Secondary Ultrasound Examination Increases the Sensitivity of the FAST Exam in Blunt Trauma

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Introduction: **Approximately one third of stable patients with significant intra-abdominal injury do not have significant intraperitoneal blood evident on admission. We hypothesized that a delayed, repeat ultrasound study (Secondary Ultrasound – SUS) will reveal additional intra-abdominal injuries and hemoperitoneum.**

Methods: **We performed a prospective observational study of trauma patients at our Level I trauma center from April 2003 to December 2003. Patients underwent an initial ultrasound (US), followed by a SUS examination within 24 hours of admission. Patients not eligible for a SUS because of early discharge, operative intervention or death were excluded. All US and SUS exams were performed and evaluated by surgical/emergency medicine house staff or surgical attendings.**

Results: **Five hundred forty-seven patients had both an initial US and a SUS examination. The sensitivity of the initial US in this patient population was 31.1% and increased to 72.1% on SUS ($p < 0.001$) for intra-abdominal injury or intra-abdominal fluid. The specificity for the initial US was 99.8% and 99.8% for SUS. The negative predictive value was 92.0% for the initial US and increased to 96.6% for SUS ($p = 0.002$). The accuracy of the initial ultrasound was 92.1% and increased to 96.7% on the SUS ($p < 0.002$). No patient with a negative SUS after 4 hours developed clinically significant hemoperitoneum.**

Conclusion: **A secondary ultrasound of the abdomen significantly increases the sensitivity of ultrasound to detect intra-abdominal injury.**

Keywords: **Ultrasound Blunt Abdominal Trauma Prospective study**

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Ultrasonographic examination is currently the modality of choice for the assessment of hemoperitoneum in blunt trauma patients and has broadly replaced diagnostic peritoneal lavage (DPL) in these patients.[1–3] The role of ultrasound (US) in assessing the abdomen in stable blunt trauma patients is currently undefined due to a wide range of reported sensitivities in diagnosing intraperitoneal injury (42–87%).[4,5] Computed tomography (CT) is well established for evaluating abdominal solid organ injury after blunt trauma, especially in high risk patients with pelvic fractures, gross hematuria, and lower rib fractures.[6] The use of ultrasound has been limited in stable patients due to the inability of ultrasound to evaluate the retroperitoneum, bony structures and parenchymal injuries without hemoperitoneum.

The sensitivity of US to detect intraperitoneal injury is directly related to the fact that US relies on the existence of free intraperitoneal blood and does not routinely include parenchymal imaging. The ability of ultrasound to detect intra-abdominal injury may be limited by the reported lack of significant hemoperitoneum upon admission in patients with intra-abdominal solid organ injury.[7–9] Multiple studies have also shown that the sensitivity of ultrasound to detect intraperitoneal fluid is relatively proportional to the amount of fluid in the peritoneal cavity, especially for the inexperienced ultrasound operator.[10–12]

The limited intraperitoneal blood on admission combined with the necessity for a significant amount of intraperitoneal blood (>200 cc) for most surgical ultrasound operators to detect hemoperitoneum may limit the sensitivity of US in stable blunt trauma patients as reported in the literature.[13] A repeat abdominal ultrasound (the secondary ultrasound - SUS) may allow for the duration necessary to accumulate the prerequisite amount of blood for detection by the majority of surgical ultrasound operators.

We hypothesize that the secondary ultrasound will increase the sensitivity of ultrasound to identify intraperitoneal injury and will rule out clinically significant hemoperitoneum.

METHODS

We performed a prospective observational study on all trauma patients triaged to the Ryder Trauma Center at the University of Miami/Jackson Memorial Hospital from March 2003 until December 2003. This study was approved by the University of Miami Institutional Review Board (IRB #03/254B). All patients undergoing an initial abdominal US (regardless of vital signs) and receiving a repeat abdominal US (secondary ultrasound) at the convenience of the on call trauma team were included. The on call trauma teams were

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responsible for performing the ultrasound examinations and all ultrasound operators had taken an American College of Surgeons approved introductory course and initial proctoring. Only secondary ultrasounds (SUS) performed between 30 minutes after the initial admission ultrasound until 24 hours after admission were included in the database.

