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Ultrasound findings of free fluid in non-traumatic acute abdomen: a prospective case series study

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Abstract

Background The clinical value of ultrasound findings of free fluid in non-traumatic acute abdomen evaluation is under scrutiny. This study aimed to evaluate whether ultrasound findings of free fluid can be used to assess the effusion volume in a non-traumatic acute abdomen by comparing the ultrasound-estimated effusion volume with the effusion volume determined at surgery and evaluating ultrasound-guided drainage tube placement.

Methods This prospective case series study enrolled patients with non-traumatic acute abdomen from the Hospital between January 2021 and September 2021. The volumes of pelvic and peritoneal effusion, as estimated by ultrasound findings of free fluid, were compared with the actual volumes observed during subsequent surgery.

Results Eighty-six patients underwent surgery within 7 h after ultrasound findings of free fluid. The effusion volume matching rates were 62.5%, 65.2%, 22.2%, and 3.0% for pelvic and peritoneal effusion within 0–2, 2–4, 4–6, and 6–7 h after ultrasound findings of free fluid. Successful abdominocentesis was achieved in all patients. Ultrasound findings of free fluid could effectively guide drainage tube placement and monitor the condition of 68 patients.

Conclusion This study suggests that ultrasound findings of free fluid may be an option for assessing non-traumatic acute abdomen and to guide surgical drain placement in emergency departments.

Clinical trial number not applicable.

Keywords Ultrasound, Non-traumatic acute abdomen, Pelvic and peritoneal effusion, Drainage, Prospective case series study

Background

Acute abdomen is a surgical emergency [1]. Rapid pathological changes in the abdominal or pelvic cavity or retroperitoneal tissues and organs can cause acute abdomen, manifesting as abdominal pain and sometimes systemic reactions [2, 3]. Many conditions can cause non-traumatic acute abdomen, including liver cirrhosis, intestinal obstruction, ectopic pregnancy, acute pancreatitis, gastrointestinal perforation, and renal failure, among others [4–6]. Non-traumatic acute abdomen is more frequently seen in emergency departments than traumatic acute abdomen, but less attention is paid because of the absence of external lesions. More attention should be paid to the diagnosis and treatment of non-traumatic acute abdomen.

Accurate and rapid diagnosis of non-traumatic acute abdomen is very critical because peritoneal and pelvic effusions can develop into life-threatening conditions

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[7]. Common diagnostic methods include upright position X-ray, computed tomography (CT), ultrasonography, diagnostic abdominocentesis, and laboratory tests [8–10]. The diagnostic accuracy between ultrasonography and spiral CT varies among conditions causing acute abdomen [10]. CT examinations are generally time-consuming and require a certain level of fixed body position, which is not suitable for patients with severe abdominal pain. On the other hand, in ultrasonography, the device is moveable, the probe can be kept at different angles, not requiring patient-specific position, the processing time is smaller than other diagnostic methods, and it can be used for abdominocentesis.

Focused Assessment with Sonography for Trauma (FAST) is a valuable ultrasound procedure with many applications [11, 12]. It can rapidly detect damage to intraperitoneal organs and tissues at fixed points in four major regions (right upper quadrant, left upper quadrant, pelvic cavity, and pericardial cavity) [12, 13]. Since FAST has a high diagnostic accuracy and low cost, variants of the FAST protocol have been developed to meet specific clinical needs. The extended focused assessment with sonography for trauma (E-FAST) also assesses bilateral right and left lateral thoracic regions [14]. In recent years, dynamic-extended focused assessment with sonography for trauma (D-EFAST) has been performed to detect blunt and delayed injuries [15]. E-FAST has been used to assess pain due to injuries during the perioperative period [16]. FAST has also been used to evaluate liver cirrhosis accompanied by hepatocellular carcinoma and other hepatic lesions [17, 18]. Therefore, an ultrasound assessment of the abdomen can be performed in various traumatic and non-traumatic clinical scenarios.

However, there are few studies that have applied ultrasound findings of free fluid in non-traumatic acute abdomen. Therefore, this study aimed to determine whether ultrasound findings of free fluid can be used to assess the effusion volume in a non-traumatic acute abdomen by comparing the ultrasound-estimated effusion volume with the effusion volume determined at surgery and evaluating ultrasound-guided drainage tube placement.

