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ORIGINAL ARTICLE

Diagnostic Accuracy of Focused Ultrasonography in Diagnosing Pneumoperitoneum, Taking CT Findings as Gold Standard

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ABSTRACT

Introduction: Bedside assessment of patients with acute abdomen is extensively performed using emergency ultrasonography. Its purpose in the diagnosis of pneumoperitoneum, however, needs to be further validated. The study aimed to evaluate diagnostic accuracy of the focused ultrasonography in the diagnosis of pneumoperitoneum using the findings of the computed tomography (CT) as the gold standard.

Materials and Methods: The present study is a cross-sectional study that was carried out in the Department of Radiology, Combined Military Hospital, Bahawalpur, between 22nd January 2019 and 21st July 2019. One hundred and sixty-nine patients who had acute abdomen and were aged between 15-55 years of both genders were involved. Patients who sustained penetrating abdominal injury, had chronic renal failure or were hypersensitive to the contrast agents were eliminated. The ultrasonography of the abdomen was carried out with a focused mode of image in the form of live two-dimensional (rapid B-mode) at a frequency of 36 MHz of the transducer. Then, an abdominal multislice CT was conducted prior to and after the administration of the intravenous contrast. A consultant radiologist interpreted the imaging findings and recorded the presence or the absence of pneumoperitoneum. The findings of the ultrasonography were contrasted with the CT findings.

Results: The focused ultrasonography produced 77 true-positive, 79 true-negative, 4 false-positive, and 9 false-negative feasible results. The sensitivity, specificity, and positive and negative predictive values of 89.53, 95.18, 95.06 and 89.77 and overall diagnostic accuracy of 92.31 were achieved.

Conclusions: Focused ultrasonography is a method that has a high diagnostic accuracy in the detection of pneumoperitoneal and a fast, portable, and non-invasive and cost-effective bedside imaging modality in patients who present with the acute abdomen.

Keywords: Acute abdomen, focused abdominal sonography, pneumoperitoneum, sensitivity.

INTRODUCTION

Acute abdomen is a frequent and potentially fatal clinical manifestation, which must be diagnosed and managed in time. Gastrointestinal perforation is one of the most severe causes of acute abdomen that causes pneumoperitoneum and necessitates immediate surgical treatment. Early and correct diagnosis of pneumoperitoneum is thus necessary in order to limit the morbidity and mortality of this condition caused by late diagnosis[1].

The computed tomography (CT) of the abdomen is regarded as the gold standard imaging type on the detection of pneumoperitoneum because it is highly sensitive and capable of detecting even minute amounts of free intraperitoneal air[2]. Nevertheless, CT scanning is not always immediately facilitated especially in resource constrained settings and its application may be limited in hemodynamically unstable patients, patients with contrast hypersensitivity or in patients who need fast bedside examination. Moreover, CT is associated with the exposure to the ionizing radiation, which is also an essential factor, particularly in younger patients[3,4].

Focused ultrasonography has become a speedy, non-invasive and accessible imaging modality in the emergency department. It is commonly applied to critically evaluate bedside patients with acute abdomen, trauma, and other suspected intra-abdominal pathology[5,6]. An improved peritoneal stripe, reverberation artifact and a shifting intraperitoneal air have been reported to be sonographic findings of pneumoperitoneum. Ultrasound is fast and radiation-free and can be repeated when necessary, which is why it is a desirable choice in case of emergency departments[7].

Nevertheless, the prognosis of focused ultrasonography used as a means of detecting pneumoperitoneum is not completely accurate in literature and is highly operator based. Further evidence is required to estimate its reliability in comparison to CT imaging in local populations and emergency care. The current research was undertaken with the aim of identifying the diagnostic accuracy of focused ultrasonography when used to diagnose pneumoperitoneum where the CT scan results would act as the gold standard with a patient presenting with the acute abdomen in a tertiary care hospital. This paper will evaluate the potential of focused ultrasonography as a useful preliminary diagnosis tool in emergency.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional validation study was conducted in the Department of Radiology, Combined Military Hospital (CMH), Bahawalpur.