Patients were evaluated using a Sonosite 180 (Sonosite, Inc. Bothell, WA) or an Aloka SSD 1000 (Aloka Co. Ltd., Willingford, CT.) utilizing a 3.5-MHz sector transducer. All ultrasounds were performed by general surgery/emergency medicine residents, trauma surgery fellows, and/or trauma attending physicians.

Routine trauma ultrasounds consisted of pericardial views, transverse and longitudinal images of the right upper quadrant (right subphrenic and subhepatic spaces), left upper quadrant space (perisplenic and subphrenic), and the pelvis. Often the urinary bladder was distended with sterile normal saline to enhance the visualization of the pelvis. All US and SUS exams were considered positive if any intraperitoneal fluid was identified and negative if no fluid was identified. If intraperitoneal fluid was diagnosed, then a hemoperitoneum score was calculated by the McKenney technique.[14,15] The hemoperitoneum score was determined by first identifying the largest intraperitoneal fluid collection in one of the five intraperitoneal regions while the patient was in the supine position. The largest fluid collection is measured to the nearest tenth of a centimeter in the anterior-posterior dimension. To complete the score, one point is given for every additional intraperitoneal region that is positive for fluid and is added to the largest aforementioned anterior to posterior measurement in millimeters. Direct parenchymal injuries and pericardial fluid were not included in the hemoperitoneum score or study database.

All US or SUS positive results were compared with intraoperative or CT findings. All negative ultrasound studies were compared with intraoperative findings, CT findings and/or abdominal examination with clinical observation.

An US or SUS positive for intraperitoneal fluid was confirmed positive by CT if the CT revealed intraperitoneal fluid and/or intraperitoneal solid organ parenchymal injury. Intraoperative findings to corroborate a positive US or SUS included intraperitoneal parenchymal injury and/or intraperitoneal blood.

A laparotomy was considered therapeutic if any therapeutic surgical intervention was performed. A laparotomy was considered as nontherapeutic when no surgical intervention was performed and included nonbleeding liver and spleen injuries, small bowel contusions, and stable mesenteric hematomas.

Statistical Analysis

All study parameters were compared between the two groups by student's *t* test for the differences between means and z-tests for proportions where appropriate (Primer of Biostatistics, version 4.0). Significance was determined with alpha set at $p < 0.05$.

RESULTS

During the study period 1489 patients were admitted to the Ryder Trauma Center after blunt trauma and 1361 of these patients underwent an admission US. Five hundred forty-seven patients of the 1361 patients with an initial admission ultrasound underwent a secondary ultrasound and met study inclusion criteria The ages ranged from 1–90 with a mean of 38.6. There were 385 males (70.4%) and 162 females (29.6%). Four groups were identified by the recording of results: negative initial US with a subsequent negative SUS (NEG-NEG), negative initial US and a positive SUS (NEG-POS), positive initial ultrasound and a positive SUS (POS-POS), and a positive initial US and a negative SUS (POS-NEG). Demographics for these groups are found in Table 1.

The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of the initial US and the SUS exams are found in Table 2.

The average time until the SUS was 250.1 minute after the initial admission FAST examination. All patients with a positive US or SUS underwent abdominal/pelvic CT scan or intraoperative exploration. 223/501 (44.1%) of the Negative to Negative group underwent an abdominal/pelvic CT scan, two patients who underwent a CT also underwent an exploratory laparotomy.

Table 1 Demographics of the Diagnostic Groups

	Total	NEG-NEG	NEG-POS	POS-POS	POS-NEG
Cases	547	501	26	19	1
Age	38.6	38.6	37.6	38.7	56
Sex					
Male	385 (70.4%)	353 (70.5%)	17 (65.3%)	15 (78.9%)	1
Female	162 (29.6%)	148 (29.5%)	9 (34.7%)	4 (21.1%)	
Time to SUS (min)	250.1	248.7	294.2	224.6	240

NEG-NEG: initial US negative and SUS negative; NEG-POS: initial US negative and positive SUS; POS-POS: positive initial US and positive SUS; POS-NEG: positive initial US and negative SUS.