Methods

Study design and participants

This prospective case series study consecutively included patients with non-traumatic acute abdomen from the emergency department of the First Hospital of Shanxi Medical University between January and September 2021. These patients underwent emergency ultrasonographic examinations and had pelvic or peritoneal effusion. The inclusion criteria were (1) patients who consulted with the emergency department of the First Hospital of Shanxi Medical University for acute abdomen and (2) patients who underwent ultrasonographic examination after admission and had clear ultrasonographic images with free pelvic and peritoneal effusion. The exclusion criteria were (1) patients with a history of trauma or (2) patients with a history of stroke or gastrointestinal bleeding.

This study followed the principles of the Declaration of Helsinki. The study was approved by the Medical Ethics Committee of the First Hospital of Shanxi Medical University, and the patients or their relatives signed the informed consent form. The STROBE guideline was used to ensure proper reporting of the methods, results, and discussion (STROBE Checklist).

Patient evaluation

The patient's medical history and vital signs were the primary evaluation methods. Ultrasound plays an important role in clarifying the diagnosis and providing diagnostic direction due to its advantages of rapid diagnosis, bedside use, and high sensitivity for many common causes of non-traumatic acute abdomen, such as ectopic pregnancy, intestinal obstruction or gastrointestinal perforation, and even cirrhosis. If the vital signs were stable and there were no critical hemodynamic changes, CT was performed. On the other hand, if an ectopic pregnancy was considered, the patient had pelvic and peritoneal effusion, and the patient's vital signs were unstable, or the patient presented with shock, surgery was scheduled immediately rather than a CT examination. Hence, the decision to perform a CT scan depended primarily on the clinician's judgment. If the patient's condition appeared complicated after the initial evaluation or if ultrasound findings of free fluid were inconclusive, CT scanning was sometimes used as a complementary tool to confirm the diagnosis. When the clinical diagnosis was still uncertain, or when the patient required urgent surgery, then surgery or laparoscopy was often the final diagnostic method. During the operation, the doctor could directly observe the lesions in the abdominal cavity, confirm the diagnosis, and perform the corresponding treatment. For example, patients with intestinal obstruction usually required CT to make a correct diagnosis. On the other hand, CT was not necessarily required in patients with liver cirrhosis or ectopic pregnancy, in which case other imaging modalities, such as ultrasound, can be faster and reliable.

Ultrasonographic procedure

A Philips EPIQ5 ultrasound system with convex array probe (1–5 MHz), linear array probe (5–12 MHz), phased array probe (1–5 MHz), or intracavitary probe (3–10 MHz) was used based on the needs of the study-eligible patients.

The sonographers who performed the sonographic examinations were physicians-in-charge or personnel above physicians and had ten years of experience in

ultrasonography. The patient was placed supine, and ultrasonographic measurements were made mainly in the following areas of effusion. (1) Inter-hepatic and renal space: the coronal section between the right side of the 11th subcostal posterior axillary line and the mid-axillary line was scanned. The depth of effusion in the right lobe of the liver and the right renal space was measured perpendicular to the hepatic and renal interfaces. (2) Right-side paracolonic sulcus: the probe was placed at the horizontal level of the right lumbar midaxillary line, and the right-side lumbar in a transverse section was scanned to view the right-side short axis of the colon. The depth of effusion was measured perpendicular to the abdominal wall. (3) Area between the spleen and kidney: the coronal section between the left-side 11th subcostal posterior axillary line and the midaxillary line was scanned to measure the depth of effusion in the interstitial space between the spleen and the left kidney perpendicular to the splenic-kidney interface. (4) Left-side of paracolonic sulcus: the probe was placed at the horizontal level of the left lumbar midaxillary line, and the left-side lumbar in a transverse section was scanned to view the left-side short axis of the colon. The depth of effusion was measured perpendicular to the abdominal wall. (5) Right iliac fossa: McBurney's point was scanned, and the effusion was measured perpendicular to the abdominal wall. (6) Left iliac fossa: an anterior area to McBurney's point was scanned, and the effusion was measured perpendicular to the abdominal wall. (7) The pelvic cavity: the probe was placed about 2 cm above the pubic symphysis, and a combined longitudinal and transverse section was scanned along the median line, examining the vesicorectal fossa in males and the uterorectal fossa in females.

The actual procedure was fine-tuned to the specific condition of the effusion. A laparoscopic examination was performed on patients with gynecological diseases to detect the lesions as soon as possible for immediate treatment.

