s, it has been the clinical standard for the identification of free intra-abdominal fluid accumulating either in Morison's pouch, Coller's pouch or the pouch of Douglas in major trauma patients after blunt abdominal trauma.[12]

With further developments in the field of miniaturised ultrasound systems, hand-carried ultrasound (HCU) imagers have also been introduced into the everyday clinical workflow. The major advantage of these devices is that it is a fast bedside instrument, pre-hospital available and is excellent in transportability. All this leads to a prompt diagnosis and the possibility of immediate therapeutic measures at low costs. Prior studies by Brooks *et al*, Kirkpatrick *et al* and Walcher *et al* have already shown promising results with HCU devices in the clinical and pre-clinical routine allowing appropriate triage of patients.[13–16] However, all these studies have been conducted in special settings, for example, military or air medical environments.[13 15] The HCU devices used were, for example, Sonosite 180 (Sonosite, Bothell, Washington, USA) or Premedic Handyscan (Metrax, Rottweil, Baden-Württemberg, Germany) with a weight ranging from 800 g to 2400 g.

The wide deployment of a HCU device, reliability in diagnosis and ease in transportability, could speed up the pre-hospital diagnosis of blunt

abdominal trauma and help in saving time for a patient's triage and selection of the appropriate trauma centre in coping with urgent situations.

In this prospective study, we evaluated the diagnostic yield of a new-generation HCU imager in comparison with a contrast-enhanced MDCT scan as standard of reference in patients with major trauma concerning the diagnosis of free intra-abdominal fluid or organ lacerations.

METHODS

Patients

From December 2010 to March 2011, a total of 64 patients were admitted to the emergency department unit diagnosed with major trauma, based on an injury severity score >15,[17] and all of them underwent a contrast-enhanced MDCT scan. Only patients admitted to the emergency department within the core service hours of the Department of Radiology, that is, 8:00 to 17:00 on working days were included in the study to guarantee ultrasound examination by only one examiner. This leads to a total of 31 patients being additionally examined with a HCU for the presence or absence of free intra-abdominal fluid and organ lacerations according to the 'FAST' principles.[12] The patients' basic demographic data are shown in table 1.

Ethics

The study was approved by the ethics committee of the Medical Faculty of the University Medical Centre Regensburg. As only major trauma patients with an injury severity score >15 were included, only verbal informed consent could be obtained, which was specifically approved by the ethics committee.

Imaging

The contrast-enhanced MDCT scans were acquired using either a SOMATOM Sensation 16 (Siemens, Erlangen, Bayern, Germany) or a SOMATOM Definition Flash (Siemens). All patients examined with SOMATOM Sensation 16 (16 slices CT) were given 150 ml Accupaque 300 intravenously (GE Healthcare, Waukesha, Wisconsin, USA). If diagnosis was made using SOMATOM Definition Flash (128 slices CT), 120 ml Ultravist 370 (Bayer Vital, Leverkusen Nordrhein-Westfalen, Germany) was injected intravenously. In both cases, the decision on the quantity of the contrast agent was based on the standardised major trauma examination protocol. The MDCT scan was evaluated for the presence or absence of free intra-abdominal fluid, or organ lacerations, by the same radiologist (AGS), who has expertise of over 5 years in abdominal imaging, and who was blinded to the ultrasonographic and clinical findings.

For the ultrasound examination, a new-generation HCU device (VScan, GE Healthcare) with a plane 1.7–3.8 MHz transducer for two-dimensional imaging was employed (figure 1). The 3.5-inch colour LCD display measured 135×73×28 mm, whereas the probe measured 120×33×26 mm.

Table 1 Basic demographic characteristics of enrolled patients

	Absolute numbers	Percentage (%)
Patients	31	100
Gender		
Male	19	61
Female	12	39
Median age and age range (years)	50 (18–80)	
Median weight and weight range (kilograms)	81 (58–96)	

Figure 1 Image of the hand-carried ultrasound device (VScan, GE Healthcare, Waukesha, Wisconsin, USA)—with kind permission of Mr Bastian Werminghoff (GE Healthcare, Munich, Bayern, Germany).

