Screening Sonography in Pregnant Patients With Blunt Abdominal Trauma

Michèle A. Brown, MD, Claude B. Sirlin, MD, Navid Farahmand, MD, David B. Hoyt, MD, Giovanna Casola, MD

Objective. The purpose of this study was to evaluate the accuracy of screening sonography for the detection of clinically significant abdominal injury in pregnant patients with blunt trauma. Methods. We retrospectively reviewed the records of 5173 patients with blunt abdominal trauma who underwent screening sonography. Pregnant patients were identified, and the prospective sonographic interpretations were compared with surgical findings, computed tomography (CT), subsequent sonography, cystography, and the clinical course. Results. Of 1567 female patients with trauma, 947 were of reproductive age and, 102 (11%) of these 947 were pregnant. One patient was excluded because a truth standard was not available. Five (5%) of these 101 patients were found to have injuries at surgery. These injuries involved the placenta (2 injuries), spleen (2 injuries), liver (1 injury), and kidney (1 injury); all required surgery. Initial sonographic findings were positive in 4 of 5 patients with injuries. The missed injury was a placental injury detected 15 hours after screening sonography because of fetal bradycardia. After screening sonography, 6 patients underwent additional abdominal imaging: CT (3 patients), cystography (1 patient), and additional sonography (2 patients). Of 101 patients, 95 (94%) required no additional tests, and 97 (96%) required no test involving ionizing radiation. No pregnant patient underwent diagnostic peritoneal lavage. Sensitivity was 80% (95% confidence interval, 28%–100%), and specificity was 100% (96 of 96; 95% confidence interval, 96%–100%) for detecting major abdominal injury. Conclusions. Sonography is an effective screening examination that can obviate more hazardous tests such as CT, cystography, and peritoneal lavage in most pregnant patients with trauma requiring objective evaluation of the abdomen. Key words: abdomen; pregnancy; sonography; trauma.

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Trauma is one of the leading causes of death in pregnant women, and it may lead to fetal death even if the mother survives without serious injury. Unrecognized abdominal injury is an important cause of preventable death in both pregnant and nonpregnant patients with trauma. Physical examination is notoriously unreliable, especially in patients with decreased sensoriums. Objective evaluation of the abdomen with computed tomography (CT), diagnostic peritoneal lavage (DPL), or sonography is indicated not only for patients with known or suspected trauma to the abdomen but also for patients with trauma and head injury, loss of consciousness, intoxication, or major associated thoracic or orthopedic injury.
injury is difficult to predict and is potentially fatal, many patients must be screened; initial abdominal imaging results, from either CT or sonography, are negative in 90% to 95% of patients treated in a typical North American trauma center.5–8

Pregnant patients with trauma present a particular challenge to the trauma surgeon. Computed tomography is associated with potentially harmful effects of ionizing radiation and should be performed with reservation, particularly given a population in which at least 90% are expected to have negative results. Radiographic studies such as intravenous urography and cystography also involve radiation. Diagnostic peritoneal lavage carries risks as an invasive abdominal procedure, and third-trimester pregnancy is considered a relative contraindication.9 Because of its safety, sonography would seem to be the ideal abdominal study in pregnant patients with trauma. Abdominal sonography has been used in the general trauma population with good results,5–8 whereas the few studies focused on pregnant patients have shown more varied results.10,11 The purpose of this study was to evaluate the accuracy of screening abdominal sonography in pregnant patients with blunt abdominal trauma.

Materials and Methods

Patients
Pregnant patients who underwent screening sonography for blunt abdominal trauma were identified from the trauma registry database at a level 1 trauma center including admissions from April 1994 through April 2003. Patients in the trauma registry database met the entry criteria for the Major Trauma Outcome Study.12 These criteria, which include a hospital stay longer than 72 hours, admission to the intensive or intermediate care unit for any duration, and death, are used to identify patients with nontrivial mechanisms of blunt abdominal trauma. The decision to perform objective evaluation of the abdomen (screening sonography, CT, or DPL) is made by the trauma surgeon. At our institution, patients who require objective evaluation during hours when sonographic examinations are available undergo sonography, whereas patients who appear at other times undergo CT. Typically, sonography was available from 7 AM to 11:30 PM, although early in the study period, sonography was available 24 hours a day. Patients were entered prospectively into the trauma registry by the trauma service at the time of discharge from the hospital, and the registry was updated regularly by the trauma service if new injuries were discovered after discharge. To identify missed injuries after discharge, the trauma service performs monthly audits of all trauma centers in the county. We identified all pregnant patients in the database according to prospective entries of pregnancy status. This status was based on all available data including serum pregnancy tests and sonographic results. At this institution, serum pregnancy tests are routinely performed in all female patients with trauma.

