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Feasibility of ultrasonography compared to plain radiography in detection of pneumoperitoneum in patients presenting with acute abdominal pain in the ED

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***Abstract*---**Background: Pneumoperitoneum is frequently considered one of the commonest surgical emergencies due to its association with gastrointestinal perforation that can result in peritonitis, septic shock, multiorgan failure and death. Accurate and Timely detection of these emergencies is of paramount importance in the management and outcome of the patients. Thus prompt diagnosis is a vital to avoid unnecessary interventions. Objectives: The study aimed to verify the feasibility and usefulness of Ultrasound in the diagnosis of pneumoperitoneum through comparing both Ultrasound and plain radiography findings with the intraoperative findings (the gold standard diagnosis). Methodology: The study was carried out in the Emergency Medicine and Traumatology department at Tanta University Hospitals in the period from September 2019 to September

2021, included eighty three adult patients presented with acute abdominal pain with suspected gastrointestinal perforation. Ultrasound examination was performed by the emergency physician and Plain radiography (erect or lateral decubitus) was done as an important diagnostic tool in acute abdominal pain. All enrolled patients underwent surgical intervention. Results: Sensitivity of ultrasound was higher than that of plain radiography in the diagnosis of pneumoperitoneum (89.39% and 86.63%) respectively. While plain radiography was more specific than ultrasound (88.24% and 94.12%) respectively. Conclusion: Ultrasound is a simple, reliable, noninvasive bedside diagnostic modality of pneumoperitoneum with higher sensitivity than plain radiography hence better used as screening tool for pneumoperitoneum in cases of acute abdominal pain.

***Keywords*---**pneumoperitoneum, ultrasound, abdominal pain.

Introduction

Acute abdomen denotes rapid onset of severe abdominal symptoms that may necessitate urgent surgical intervention with a maximum duration of 5 days [1]. Non traumatic acute abdominal pain is one of the chief complaints in the emergency department that account about 7-10% of all admissions in USA [2]. Acute abdomen is often surgical emergency and considered a substantial challenge for emergency physicians as its differential diagnosis is vast, ranging from benign to life-threatening [3]. Prompt diagnosis is imperative to ensure high quality outcomes for patients with intra-abdominal emergencies. Underestimation of acute abdominal pain may lead to delayed diagnosis, delayed surgical intervention and higher risks of morbidity and mortality [4]. The differential diagnosis of acute abdominal pain in the adults is somewhat broad. An accurate knowledge of all the different causes is of paramount importance so as to easily classified into urgent causes; require early prompt treatment to prevent the complications as appendicitis, diverticulitis, cholecystitis, and bowel obstruction and non-urgent causes; not need urgent management and can safely wait [5]. Despite remarkable advances in the diagnostic approach of abdominal pain, non-specific abdominal pain remains the most frequent diagnosis that represent 24-44.3% of all cause of acute abdominal pain [6]. Pneumoperitoneum is frequently considered one of the commonest surgical emergencies due to its association with gastrointestinal perforation that can result in peritonitis, septic shock, multiorgan failure and death. Accurate and Timely detection of these emergencies is of paramount importance in the management and outcome of the patients. Thus prompt diagnosis is a vital to avoid unnecessary interventions [7]. Pneumoperitoneum denotes presence of abnormal air within the peritoneal cavity, usually considered surgical emergency due to its association with abdominal viscus perforation in more than 90% of cases. The most common cause is perforated duodenal ulcer, however, can occur as a result of perforation of any part of the bowel [8].

Simple pneumoperitoneum may progress to tension pneumoperitoneum; a life threatening condition in which excessive amounts of gas contained in the