Study Duration: The study was carried out over a period of six months, from 22nd January 2019 to 21st July 2019.

Sample Size: A total sample size of 169 patients was calculated using a 95% confidence level. The prevalence of pneumoperitoneum secondary to gastrointestinal perforation was taken as 65%. The desired precision for sensitivity and specificity of focused ultrasonography was set at 6%, with expected sensitivity and specificity of 90.9% and 94.2%, respectively, as reported in previous literature.

Sampling Technique: Non-probability purposive sampling technique was used.

Sample Selection: All patients presenting with acute abdomen (as per operational definition) with duration of symptoms ≤48 hours, aged between 15 and 55 years, of either gender, were included in the study. And Patients with penetrating abdominal injuries were excluded. Patients with chronic renal failure, assessed on history and medical records (serum creatinine >1.5 mg/dL), were excluded due to contraindication to contrast administration. Patients with a known history of hypersensitivity to contrast agents were also excluded.

Data Collection Procedure: After obtaining approval from the Institutional Ethical Review Committee, informed written consent was taken from each patient prior to enrollment. A total of 169 patients fulfilling the inclusion criteria were included in the study.

Every patient was initially subjected to focused abdominal ultrasonography with an ultrasound machine with live two-

dimensional (rapid B-mode) imaging and a transducer frequency of 36MHz. Upon ultrasonography, a multislice computed tomography (CT) of the abdomen was done on a Toshiba Aquilion Multislice CT scanner, prior to and following administration of intravenous contrast. The findings of both focused ultrasonography and CT scans were analyzed by one consultant radiologist with at least three years of post-fellowship experience to eliminate inter-observer bias. The pneumoperitoneum was noted or absent depending on the definition of operation. Results of focused ultrasonography were later compared with those of CT scan that were taken as the gold standard. The information such as age, sex, period of symptoms, and pneumoperitoneum status on the focused ultrasonography and CT scan were noted on a specially created proforma.

Data Analysis: Data were entered and analyzed using Statistical Package for Social Sciences (SPSS) version 20.0. Mean and standard deviation were calculated for continuous variables such as age and duration of symptoms. Categorical variables including gender and presence or absence of pneumoperitoneum on focused ultrasonography and CT scan were expressed as frequencies and percentages.

A 2×2 contingency table (Table 1) was constructed to calculate sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of focused ultrasonography in diagnosing pneumoperitoneum, taking CT scan findings as the gold standard. Receiver operating characteristic (ROC) curve analysis and likelihood ratios were also calculated. Stratification was performed for age, gender, and duration of symptoms, and post-stratification diagnostic parameters were recalculated using 2×2 contingency tables.

Table 1: Diagnostic Accuracy Calculations

Focused USG	CT Present	CT Absent
Present	True Positive (a)	False Positive (b)
Absent	False Negative (c)	True Negative (d)

- Sensitivity = a / (a + c) × 100
- Specificity = d / (b + d) × 100
- Positive Predictive Value = a / (a + b) × 100
- Negative Predictive Value = d / (c + d) × 100
- Diagnostic Accuracy = (a + d) / (a + b + c + d) × 100

RESULTS

The study included 169 patients who came with acute abdomen. Patients in the age group were between 15-55 years with mean age of 36.59/9.91. Most of the patients, 93 (55.03%), fell in the age bracket of 1535 years with 76 (44.97) patients falling in the 3655 years age group. On gender distribution, 101 (59.76) patients were male and 68 (40.24) females with the male to female ratio being 1: 1.5. The average length of the symptoms exhibited was 28.11 7.59 hours; the majority of the patients (132-78.11) presented with the duration of 25-48 hours, after the symptom onset (Table 2).