The depth of pelvic and peritoneal effusion in the above seven sonographic sites was measured, and the amount of pelvic and peritoneal effusion was calculated. The patient underwent other imaging and laboratory examinations at the discretion of the attending physicians. Then, the choice of surgical or medical treatment was based on the primary disease determined by the comprehensive examinations. The significance of ultrasound was to help clinicians determine whether the patient needed surgery or other treatment based on the presence and quantity of effusion, such as whether a drainage tube was needed and the drainage volume. If the patients underwent surgical treatment, the amount of effusion was compared with the amount of effusion during surgery. The surgery was conducted according to the patient's condition with the criterion of avoiding blood vessels, intestines, liver, spleen, lungs, and other organs. The amount of pelvic and peritoneal effusion was categorized as follows. (1) Large volume of effusion (more than 1000 mL) was considered when the image had a dark area of free effusion at 5–7 scanning points with a depth of more than 3.5 cm. (2) Medium volume of effusion (500–900 mL) was considered when the image had a dark area of free effusion at 3–5 scanning points with a depth of 2.5–3.5 cm. (3) Small amount of effusion (< 300–400 mL) was considered when the image had a dark area of free effusion at 1–3 scanning points with a depth of ≤ 2.5 cm. The difference between the ultrasonographic estimated volume and the intraoperative observed volume was judged to be discordant if the difference was > 300 mL, while the difference between the two was judged to be concordant if the difference was < 300 mL. Those cutoff points were selected for research convenience but also based on the investigators' experience with abdominal effusion management. For clinical decision-making, the emphasis is on fluid volume. Ultrasonographic examination was used to estimate ascites volume to help clinicians make the next treatment plan. Ultrasonographic examination reports included diagnosis, the presence or absence of effusions, and the volume and location of the effusions.

Data collection

The data collected included age, sex, diagnosis, abdominal fluid volume estimated by ultrasound findings of free fluid, the interval between ultrasound findings of free fluid and surgery, diagnostic puncture, abdominal fluid volume determined during surgery, and drain placement.

Statistical analysis

Only descriptive statistical analysis was performed. Categorical data (proportions of diagnosis, patients who underwent surgery at different delays after ultrasound findings of free fluid, the proportions of patients with volume concordance between ultrasound findings of free fluid and surgery, the diagnostic puncture success rate, and the success rate of ultrasound-guided drainage tube placement) were presented as n (%). Continuous variables (age) were presented as mean ± standard deviation (SD).

Results

A total of 592 patients underwent emergency ultrasonographic diagnostic examinations and had pelvic and peritoneal effusion during the study period (January to September 2021). Among them, 145 underwent surgery, including laparoscopic and conventional open surgical intervention. Finally, 86 (59.3%) patients underwent surgical intervention within 7 h after ultrasound findings of free fluid; those patients were included in the present study. The cohort consisted of 16 males and 70

Table 1 Basic characteristics

N = 86	*n* (%) or mean ± SD
Age (years)	41.6 ± 17.6
Sex	
Male	16 (18.60%)
Female	70 (81.40%)
Diagnosis	
Ruptured ectopic pregnancy	34 (39.5%)
Ischemic bowel disease	12 (14.0%)
Gastrointestinal perforation	14 (16.3%)
Intestinal obstruction	16 (18.6%)
Ruptured ovarian corpus luteum cyst	6 (7.0%)
Ruptured ovarian endometriotic cyst	3 (3.5%)
Pelvic abscess	1 (1.2%)

females, ranging in age from 19 to 78 years (mean age: 41.6 ± 17.6). The diagnoses included ruptured ectopic pregnancy (34 cases), ischemic bowel disease (12 cases), gastrointestinal perforation (14 cases: gastric perforation in eight, small intestine perforation in five, and rectal perforation in one), intestinal obstruction (16 cases), ruptured ovarian corpus luteum cyst (six cases), ruptured ovarian endometriotic cyst (three cases), and pelvic abscess (one case) (Table 1). Surgery was performed within 0–2, 2–4, 4–6, and 6–7 h after ultrasound findings of free fluid in 24 (27.9%), 23 (26.7%), nine (10.5%), and 30 (34.9%) patients, respectively. The number of patients with ultrasound-estimated pelvic and peritoneal effusion volume matching intraoperatively measured volume were 15 (62.5%), 15 (65.2%), two (22.2%), and one (3.0%) for surgery performed within 0–2, 2–4, 4–6, and 6–7 h after ultrasound findings of free fluid, respectively. Diagnostic puncture was performed in 77 patients, with a success rate of 100%. Drainage tubes were appropriately placed under ultrasonographic guidance in 68 (100%) patients to relieve abdominal distension and other complications.