abdominal cavity associated with progressive increase of intra-abdominal pressure that is enough to compromise blood flow and visceral function lead to compartment syndrome [9]. Also increased intra-abdominal pressure compress the aorta and the inferior vena cava decreasing venous return and cardiac output with subsequent hypotension and hemodynamic instability. Tension pneumoperitoneum affect the diaphragmatic function with resultant respiratory acidosis and hypercapnia [10]. Over the years, plain radiography (upright or lateral decubitus) was the most often used diagnostic imaging for pneumoperitoneum but carried the risk of radiation exposure and insufficient sensitivy for small to moderate amounts of free air and may miss the diagnosis and delay management. Abdominal computerized tomography (CT) is highly accurate for even small amounts of free intra-abdominal air and is considered gold standard imaging for this diagnosis, however, it is expensive, associated with higher exposure to ionizing radiation and require patient transfer to the radiology unit [11]. Ultrasound (US) is an essential bedside tool to facilitate rapid and efficient diagnosis of patients with acute abdominal pain. Ultrasound is a fundamental tool for the front-line physicians who are the first to come into contact with patients, such as emergency physicians, who are not ultrasound specialists. Ultrasound has the advantages of being readily available, noninvasive, radiation free , require minimal positioning. require minimal training so, can be performed by the emergency physician during the physical examination in a short period of time. Critically ill and hemodynamically unstable patients may particularly benefit from such a portable imaging modality [12]. Ultrasound findings in pneumoperitoneum can be categorized into direct signs: Enhancement of the peritoneal strip sign (EPSS), Reverberation artifacts (A lines), shifting phenomenon and Gut point. Other indirect findings include: Air bubbles in ascitic fluid, Intraperitoneal free fluid and Thickened bowel loops with ileus [13].

EPSS sign

Intra-abdominal free air increases the echogenicity under the abdominal fascia stripping the layers of the peritoneum causing focal enhancement and apparent thickening of the peritoneal stripe with or without multiple reflection artifacts, depending on the amount of the peritoneal air [13].

Reverberation artifacts

Tissue- air interface act as a strong reflector of the ultrasonic waves and appear as bright repeated horizontal artifacts that resemble A lines below the pleural line in the lung [13].

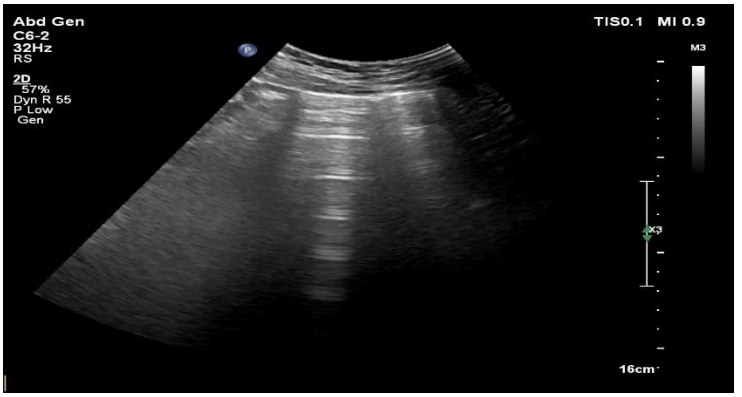
Shifting phenomenon

Position of the air changes from site to another regarding to the patient position. The air tends to accumulate in the uppermost part. When the patient position changes from supine to left lateral decubitus, EPSS and reverberation artifacts move from the anterior abdomen to lateral aspect of the liver [14].

Gut point

Gut point is analogous to lung point found in pneumothorax, the transition zone between the pathological free air that stripping the two layers of peritoneum and the physiological bowel gas. Gut point can be detected by sliding the probe laterally. Gut point is the hallmark of diagnosis of pneumoperitoneum [15].

Figure 1: Abdominal ultrasound using the curvilinear probe showing thickening of the peritoneum (EPSS) followed by reverberation artifacts



Aim of the work

The study aimed to verify the feasibility and usefulness of Ultrasound in the diagnosis of pneumoperitoneum through comparing both Ultrasound and plain radiography findings with the intraoperative findings (the gold standard diagnosis).

Patients and Methods

This prospective study was carried out in the Emergency Medicine and Traumatology department at Tanta University Hospitals in the period from September 2019 to September 2021 after approval from the ethical committee. The study was conducted upon total number eighty three (83) adult Patients of both sexes.

Inclusion criteria

The study included adult patients aged more than18 years, presented with acute abdominal pain with suspected gastrointestinal perforation and underwent surgical intervention.