Table 2 Ultrasound Evaluation

	Initial US	SUS	
Sensitivity	31.1%	72.1%	$p < 0.001$
Specificity	99.8%	99.8%	$p = 1$
PPV	95.0%	97.8%	$p = 0.856$
NPV	92.0%	96.6%	$p = 0.002$
Accuracy	92.1%	96.7%	$p = 0.002$

US, ultrasound; SUS, secondary ultrasound; PPV, positive predictive value; NPV, negative predictive value.

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Hemoperitoneum Score

The average hemoperitoneum score for the initial US was 2.02 and increased to 2.87 on the SUS in the POS-POS group ($p = 0.25$). The average hemoperitoneum score on the SUS was 2.33 in the NEG-POS group. Patients undergoing a therapeutic laparotomy (n = 8) in the NEG-POS group had a significantly higher hemoperitoneum score (3.3) than the hemoperitoneum score (1.71) in the patients in this group who either had a nontherapeutic laparotomy or did not undergo an exploratory laparotomy ($p < 0.001$). The hemoperitoneum scores for the POS-POS group are shown in Figure 1.

Laparotomies

All patients in this study undergoing an exploratory laparotomy had unstable vital signs or peritonitis. Two of the 501 patients in the NEG – NEG group underwent a laparotomy - both were therapeutic (Fig. 2).

Ten of the 26 (37%) patients in the NEG-POS group underwent laparotomy; 8/10 (80%) had a therapeutic laparotomy (Fig. 3). Four of the 19 (21%) patients in the POS-POS group underwent laparotomy; all were therapeutic (Fig. 4).

DISCUSSION

Before initiating this study, we noticed on an anecdotal basis that some of our negative abdominal ultrasounds in patients with blunt trauma subsequently turned positive for intraperitoneal fluid after a repeat study was performed. The idea that a repeat imaging study will increase the ability to diagnose a specific clinical entity after allowing for the critical duration for the process to present is not new. Sequential diagnostic peritoneal lavage has been used to enhance the ability of the modality to diagnose small bowel injury after blunt trauma.[16,17] Delayed, repeat chest roentograms are rou-