Discussion

This study showed that 86 (59.31%) patients who underwent emergency ultrasonographic procedures and had pelvic and peritoneal effusion underwent surgery within 7 h of ultrasound findings of free fluid. Of note, the concordance rate in volume assessed by ultrasound findings of free fluid vs. surgery was 57% when surgery was performed within 6 h of ultrasound findings of free fluid, but the concordance rate was lower, at 38% when surgery was performed within 7 h of ultrasound findings of free fluid (i.e., when adding the patients who underwent surgery 6–7 h after ultrasound findings of free fluid). Hence, the results suggest that the patients should be reevaluated using ultrasound findings of free fluid when surgery is still not performed 6 h after ultrasound findings of free fluid. This study may provide a reference for clinicians who adopt ultrasound findings of free fluid to evaluate non-traumatic acute abdomen and determine drainage tube requirements.

FAST and its variants have been extensively used in evaluating traumatic injuries of peritoneal and pelvic tissues and organs at certain focused points [19–21]. FAST has been recently tried in assessing fluid effusion in patients without trauma. Pericardial effusion was assessed in 37 patients by FAST, a deep learning algorithm was developed, and the algorithm specificity and sensitivity were 92% and 89%, respectively, in assessing the effusion [22]. Another deep learning algorithm had 95% sensitivity, 94% specificity, 95% accuracy, and 97% area under curve in identifying the presence and location of free fluid in the right upper quadrant of the FAST examination in adult patients with hemoperitoneum [23]. FAST showed an incidental finding of massive pericardial fluid in a 39-year-old male patient [24]. Traditional FAST is applied to trauma patients, focusing on evaluating whether the patient has organ damage by observing the presence of pericardial effusion and pelvic and peritoneal effusion. However, no previous study has specifically examined the value of a FAST-like protocol to guide drainage tube placement, although ultrasound guidance for abdominal effusion drainage is a recognized approach [25, 26]. In the present study, ultrasound findings of free fluid were adapted to patients with non-traumatic acute abdomen, which is divided into those who need surgery and those who do not. For those who do not need surgery, it is necessary to distinguish whether drainage is needed and determine the amount of drainage. Therefore, increasing the number of effusion sites from four to seven can help determine the amount of effusion more accurately.

In the present study, the patients who underwent surgery within 4 h of ultrasound findings of free fluid had a relatively high concordance rate between the estimated volume of pelvic and peritoneal effusion by ultrasound findings of free fluid and the observed volume of pelvic and peritoneal effusion during surgery. As the time to surgery was prolonged, more patients could have discordant volumes (i.e., lower or higher) between the calculated effusion volume by ultrasound findings of free fluid and the observed effusion volume by surgery. The concordance rate between the estimated volume of pelvic and peritoneal effusion by ultrasound findings of free fluid and the measured volume of pelvic and peritoneal effusion during surgery between 6 and 7 h was poor, which could be because the body adapted to reduce the amount of effusion fluid to reach a relatively stable state. No previous studies examined the concordance between the ultrasound-estimated and surgically-confirmed fluid volume. The issue should be examined in future studies.

Nevertheless, a previous study reported that the "black pattern", i.e., the amount of anechoic fluid appearing black

in the ultrasound examination of free fluid, can help physicians determine the course of action in non-traumatic abdominal emergencies with point-of-care ultrasound (PoCUS) being performed as needed to refine the diagnoses [27], supporting the present study. A review supports ultrasonography as the first examination in patients with non-traumatic abdominal emergencies [28]. Indeed, ultrasound findings of free fluid can provide a time point for surgical intervention in patients with acute abdomen and pelvic and peritoneal effusion to drain out effusion and to relieve from acute abdomen. Besides, FAST is used in assessing injuries from liver cirrhosis, renal failure, heart failure, and other non-traumatic acute abdomen due to its rapidity, accuracy, and cost-effectiveness. Internists, surgeons, obstetricians, and gynecologists need to be trained to use FAST-like protocols promptly and properly when needed [29, 30].