Exclusion criteria

Patients were not managed by surgical intervention and pregnant women were excluded from the study. All patients in the study were subjected to: Full history taking regarding age , sex, Medical history, Drugs (especially non steroidal anti-inflammatory drugs) , surgical history (recent endoscopy, laparoscopy,

laparotomy) and Exposure to corrosives. Physical examination: ABCDE approach, Toxic look, hypotension, tachycardia, tachypnea, fever, abdominal tenderness, guard and rigidity. Laboratory investigations: Complete blood count, Blood glucose level, metabolic profile and βHCG to exclude pregnancy if suspected.

Methods of the study

Ultrasound examination was performed in the ED during the physical examination by an emergency physician who is well trained and familiar with the use of Ultrasound as a part of the daily work with the patient. Then plain radiography (erect or lateral decubitus) was done as an important diagnostic tool of acute abdominal pain. All enrolled patients underwent surgical intervention. Both sonographic and radiographic findings were compared to the intraoperative findings which is considered the gold standard diagnosis of pneumoperitoneum.

Technique

Sonographic examination was done using Philips Affiniti 50G equipped with a linear transducer (L12-4) and Curvilinear transducer (C6-2). Both transducers can be used but the Linear transducer is the best to visualize the superficial peritoneal layer and associated free air. While the patient supine, the linear array transducer of the Ultrasound was placed in the epigastrium in the longitudinal plane which is the optimum position to detect intraperitoneal free air. Air reflections trapped between the left hepatic lobe and the abdominal wall. Free air lead to superficial thickening of the peritoneal strip that appear as highly echogenic lines (brightness area in the image) associated with distal reverberation and dirty shadows. That specific sign is called "Enhancement of the Peritoneal Strip Sign" (EPSS) where the peritoneal line is prominently hyperechoic reflections. The area where the normal peritoneum is demarcated from pneumoperitoneum is called the gut point. When pneumoperitoneum was suspected, the patient was positioned on the left side (semi lateral decubitus position) for at least 2 minutes before re-examination. Air collect in the upper most area of the peritoneal space, the lateral aspect of the liver) which is known as shifting phenomenon. Records and data of the patients regarding demographic data, medical history, vital signs, laboratory investigations, admission and outcome were collected and The results are summarized, tabulated and statistically analyzed in the following tables and figures.

Results

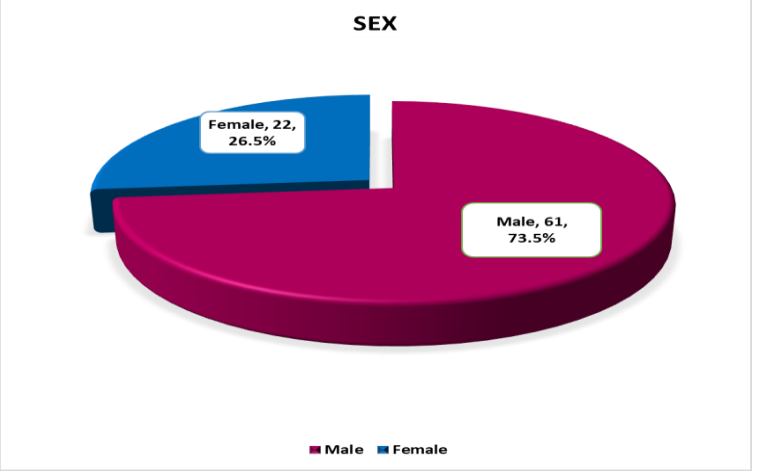
The incidence of gastrointestinal perforation was higher in the age 40-59y. The age of the studied patients ranged from 24-76y and the mean age was 50.4 y with predominance of males (male: female 2.7:1). as shown in (table 1) and (figure 2).