There were 5173 patients (3606 male and 1567 female) who met the Major Trauma Outcome Study criteria12 and underwent sonography. Of 1567 female patients, 947 were of reproductive age (defined arbitrarily as 15–45 years old), and 102 were pregnant. This retrospective review was approved by the Institutional Review Board. The Institutional Review Board waived patient consent for review of medical records and imaging data.

Sonographic Technique
Trauma sonographic examinations were performed by certified sonographers (with 1 to 20 years’ experience) in the resuscitation suite using current equipment with Doppler capabilities. Examinations were performed with 2.25-, 3.5-, or 5.0-MHz sector or 5.0-MHz curved array transducers of HDI 3000 (Philips Medical Systems, Bothell, WA), Acuson 128XP (Siemens Medical Solutions, Mountain View, CA), and Sonoline Anteres (Siemens Medical Solutions, Erlangen, Germany) systems. Studies were interpreted prospectively by radiologists (as explained below). Seven areas were examined for fluid, including the right and left upper quadrants, the paracolic gutters, the renal fossae, and the pelvis. Empty bladders were filled with sterile saline to optimize visualization of pelvic free fluid. The number of times in which retrograde filling of the bladder was done was not recorded. The heart was imaged for pericardial collections, and the liver, spleen, and kidneys were examined for parenchymal abnormalities that could be consistent with traumatic injury.

Initially there were no specific additional requirements for sonographic examinations in pregnant patients, although fetal heart motion was routinely documented. The extent to which
the fetus, placenta, and amniotic fluid were imaged varied from examination to examination. In January 1997, several new requirements were added to the sonographic protocol for pregnant patients. The revised protocol for pregnant patients required assessment of fetal heart motion and heart rate by M-mode Doppler sonography. The biparietal diameter was measured to estimate fetal age. The placenta was imaged for evidence of abruption (abnormal echo texture or subchorionic collections), and a brief survey of amniotic fluid volume was performed. Of the 102 pregnant patients, 31 underwent sonography before the protocol revision, and 71 underwent sonography according to the revised protocol.

Representative images were recorded and viewed by an attending radiologist when the sonographer returned to the Radiology Department or the following morning if studies were done after-hours.

**Sonographic Interpretation**

From 1994 to 2001, images were reviewed on film (Image Link system; Eastman Kodak Company, Rochester, NY). After April 2001, studies were archived digitally on a Healthcare IMPAX picture archiving and communication system network (Agfa Corporation, Ridgefield Park, NJ) and reviewed on a 19-inch MWD 421 color monitor with 1024-pixel resolution (Barco Display Systems, Kortrijk, Belgium). Scans were interpreted prospectively by a resident and staff radiologist. Sonographic findings were considered positive if free fluid was present or suspected or if parenchymal findings were seen that could potentially represent injury. Sonographic findings were considered negative in the absence of these findings. No sonographic findings were considered indeterminate; if there was sufficient suspicion to recommend an additional study on the basis of the sonographic results, those sonographic findings were considered positive.

**Data and Statistical Analysis**

For each patient, all reports from abdominal radiologic studies and surgeries were reviewed by 2 authors (M.A.B. and N.F. or M.A.B. and C.B.S.) in consensus. Sonographic findings were considered true-negative if findings at follow-up CT, additional sonography, intravenous urography, cystography, or laparotomy showed no evidence of abdominal injury. Sonographic findings were also considered true-negative in patients who did not undergo additional tests who had no clinically apparent abdominal injuries during admission or at follow-up trauma clinic appointments and in audits from other county trauma centers. Sonographic findings were considered true-positive if follow-up confirmed abdominal injury. Sonographic findings were considered false-negative if abdominal injuries were found at follow-up and false-positive if the sonographic findings were thought to be suggestive but follow-up revealed no injuries.