Each patient was subjected to targeted abdominal ultrasonography and then an abdominal computed tomography. The targeted ultrasonography was able to identify pneumoperitoneum on 81 patients and CT scan was able to identify pneumoperitoneum on 86 patients. Focused ultrasonography showed more true-positive, true-negative, false-positive, and false-negative findings than CT results with 77, 79, 4, and 9 results, respectively. The correlation between the focused ultrasonography and CT results was statistically significant (p = 0.0001) (Table 3).

The sensitivity of the focused ultrasonography was 89.53, specificity was 95.18, positive predictive value was 95.06, negative predictive value was 89.77 and the overall diagnostic accuracy was 92.31. The probability of a positive test was 18.58 and that of a negative test was 0.109. The analysis of receiver operating characteristic (ROC) curves showed that focused ultrasonography has a high level of discriminative ability. The stratification analysis revealed high diagnostic accuracy of the various age groups. Focused ultrasonography showed slightly greater sensitivity in patients of the age (15) to (35) years, specificity was slightly greater in patients aged (36) to (55) years (Table 4).

Gender-based stratification revealed comparable diagnostic performance in both males and females. Specificity was highest among female patients (Figure 1).

Focused ultrasonography demonstrated some greater diagnostic accuracy in patients who presented within 24 hours after symptom onset than in those who presented later, but the accuracy in the latter is still high (Table 5).

Table 2: Baseline demographic characteristics of the study population (n = 169)

Variable	Category	n (%) / Mean ± SD
Age (years)	15–35	93 (55.03%)
	36–55	76 (44.97%)
	Mean ± SD	36.59 ± 9.91
Gender	Male	101 (59.76%)
	Female	68 (40.24%)
Duration of symptoms (hours)	≤24	37 (21.89%)
	25–48	132 (78.11%)
	Mean ± SD	28.11 ± 7.59

Table 3: Diagnostic performance of focused ultrasonography compared with CT scan (n = 169)

Focused Ultrasonography	Pneumoperitoneum Present on CT	Pneumoperitoneum Absent on CT
Present	77 (True Positive)	4 (False Positive)
Absent	9 (False Negative)	79 (True Negative)

Table 4: Stratification of diagnostic accuracy by age groups

Age Group (years)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy (%)
15–35 (n=93)	91.84	93.18	93.75	91.11	92.47
36–55 (n=76)	86.49	97.44	96.97	88.37	92.11

Figure 1: Stratification of diagnostic accuracy by gender

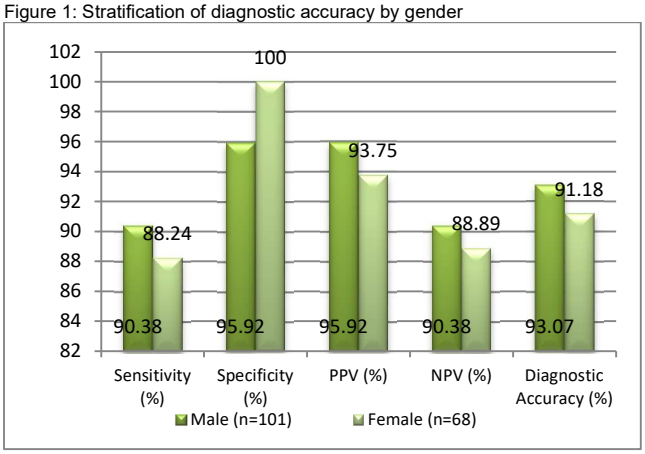

Table 5: Stratification of diagnostic accuracy by duration of symptoms

Duration (hours)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Diagnostic Accuracy (%)
≤24 (n=37)	94.74	94.44	94.74	94.44	94.59
25–48 (n=132)	89.61	95.38	95.83	88.57	92.25

DISCUSSION

Pneumoperitoneum is a complication most often caused by the perforation of hollow viscus and is a surgical emergency that has to be diagnosed and treated immediately. Delays in diagnosis despite having less than one percent of presentations to the emergency department are linked to high morbidity and mortality. Clinical observation on its own does not have good diagnostic accuracy as plain abdominal radiograph reveals the free

intraperitoneal air in only 55 -85 percent of the cases[8]. Computed tomography is the gold standard in the diagnosis of pneumoperitoneum but due to cost, radiations, availability and transfer of patients especially in the case of hemodynamically unstable patients, the use of computed tomography as a first-line screening method is minimized[9].