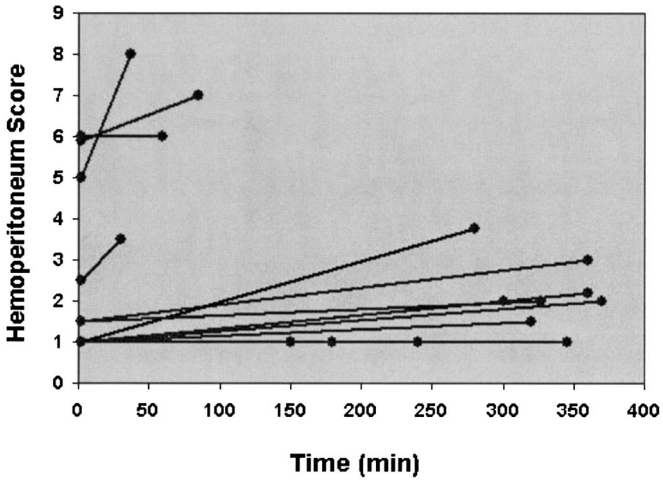

Fig. 1. *Hemoperitoneum score vs. time in the POS-POS group.*

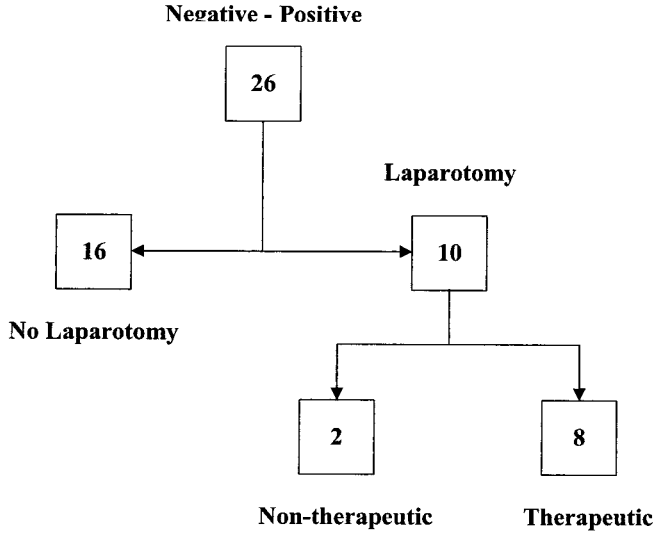

Fig. 3. *Negative FAST and positive secondary ultrasound group.*

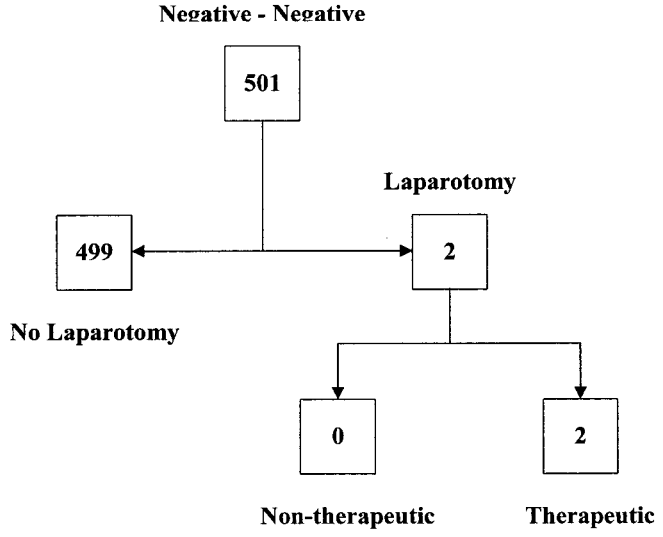

Fig. 2. *Negative FAST and negative secondary ultrasound group.*

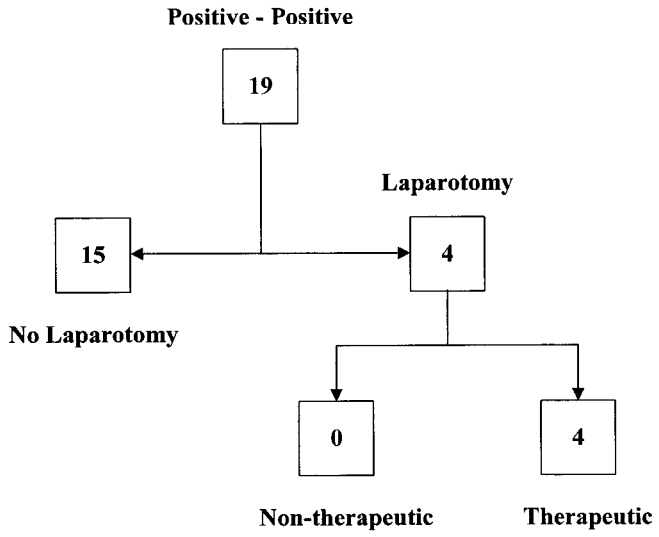

Fig. 4. *Positive FAST and positive secondary ultrasound group.*

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tinely used to rule out pneumothorax after penetrating chest trauma.[18] While several papers have recommended "serial ultrasonography" or "repeat US" in the evaluation algorithm for blunt trauma patients, we can find no published data on the actual results for these studies.[19,20] We hypothesized that many abdominal injuries that do not present with hemoperitoneum will subsequently accumulate the prerequisite intraperitoneal blood necessary for surgeons to identify hemoperitoneum and will increase the sensitivity of ultrasound to detect intraperitoneal blood and thus intraperitoneal injuries compared with the initial abdominal ultrasound. The majority of initially positive ultrasound exams in this study revealed an increase in the hemoperitoneum score over time on the SUS and we see this as evidence to support our hypothesis that time will allow for the accumulation of shed blood. Furthermore, our data shows that the use of SUS does indeed increase the ability of ultrasound to detect intraperitoneal fluid and intraperitoneal injury by the documented increase in the sensitivity of the SUS (72.13%) compared with the initial admission US sensitivity (31.14%, $p < 0.0.001$).