For patients with true-positive, false-positive, and false-negative results, all abdominal radiologic images and medical charts were reviewed in detail by 3 abdominal radiologists (M.A.B., C.B.S., and G.C.) in consensus. Not all patients had the same follow up studies; therefore, the most definitive data available in each case were used as the reference standard. Surgical findings were considered the most definitive, followed by imaging tests. In our series, no patient had more than 1 type of abdominal imaging test as a follow-up after screening sonography. Clinical follow-up was used as the reference standard only for those patients with no surgical or imaging follow-up. Clinical follow-up included a period of mandatory inpatient observation, subsequent outpatient visits or admissions to our medical center, and data from trauma registry updates performed by the trauma service. All patients underwent a period of inpatient observation, ranging from 6 hours to 5 days (mean, 49 hours), and were scheduled for an appointment in the trauma clinic 1 week after discharge. Data were analyzed descriptively, and 95% confidence intervals were calculated by InStat software version 3.05 (GraphPad Software, Inc, San Diego, CA).

**Results**

Of the female trauma patients of reproductive age 102 (11%) of 947 were pregnant. Pregnant patients were 17 to 40 years old (median, 24 years), and gestational age ranged from 5 to 39 weeks (median, 24 weeks 1 day). One patient was excluded from data analysis because of lack of an acceptable reference standard. Injuries were confirmed in 5 (5%) of the remaining 101 patients. All 5 injured patients were treated surgically, either by laparotomy or emergent cesarean delivery. The prospective sonographic findings
were positive in 4 of 5 injured patients (sensitivity, 80%; 95% confidence interval, 28%–100%). Injuries in the 5 patients involved the placenta (2 injuries), spleen (2 injuries), liver (1 injury), and kidney (1 injury). The liver and kidney injury occurred in the same patient (Figure 1). One patient proceeded directly to the operating room after sonography revealed placental abruption at 33 weeks 5 days’ gestation (Figure 2), and emergency cesarean delivery was performed. The other 3 patients with positive sonographic findings were hemodynamically stable and underwent CT to further define their injuries.

One false-negative finding occurred: a placental hematoma was not seen on screening sonography. The sonographically missed injury was discovered when the patient underwent cesarean delivery for fetal bradycardia on external fetal monitoring 15 hours after admission. This case occurred before the pregnant trauma sonographic protocol was revised in January 1997.

All 96 patients without abdominal injury on the basis of follow-up had negative sonographic findings. Specificity was 100% (96 of 96; 95% confidence interval, 96%–100%). Positive predictive value was 100% (4 of 4; 95% confidence interval, 40%–100%), and negative predictive value was 99% (96 of 97; 95% confidence interval, 94%–100%) for the detection of clinically significant abdominal injury.

Of 101 pregnant patients with trauma, follow-up abdominal imaging was performed in 6, 4 of whom were exposed to ionizing radiation. Three patients with true-positive sonographic findings had their injuries confirmed and localized by CT. One patient with true-negative sonographic

Figure 1. Images from a 29-year-old pregnant woman at 33 weeks’ gestation involved in a motor vehicle collision. A, Transverse sonogram of the right kidney shows free fluid in the hepatorenal recess (arrow), with a large isoechoic collection (asterisks) around the right kidney (K). Intravenous contrast-enhanced CT of the abdomen and pelvis (125 mL of ioversol [Optiray 320; Mallinckrodt, St Louis, MO]) was performed to determine the extent of injury. B and C, Axial CT images show a large liver laceration (arrows) and right renal injury (arrowheads). D, Axial CT image shows no enhancement of the posterior half of the lower pole of the right kidney (asterisk). The gravid uterus can also be seen in this 33-week gestation (arrowheads).
findings had follow-up cystography, and 2 had additional sonographic examinations. Of all pregnant patients screened with sonography, 97 (96%) of 101 required no follow-up abdominal studies involving ionizing radiation, and 95 (94%) of 101 required no follow-up abdominal imaging of any kind. No pregnant patient had DPL.

Most of the patients in this series did not give birth at our institution during or after their admission for trauma. Four patients had delivery during their hospitalizations. All 4 patients underwent cesarean delivery, and all had substantial injuries that contributed to the decision to perform cesarean delivery. Two of these patients were those with placental injuries (described above), and 2 had spine injuries. In these cases, gestational age averaged 33 weeks (range, 30 weeks–34 weeks 1 day). All 4 neonates survived and were in good condition at discharge.