Table 1: Distribution of the age between the studied patients

Age	Number	%
20 - 29 y	4	4.8%
30 - 39 y	11	13.2%

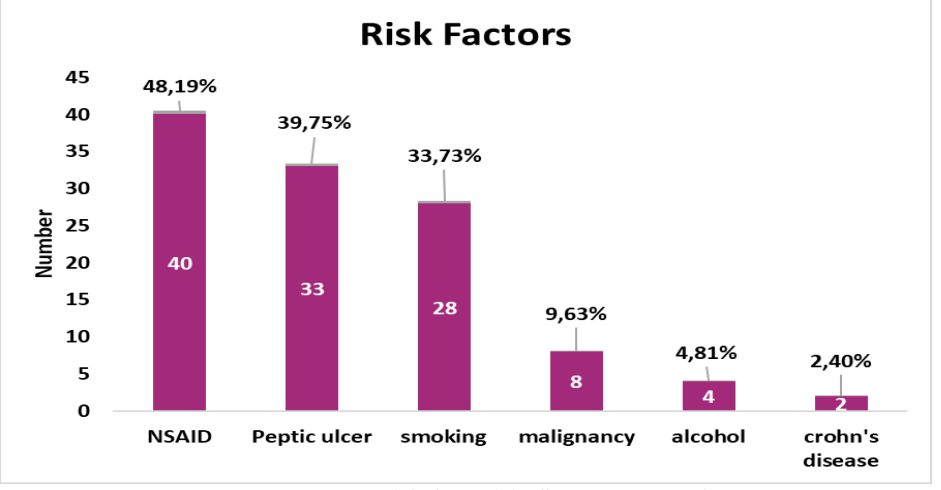
40 - 49 y	27	32.5%
50 - 59 y	28	33.7%
≥60 y	13	15.6%

Figure 2: Distribution of sex in the studied patients



Chronic use of NSAID and acid peptic disease were the most common risk factor of gastrointestinal perforation among the studied patients as shown in (Figure 3).

Figure 3: Risk factors of gastrointestinal perforation



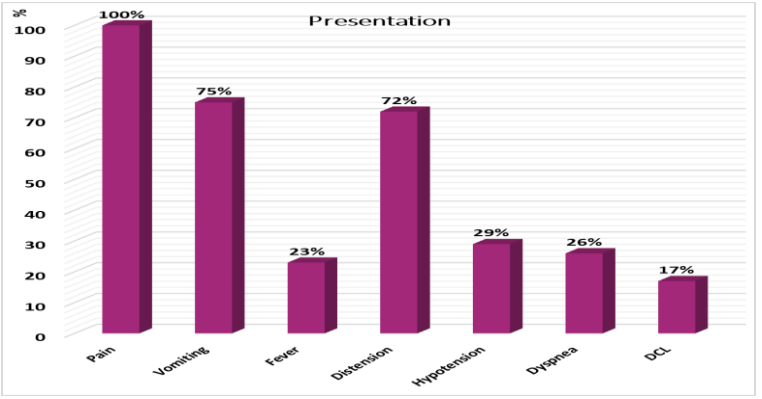
NSAID: Non steroidal anti inflammatory drugs

Abdominal pain, distension and vomiting were the most common presentation while fever, hypotension, dyspnea, signs of peritonism and DCL were found in small proportions of patients as shown in (figure 4). Time delay between development of symptoms and ED arrival is illustrated in (Table 2).

Table 2: Delay between symptoms and ED arrival (hours)

Delay (hours)	Number	%
Less than 24 h	22	26.5%
24-48h	45	54.2%
48-72h	9	10.8%
72-96h	4	4.8%
More than 96h	3	3.6%

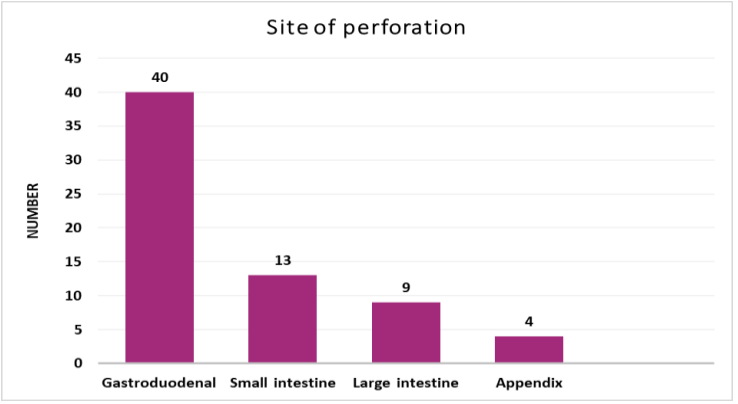
Figure 4: Presentations of the patients upon ED arrival



DCL: disturbed conscious level

The most common site of perforation found intraoperative was gastroduodenal region then small intestine then large intestine as shown in (Table 4).