The weight of the device was 390 g, and the total scan time with fully charged batteries was about 62 min. The ultrasound examination following the 'FAST' approach with the HCU imager was performed on the CT table right before the acquisition of the contrast-enhanced MDCT scan. The operator (SS) was a radiologist with a practice of more than 1000 documented ultrasound examinations in the past 12 months, and under the supervision of an experienced ultrasound examiner who has been conducting more than 5000 ultrasound examinations each year for more than 10 years. The operator was also unaware of the contrast-enhanced MDCT scan results or the clinical findings.

Following the 'FAST' guidelines[12] for the abdomen, Morison's pouch, Coller's pouch and the pouch of Douglas were songraphically scanned followed by a short examination of the pericardial sac, and evaluated for free intra-abdominal fluid and organ lacerations.

Statistical analysis

Data was documented using Excel tables (Excel 2007, Microsoft, Redmond, Washington, USA). Statistical analysis was performed using PASW V.18 (PASW V.18, IBM SPSS Inc., Armonk, New York, USA). Agreement between the findings of HCU with the diagnosis made by contrast-enhanced MDCT scan as standard of reference was assessed from 2×2 tables.

RESULTS

HCU was carried out successful in all 31 patients with a mean scanning time of approximately 60 s ranging from 45 s to 1.5 min.

The reading of the contrast-enhanced MDCT scans diagnosed free intra-abdominal fluid in four out of 31 patients resulting in a prevalence of 12.9% patients with free intra-abdominal fluid.

HCU examination revealed free intra-abdominal fluid correctly in three out of four patients with no false positive results. The absence of free intra-abdominal fluid was correctly verified by HCU in all 27 patients. Based on our data, this results in a sensitivity of 75% and a specificity of 100%. In the single case where the HCU examination was false negative, analysis of the contrast-enhanced MDCT showed approximately 20 ml fluid in the pouch of Douglas (figure 2). Positive predictive value (PPV) and negative predictive value (NPV) for the diagnosis of

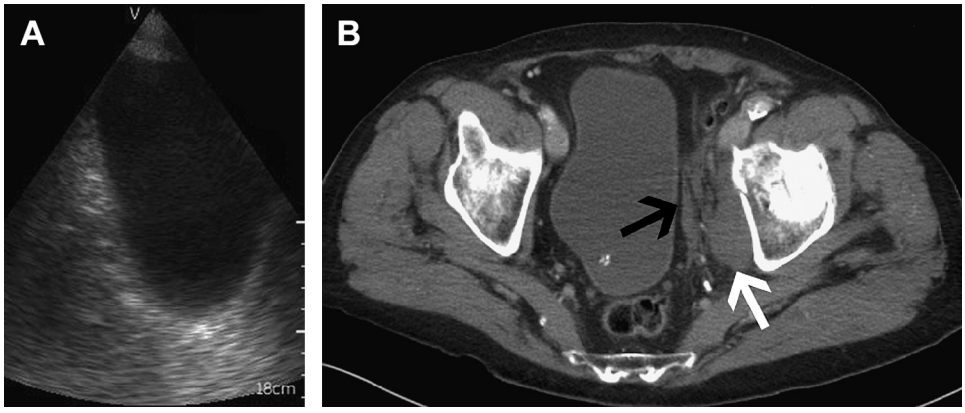

Figure 2 In a 75-year-old man, a fracture of the left acetabulum and a surrounding haematoma, additionally, with small amounts of free intra-abdominal fluid (approximately 20 ml) following a car accident, were found using contrast-enhanced multidetector CT. There was no evidence of free intra-abdominal fluid collection in the hand-carried ultrasound examination. (A) Longitudinal B-Scan hand-carried ultrasound image of the urinary bladder giving no evidence of the small amount of free intra-abdominal fluid. (B) Contrast-enhanced multidetector CT scan image showing haematoma beneath the left acetabulum (marked with white arrow) and small amounts of free intra-abdominal fluid (marked with black arrow).

free intra-abdominal fluid collection with HCU were 100% and 96%, respectively.

The statistics of diagnosis and assessment of free intra-abdominal fluid by means of HCU are summarised in table 2.

The contrast-enhanced MDCT scan depicted organ lacerations in five out of 31 patients resulting in a prevalence of 16.1% with organ lacerations. In four patients, a liver laceration was detected, and in another patient, a mesenteric bleeding was found. In all 31 patients, no injury of the spleen could be found.