**Discussion**

In our series, 102 (11%) of 947 female patients of reproductive age with trauma were pregnant. We found the accuracy of sonography in pregnant patients to be similar to that reported previously for the general trauma population, although it should be emphasized that, because most patients had only clinical follow-up as a reference standard, we can only report sensitivity and specificity for clinically significant injury. An important finding of this study is that screening sonography allowed us to avoid ionizing radiation in 96% (97 of 101) of pregnant patients with trauma who required objective evaluation of the abdomen. Because these patients met clinical criteria mandating objective abdominal evaluation (eg, known or suspected trauma to the abdomen, head injury, loss of consciousness, intoxication, or major associated thoracic or orthopedic injury), all would have otherwise undergone CT or DPL.

Computed tomography is indicated if sonographic findings are positive; however, the advantage of avoiding CT is not trivial. Computed tomography is the largest contributor to medically induced radiation. Reports from one North American trauma center indicated that in 85% of pregnant patients treated, exposure exceeded the maximum recommended by the American College of Obstetricians and Gynecologists. In that series, pregnancies were unsuspected in 11% of pregnant patients; those patients had 100% fetal mortality. Fetal death was due to spontaneous abortion in 6 of 9 patients and elective abortion based on radiation counseling in 3 of 9. In addition to screening for injury, sonography can quickly screen for pregnancy during the initial evaluation of a female patient with trauma, although very early pregnancies require urine or serum pregnancy tests. Many institutions, including ours, rely on the serum pregnancy test, which does not yield immediate results. For patients who do not know of their pregnancy or cannot communicate because of their injuries, screening sonography may be the first indication of pregnancy to the trauma team. Sonography also has the advantage of determining the status of the fetus.

When performing screening sonography in pregnant patients with blunt trauma, it is important to carefully examine the placenta and to evaluate the amniotic fluid. In our series, we had 1 study with false-negative findings early in the study period in a patient who was found to have a placental hemorrhage without hemoperitoneum at cesarean delivery. Cesarean delivery was performed on the basis of fetal monitoring, which revealed bradycardia several hours after admission. It was after this case that the trauma sonographic protocol was specifically changed to require careful real-time scanning of the placenta in all pregnant patients with trauma undergoing screening abdominal sonography.

**Figure 2.** Image from a 30-year-old pregnant woman at 33 weeks 3 days involved in a motor vehicle collision. Transverse sonogram of the gravid uterus shows a heterogeneous, predominantly echogenic hematoma (black arrowheads) between the placenta (white arrowheads) and the uterine wall (arrow). Emergency cesarean delivery confirmed placental abruption.
Since that time, no missed injuries have been observed in pregnant patients with trauma. Although not proved by the results of our study, we think that this revised trauma sonographic protocol would have higher sensitivity for detecting fetal or placental injury than CT, in addition to avoiding harmful radiation.

There are several limitations to this study. Certain biases are unavoidable because of the retrospective study design. In addition, the small number of positive findings limits our ability to make definitive conclusions about the diagnostic performance of sonography in this population. As shown by the wide confidence interval, we cannot make strong conclusions about sensitivity on the basis of this small study; a larger study is needed. Another limitation is the use of clinical follow-up as a reference standard in most cases because CT and surgery were infrequently performed. Some injuries missed by sonography could resolve without intervention, and the sonographic findings would still be considered true-negative. Clinical observation is used as a reference standard in many studies of sonography in the trauma setting because CT is not thought to be justified after negative sonographic findings without persistent clinical suspicion of injury. It would be particularly inappropriate to perform unnecessary CT in pregnant women for the purpose of confirming negative sonographic findings. Moreover, injuries missed by sonography that resolve without intervention are, by definition, nonsurgical and therefore have little impact on clinical treatment. It is conceivable that some patients may have had missed injuries detected after discharge in medical centers outside the county, but this is unlikely.

In both pregnant and nonpregnant patients, the clinical value of negative screening sonographic findings has been found to be high. In a report from an institution where the trauma protocol involves a period of observation before discharge, most (93%) patients with trauma did not require CT. Of the minority (1%) with false-negative initial sonographic findings, 89% had injuries diagnosed within 24 hours. We found similar results in our study of pregnant patients. Specific predictors of missed injury on sonography have been described, including hematuria, fractures of the lower ribs, and fractures of the thoracic or lumbar spine. Consideration of these predictors and appropriate additional tests can further decrease the likelihood of missed injury when sonography is used as the initial screening examination.

In conclusion, sonography is an effective screening examination for pregnant patients with trauma. For all patients with trauma, negative findings must be followed by a period of observation, and any sonographic result should be considered together with all clinical information. Used appropriately in a trauma protocol, screening sonography can obviate more hazardous tests in most pregnant patients with abdominal trauma.

References