Figure 5: Sites of perforations



Acid peptic disease was the most common cause of perforation as shown in (Figure 6).

Figure 6: Etiology of perforation

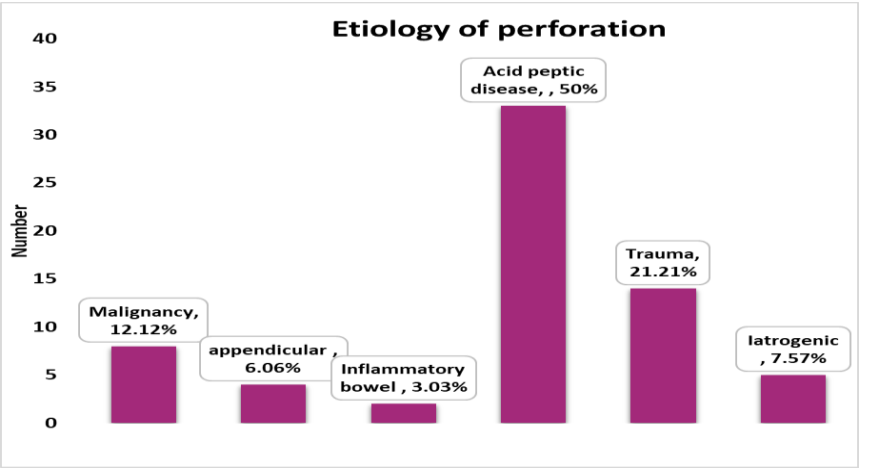


Table 3: US findings compared to the intraoperative findings

True positive	True negative	False positive	False negative
N= 59	N= 15	N= 2	N= 7

$$Sensitivity = \frac{True\ positive\ 59}{Total\ positive\ (\ true\ positive\ 59 + false\ negative\ 7)} = 89.39\%.$$

$$Specificity = \frac{\text{True negative } 15}{\text{Total negative (true negative } 15 + \text{false positive } 2)} = 88.24\%.$$

$$(PPV) = \frac{\text{True positive } 59}{\text{True positive } 59 + \text{False positive } 2} = 96.72\%.$$

PPV: Positive predictive value.

$$(NPV) = \frac{\text{True negative } 15}{\text{True negative } 15 + \text{false negative } 7} = 68.18\%.$$

NPV: Negative predictive value.

$$Accuracy = \frac{\text{True positive } 59 + \text{true negative } 15}{\text{Total number } 83} = 89.16\%.$$

Table 4: Plain radiography findings compared to the intraoperative findings

True positive	True negative	False positive	False negative
N= 57	N= 16	N= 1	N= 9

$$Sensitivity = \frac{True\ positive\ 57}{Total\ positive\ (\ true\ positive\ 57 + false\ negative\ 9)} = 86.36\%.$$

$$Specificity = \frac{\text{True negative } 16}{\text{Total negative (true negative } 16 + \text{false positive } 1)} = 94.12\%.$$

$$(PPV) = \frac{\text{True positive } 57}{\text{True positive } 57 + \text{False positive } 1} = 98.28\%.$$

PPV: Positive predictive value.

$(NPV) = \frac{\text{True negative 16}}{\text{True negative 16+false negative 9}} = 64\%.$

NPV: Negative predictive value.

$Accuracy = \frac{\text{True positive 57+true negative 16}}{\text{Total number 83}} = 87.95\%.$