The initial US sensitivity of 31.1% is relatively low compared with other studies. This low sensitivity may be explained by several factors. First and foremost, the initial US studies revealing a large amount of hemoperitoneum and going straight to the operating room for a laparotomy were not included in the database. These patients would approach a sensitivity of 100% even if the operator was inexperienced. Second, we used CT and/or operative findings only to confirm the positive ultrasound findings and utilizing these strict criteria, Miller et al.[4] reported an overall sensitivity of 42%. Utilizing these strict confirmatory standards, small and probably insignificant injuries not identified by the US were still counted as false negatives.

The deficiencies of an unblinded, prospective, observational data collection by convenience sampling are well known and our study is no exception. Also, at first glance, having junior residents perform the majority of ultrasound examinations in this study appears as a weakness in the study design. But upon further analysis, this group of ultrasound operators may actually be optimal for showing a difference in the amount of intraperitoneal blood as this group has been reported to have a low sensitivity and a very high specificity for identifying intraperitoneal blood.[12] These resident physicians also need a significant amount of intraperitoneal blood for a positive result, making the chances of a positive SUS after further accumulation of blood more likely.

The optimal timing of a SUS will need to be defined. The possibility of being too early or too late for the optimal diagnosis of hemoperitoneum is real. To avoid this pitfall we took a highly inclusive approach and accepted data from any SUS performed up to 24 hours after admission since there was no previous data to guide this protocol decision. Thirteen of the 14 patients that underwent a therapeutic laparotomy had a positive SUS timed less than 4 hours after admission and the initial US. The one patient with a positive SUS after 4 hours was one of the 10 patients in the group with an initial negative US and a subsequent positive SUS. This patient had a therapeutic laparotomy with a splenectomy due to failed nonoperative management. This SUS was performed 18 hours after admission with a fall in hematocrit and a hemoperitoneum score of 6. We surmise that if a SUS had been performed earlier, perhaps within 4 hours, as with the rest of the therapeutic laparotomy group that the SUS in this patient may well have been positive. The optimal timing of a SUS will be the focus of future studies and the clinical significance of increasing hemoperitoneum scores with specific injuries versus specific time durations will need to be defined.

In the two patients undergoing a therapeutic laparotomy who had a negative FAST and a negative SUS, had a hollow viscus injury. Hollow viscus injuries often do not result in significant intraperitoneal fluid. Stassen et al. revealed that initial admission US had a prohibitively high false negative rate to be of any clinical use in diagnosing small bowel injury after blunt trauma especially in patients with the "seat belt" sign.[21] Our data corroborates that US at anytime cannot be used to rule out a hollow viscus injury, especially as an isolated injury.

The obvious question is: How can this information be utilized in the care of blunt trauma patients? The main clinical role of SUS may be in ruling out significant hemoperitoneum (including the patient with a CT diagnosed solid organ injury) and the likelihood of the blunt trauma patient exsanguinating from an intraperitoneal source. No patient with a negative SUS after 4 hours had significant hemoperitoneum and only two out of 501 patients with a negative SUS underwent a therapeutic laparotomy (small bowel injury with minimal intraperitoneal blood and a gallbladder laceration with minimal intraperitoneal blood/bile) both of which did not reveal significant hemoperitoneum. One definite clinical use of SUS based on this data will be to perform a SUS study in any stable blunt trauma patient where the decision has been made not to perform an abdominal CT scan. SUS may give clinical reassurance that significant hemoperitoneum is not present and may decrease the chances of missing a significant intraperitoneal injury in these patients.

One area of future investigation for the use of SUS will be the blunt trauma patient who currently undergoes an abdominal CT scan to rule out significant hemoperitoneum and abdominal injury before a nonthoraco-abdominal operation (e.g., femur fracture) with the default "distracting" injury. The SUS examination may also play a role in military and mass casualty triage. Future studies will need to exploit the added benefits in radiation, time and cost reductions anytime ultrasound can replace the CT scan in the evaluation of the abdomen in trauma patients.

In conclusion, our data supports the hypothesis that time allows for an increase in shed intraperitoneal blood after blunt trauma and that a secondary ultrasound study of the abdomen increases the sensitivity of ultrasound to diagnose hemoperitoneum in blunt trauma patients.

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