Examination with a HCU revealed all four liver lacerations correctly and showed no false positive results. The mesenteric bleeding was not recognised correctly by the HCU, which resulted in one false negative case. A sensitivity of 80% with a specificity of 100% for the diagnosis of organ lacerations was calculated. PPV and NPV for the diagnosis of organ lacerations with the HCU were 100% and 96%, respectively.

The HCU results of organ lacerations are summarised in table 3. An example of one of the patients with a liver laceration diagnosed in both HCU and MDCT examination is shown in figure 3.

DISCUSSION

Abdominal ultrasound is a common and accepted method for the evaluation of intra-abdominal injuries in major trauma patients following blunt abdominal trauma.[18] Its sensitivity and specificity for the exclusion of free intra-abdominal fluid using conventional ultrasound B-Scan have been reported by several authors, with 81–89% and 93–100%, respectively.[19–21] These numbers are supported by the data acquired in our study.

Diagnosis of organ lacerations based on ultrasound examinations proved more challenging. Lacerations of the liver or spleen are better evaluated, while data concerning pancreas, gallbladder or bile duct injuries are quite rare.[4 5 20]

HCU imagers have been tested previously in the assessment of major trauma patients concerning abdominal injuries, and these prior studies have also been disclosing promising findings, but HCU imagers have not yet made their way into clinical daily workflow.[16 22–24] HCU devices have even been employed in pre-hospital settings. Walcher *et al* and Ruesseler *et al* demonstrated their reliability and usefulness earlier.[16 21 22]

In 2002, Walcher *et al* conducted a study with 61 abdominal trauma patients who were examined using a Premedic Handy-scan (Metrax), following 'FAST' guidelines,[12] directly at the accident scene. After admission routine, an ultrasound and MDCT scan were obtained to control the pre-hospital ultrasonographic findings. The mean investigation time was 2.8 min, and in 16 patients, free intra-abdominal fluid was detected (26.2%). There was one false positive and no false negative result in HCU examinations for the diagnosis of intra-abdominal fluid and, therefore, a sensitivity of 97.9% and a specificity of 100% were calculated leading to a PPV of 94.2% and an NPV of 100%.[16]

In 2004, Kirkpatrick *et al* tested a HCU imager in patients with penetrating abdominal trauma. A total of 38 patients were examined with the Sonosite 180 (Sonosite) in a clinical environment according to the 'FAST' guidelines.[12] Definite diagnosis of free intra-abdominal fluid was made with a routine ultrasound scan with the Acuson XP128 (Acuson, Mountain View, California, USA) or the Toshiba SSH 140A (Toshiba American Medical Systems, Tustin, California, USA). If available, MDCT results, operative findings and autopsy studies were considered. Free intra-abdominal fluid was detected correctly in 11 of 12 patients by means of HCU, and there was only one false negative case. Therefore, a sensitivity of 91.7% and a specificity of 100% were calculated, and a PPV and an NPV of 100% and 96.3%, respectively, were found for the diagnosis of free intra-abdominal fluid.[23]

Table 2 Diagnosis of free intra-abdominal fluid using the hand-carried ultrasound device with a contrast-enhanced multi-detector CT scan as standard of reference

	Diagnosis of free intra-abdominal fluid (%)
Sensitivity	75
Specificity	100
Positive predictive value	100
Negative predictive value	96

Table 3 Diagnosis of organ lacerations using hand-carried ultrasound imager with a contrast-enhanced multi-detector CT scan as standard of reference

	Diagnosis of organ lacerations (%)
Sensitivity	80
Specificity	100
Positive predictive value	100
Negative predictive value	96