Figure 7: Receiver-Operating Characteristic curve of plain radiography

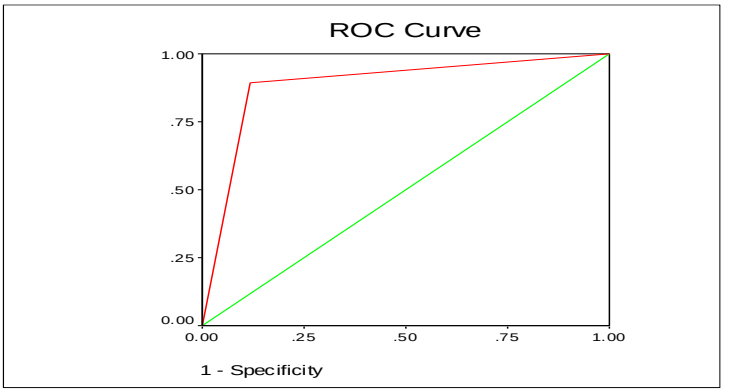
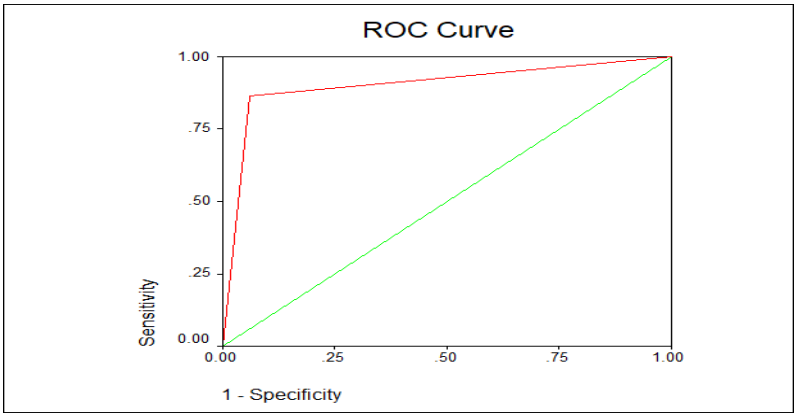


Figure 8: Receiver-Operating Characteristic *curve of plain radiography.*



Discussion

Hollow viscus perforation, is one of the most common surgical emergencies that result in peritonitis, sepsis and death. Hence immediate diagnosis and intervention are the key to avoid these complications. Over the years, plain radiography was the most often used diagnostic imaging for pneumoperitoneum but carried the risk of radiation exposure and insufficient sensitivity for small to moderate amounts of free air. Thus plain radiography can miss the diagnosis and delay the management. Abdominal computerized tomography (CT) is highly accurate for even small amounts of free intra-abdominal air and is considered the gold standard imaging for this diagnosis. However it is expensive, associated with higher exposure to ionizing radiation and require transfer of the patient to the radiology unit. US was found to be highly sensitive than pain radiography in

detection of pneumoperitoneum with sensitivity 89.35% and 86.36% respectively. While US was less specific than plain radiography with specificity 88.24% and 94.12% respectively. A study by (Gul W, et al. 2018) enrolled 163 patients with blunt abdominal trauma to determine the diagnostic accuracy of US in detection of pneumoperitoneum compared to the intraoperative findings. US was found to be a feasible diagnostic modality of pneumoperitoneum. Sensitivity and specificity of US was 90.9% and 94.2% respectively [16]. Another study by (Nazerian p et al., 2015*)* reported that US can be a useful bedside screening test for pneumoperitoneum with sensitivity 95.5% and specificity 81.8% [17]. (Moriwaki Y, et al. 2009) estimated the diagnostic accuracy of US in detection of pneumoperitoneum in patients with acute abdominal pain. US sensitivity and specificity was 85% and 100% respectively [18]. A study by (Al-Shadydy IK, et al. 2006) compared the ultrasound finding to radiographic findings. Ultrasonography was found to be more sensitive and accurate in the detection of pneumoperitoneum than plain radiography (US sensitivity 90%, sensitivity 50% while plain radiography sensitivity 75% and specificity 50%) [19]. *(Chen SC, et al. 2002)* revealed that US is a more sensitive diagnosing modality than plain radiography for the diagnosis of pneumoperitoneum with sensitivity 93% and specificity 64% [20]. (Guntupalli S, et al. 2017) studied the correlation between the US and plain radiography and reported that US is a valuable diagnostic tool of pneumoperitoneum. US and plain radiography nearly have equal sensitivity and specificity. US sensitivity 73.2% and specificity 75%. Plain radiography sensitivity and specificity was 83.92% and 75% respectively **[21]**.

Conclusion

Ultrasound is a useful diagnostic modality of pneumoperitoneum with higher sensitivity than plain radiography hence can be used as screening tool.

Limitations of the study

- First of all small sample size.
- Technical errors are possible (US is operator dependent).
- The study did not include pregnant women.

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