The use of bedside ultrasound in the emergency department is not new in the assessment of the acute abdomen, including abdominal aortic aneurysm, biliary pathology, hydronephrosis, and free intraperitoneal fluid[10]. A number of studies have been conducted in the recent years to determine the use of ultrasonography in the detection of pneumoperitoneum with better sensitivity than plain radiography. Typical sonographic appearances are peritoneal stripe enhancement, reverberation artifacts and ring-down artifact originating along the peritoneal surface[11].

In the given study, focused ultrasonography was found to be highly diagnostic than CT findings in identifying pneumoperitoneum. Concentrated ultrasonography properly detected 77 true-positives and 79 true-negatives with only 4 false-positives and 9 false-negatives. Its sensitivity, specificity, positive predictive value, negative predictive value, and total diagnostic accuracy were 89.53, 95.18, 95.06, 89.77 and 92.31 respectively. These results are also aligned with the previously published local studies with the senses of 82.1% to 90.9% and the diagnostic accuracy of 83.9 to 92.0%[12].

Differences in the diagnostic performance of the studies may be explained by variations in the patient population, the time of examination, the sonographic skill, and the etiology of pneumoperitoneum. Trauma based literature has noted reduced sensitivity of ultrasonography especially when looking at isolated bowel and mesenteric injuries because free intraperitoneal fluid may not be present in early or isolated perforation. Nevertheless, delayed or repeat ultrasonographic studies have been revealed to be very useful in enhancing the sensitivity and hence, the dynamic gastrointestinal perforation[13].

One study tested the sensitivity (high 85.7%), specificity (99.6%), and accuracy (98.9%) of ultrasonography in diagnosing gastrointestinal perforation based on intraoperative results as the gold standard[14] in 289 patients with blunt abdominal trauma. Previous researchers also found out that ultrasonography is more effective in the detection of free intraperitoneal air compared to plain radiography and this is especially in upper gastrointestinal perforations[15]. Radiography had a sensitivity of 79 and ultrasonography had a better sensitivity of up to 93 and an equivalent specificity[15].

Other sonographic signs which include interference echo pattern and the shifting phenomenon have been reported to be useful signs in the detection of intraperitoneal free air. The best results are obtained when the patient is lying in the supine position with slight thoracic elevation and a high-frequency linear transducer is used to enhance near-field resolution as the air collects[16].

FAST examination has become an inseparable part of the trauma examination with the growing popularity of ultrasound in the emergency department and intensive care units. A number of studies indicate the usefulness of ultrasonography in the diagnosis of pneumoperitoneum and a few have shown the same diagnostic performance as plain radiography or better[17,18]. Ultrasound has a couple of merits such as the availability at the bedside, the absence of radiation, repeatability and the possibility to determine other intra-abdominal pathology. These features make it especially useful in the unstable patients and resource-limited conditions[19].

Although these benefits exist, ultrasonography is yet to be adopted as a universal diagnostic algorithm to detect pneumoperitoneum because of operator dependency and inconsistent reported sensitivity. Nevertheless, a high diagnostic accuracy that is evident in the current study justifies its use as a useful first-line imaging technique in patients with acute abdomen.

CONCLUSION

This paper concludes that focused ultrasonography is highly diagnostic in diagnosis of pneumoperitoneum in comparison to computed tomography. It is an easy to access, mobile, fast, non-invasive, and a low cost imaging modality, which can be done at the bedside in a few minutes. Concentrated ultrasonography therefore should be taken as a regular investigation to be used as a first line imaging investigation in patients with acute abdomen to detect hollow viscus perforation at an early stage especially in emergencies and resource constrained settings.

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