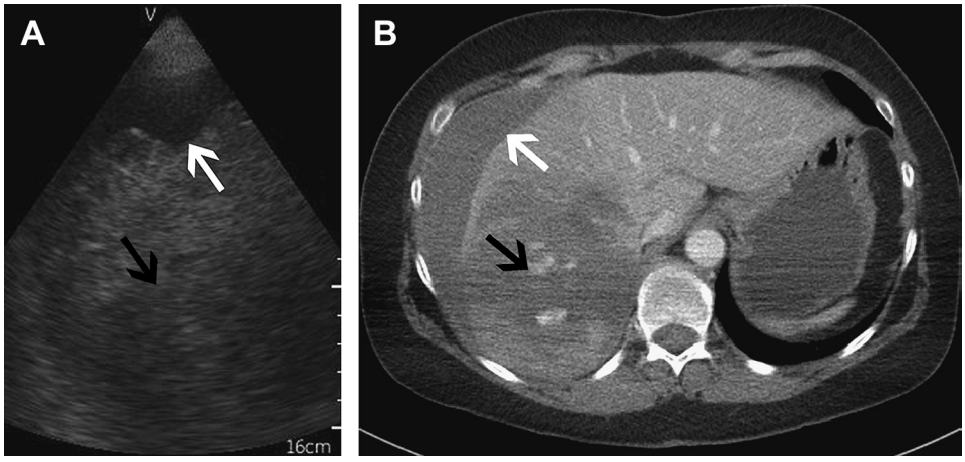

Figure 3 In a 63-year-old woman, a sub-capsular liver haematoma and a hepatic laceration were congruently diagnosed by contrast-enhanced multidetector CT scan and hand-carried ultrasound after she fell down some stairs. (A) Transverse B-Scan hand-carried ultrasound image of the liver showing the sub-capsular liver haematoma (marked with white arrow), and the hepatic laceration (marked with black arrow). (B) Contrast-enhanced multidetector CT scan image, showing sub-capsular liver haematoma (marked with white arrow) and the liver laceration (marked with black arrow).

However, the results of prior studies, and the results of this current study, indicate that modern HCU imagers provide an excellent alternative for the detection of free intra-abdominal fluid collections and organ lacerations in comparison with contrast-enhanced MDCT scans. Absence of radiation and quick availability, and low costs and mobility, are additional advantages. As mentioned above, this study was performed with a latest-generation HCU device (VScan, GE Healthcare) with a plane 1.7–3.8 MHz transducer for two-dimensional imaging, and a 3.5-inch colour LCD-display with a weight of only 390 g, and a scanning time of approximately 1 h with a set of fully charged batteries. Such modern devices are easy and quick to handle and are highly recommended by the authors for use in emergency situations like major trauma patients or blunt abdominal traumas in general.

Based on our results, comparing a HCU examination to a state-of-the-art MDCT scan, and with the ultrasound scan being conducted directly on the CT table and immediately prior to the CT scan, we consider the quality of a HCU examination in all cases sufficient for a successful screening for free intra-abdominal fluid and organ lacerations in patients with major trauma. The use of such small and light HCU devices in a pre-clinical trauma setting could be helpful, especially for triage and fast patient transport to an appropriate trauma centre. But, however, the authors are convinced that HCU imagers cannot replace the use of either the high-end ultrasound imagers because of the better image quality, or of the MDCT scans because of the better recognition of oblique lesions (like the one case of mesenteric bleeding in this current study) in the near future.

LIMITATIONS

Limiting factors of the study might be that only 31 patients were included, and the incidence of severe abdominal injury was generally low. Still, patients were prospectively acquired representing the daily routine in a tertiary care emergency centre. Furthermore, only one operator was working on the HCU system, and ultrasound examination is normally an operator-dependent modality, with different operators likely to obtain different results. However, we are convinced that only experienced operators are qualified in conducting the examination with HCU imagers, while inexperienced operators might not obtain the correct diagnosis in urgent situations.

CONCLUSION

The use of a HCU device according to the 'FAST' principles for the examination of major trauma patients is reliable for the diagnosis of free intra-abdominal fluid and organ lacerations, and can help save precious time in emergency situations. The diagnostic advantages of latest-generation HCU devices for the detection of free intra-abdominal fluid and organ lacerations in a pre-clinical workflow should be evaluated further.

Contributors SS, AE, E-MJ and P Heiss contributed to the conception and design of the study. SS and AGS were involved in analysis and interpretation of data and along with L-MD drafted the manuscript. AE, MN, E-MJ, CS and P Hoffstetter critically revised the manuscript. All the authors read approved the revised manuscript for submission.

Competing interests None.

Patient consent As only major trauma patients with an injury severity score >15 were included, only verbal informed consent could be obtained, and this was specifically approved by the ethics committee.

Ethics approval The ethics approval was provided by the Ethics Committee of the Medical Faculty, University Medical Centre Regensburg, Germany.

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