In hemodynamically unstable trauma patients, a positive FAST scan requires immediate surgical intervention [31]. As a result, FAST has largely replaced diagnostic peritoneal lavage (DPL) for assessing traumatic intraperitoneal bleeding. On the other hand, the present study included patients without trauma who were hemodynamically stable. In such patients, computed tomography (CT) remains the preferred diagnostic method. Clinicians should recognize that free fluid and acute abdomen in non-trauma patients can have diverse underlying causes (e.g., liver cirrhosis, intestinal obstruction, ectopic pregnancy, acute pancreatitis, gastrointestinal perforation, and renal failure) [4–6]. In such patients, surgery can be performed to manage the underlying cause, and the effusion can disappear naturally once the underlying cause is managed, but some patients may require drains for faster recovery. Nevertheless, other ultrasonography protocols could be explored in patients with non-traumatic acute abdomen, such as PoCUS or Rapid Ultrasound for Shock and Hypotension (RUSH), which should be evaluated against ultrasound findings of free fluid in future studies.

This study also had some limitations. The small sample size in this study may also have influenced the accuracy of the concordance rate. Due to limitations in data collection and archival, additional details regarding specific surgical procedures, the number of paracenteses, and fluid extraction results are unavailable. Nevertheless, in these patients, the underlying cause of the acute abdomen was removed after surgery, the effusion was aspirated during the operation, and the postoperative outcomes were good. There was no effusion recurrence or only a small amount of effusion was slowly drained or absorbed. When comparing the effusion volume by ultrasound findings of free fluid to the actual volume by surgery, the two procedures must have been performed close to each other. As time progresses, the acute abdomen can either become severe or recover on its own, depending on the underlying causes and the body's responses. Therefore, the effusion fluid volume may change by the body's responses as time passes. The study initially set up a 7-hour cutoff inclusion criterion; it was not determined before the study, but it was based on experience that the difference between ultrasound and surgical evaluation became larger after 7 h. Nevertheless, in this study, the time interval between ultrasound findings of free fluid and surgery in determining the effusion fluid volume was 0–7 h, but the concordance rate began to decline after 6 h. Longer time intervals may have affected the concordance rate for volume comparison by these two procedures. Furthermore, the sample size was small, even for the time interval of 0–7 h. Since this was a case series study, it lacked controls for comparison. In addition, the present study focused solely on the ultrasound findings of free fluid evaluation of the effusion volume, not follow-up or patient outcomes. Therefore, in future studies, the sample size needs to be increased, and the time interval between ultrasound findings of free fluid and surgery needs to be shorter. Regarding small effusions (< 300–400 mL), we agree that this threshold might not be as applicable for very small fluid collections. In such cases, the mere presence or absence of effusion might be more clinically relevant than the exact volume.

Conclusions

This study suggests that ultrasound findings of free fluid may be an option for the assessment of non-traumatic acute abdomen and to guide surgical drain placement in the emergency department. Compared with the volume determined by surgery, the pelvic and peritoneal effusion volume estimated by ultrasound findings of free fluid was more similar when the time interval was < 6 h between the two procedures. Prospective studies with large samples are needed in the future to substantiate these results.

Abbreviations

FAST	focused assessment with sonography for trauma
D-EFAST	dynamic-extended focused assessment with sonography for trauma
CT	computed tomography.
E-FAST	extended focused assessment with sonography for trauma
ICH-GCP	International Conference on Harmonization-Good Clinical Practice

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-025-02903-y.

Supplementary Material 1

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Author contributions
Pingchuan Liao performed the statistical analysis and participated in its design. Huiying Wang and Pingchuan Liao carried out the studies, participated in collecting data. Huiying Wang participated in drafted the manuscript, acquisition, analysis, or interpretation of data and draft the manuscript. All authors read and approved the final manuscript.

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Data availability
All data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
The study was also approved by the Medical Ethics Committee of the First Hospital of Shanxi Medical University, and the patients or their relatives signed informed consent. This study followed the principles of the Declaration of Helsinki, the guidelines of the International Conference on Harmonization-Good Clinical Practice (ICH-GCP), the International Ethical Guidelines on Biomedical Research Involving Human Subjects of the Council for International Organizations of Medical Sciences, and other relevant regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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