To correlate blunt bowel perforation with CT findings of extraluminal air, extraluminal fluid, and unexplained extraluminal fluid and determine their diagnostic values.

During a study period of 30 months, the CT findings of 394 patients with abdominal trauma were prospectively recorded. A retrospective chart review of these patients for bowel injuries, choice of treatments, and final outcome was performed. The correlation of bowel perforation with CT findings of extraluminal air, extraluminal fluid, and unexplained extraluminal fluid was computed. The diagnostic values and likelihood ratios of these CT findings were determined.

Among 394 CT scans, 22 had extraluminal air, 259 had extraluminal fluid, 82 had unexplained extraluminal fluid. Blunt bowel perforation occurred in 24 (6.1%) patients and was significantly correlated with extraluminal air (68.2% vs. 2.4%, \(p<0.001\)), extraluminal fluid (8.9% vs. 0.7%, \(p=0.001\)), as well as unexplained extraluminal fluid (23.2% vs. 2.3%, \(p<0.001\)). The likelihood ratio of positive extraluminal air, extraluminal fluid, and unexplained extraluminal fluid for bowel perforation was 32.9, 1.5, and 3.1 respectively. Extraluminal air had the highest specificity (98.1%) but low sensitivity (62.5%), extraluminal fluid had the highest sensitivity (95.8%) but low specificity (36.2%). By comparison, unexplained fluid in the absence of solid organ injury had a higher specificity than unspecified extraluminal fluid (73.3% vs. 36.2%).

The presence of extraluminal air or fluid on trauma CT is significantly correlated with blunt bowel perforation. Extraluminal air is specific and warrants immediate surgical attention, whereas unexplained fluid should initiate aggressive work-up such as diagnostic peritoneal lavage for clarifying bowel perforation.

Traffic accident is the most common cause of blunt abdominal trauma. The incidence of blunt bowel injury (BBI) varies from 5% to 15%, and the bowel is the third most common organ of injury in blunt abdominal trauma patients [1-3]. Early treatment of BBI may not alter the mortality rate, but delayed treatment (>24 hours after injury) could significantly increase the rate of complications [4, 5]. The complications include sepsis, enterocutaneous fistulae, abdominal wound dehiscence and intra-abdominal abscess. Moreover, delayed treatment would prolong the period of fasting as well as the length of hospital stay [4]. Because early treatment of BBI is more beneficial than delayed treatment, timely diagnosis of BBI is of utmost importance.

The modalities widely used for the assessment of patients with blunt abdominal trauma are diagnostic peritoneal lavage, ultrasound, and computed tomography (CT). Because diagnostic peritoneal lavage is more readily available and can be performed at bedside even during resuscitation, it is often used as a first line diagnostic tool especially when the patient is hemodynamically unstable. The reported diagnostic values of diagnostic peritoneal lavage for BBI using conventional criteria vary, however, the cell count ratio has been advocated
as a more specific and sensitive criterion [6]. The disadvantages of diagnostic peritoneal lavage are the invasiveness of the procedure, low accuracy for retroperitoneal injury, and a high probability of non-therapeutic laparotomy as a result of its high false positive results [7].

The conventional CT has been used for the diagnosis of BBI and the results vary in different papers. In most of the previous studies, the slice thickness of CT scan ranged from 7mm to 10mm, and the reported specific CT findings of BBI such as spillage of oral contrast material and bowel wall discontinuity were not sensitive for the purpose of CT screening [8-10]. Moreover, identification of these findings on CT requires a certain level of expertise. In this study, we focus on extraluminal air and extraluminal fluid of which their identification on CT has little inter-observer discrepancy among different levels of emergency physicians as well as among different subspecialties. In order to increase the detection rate of free air and free fluid, we should reduce the artifact created by respiratory motion, and acquire thin CT slices. Therefore, in this study, we used a more rapid multidetector CT (MDCT) scanner and thinner CT slices (5mm thickness) as compared to the single detector CT scanner and thick slices (7mm-10mm) to screen patients for BBI. Our objective is to determine if MDCT can serve as an imaging modality of choice to screen patients for BBI based on the findings of extraluminal air, fluid, or unexplained fluid.

**MATERIALS AND METHODS**

During a study period of 30 months, 394 patients of blunt abdominal trauma with stable hemodynamic condition were referred for CT examination. There were 294 men, 100 women, with a median age of 34 years, ranging from 1 to 85 years. All CT examinations were performed with a multidetector CT scanner (Lightspeed QX/i Scanner, General Electric Medical Systems, Milwaukee, Wisconsin) that was located next to the resuscitation bay. The informed consent was obtained from the patient or the immediate family before we proceeded with the examination. All abdominal CT examinations were obtained from the level of lower chest to the level of pubic symphysis. Oral contrast agent was not routinely given in urgent patients, since ingestion of oral contrast agent would delay the procedure. Intravenous contrast agent was routinely given to the patients unless there was contraindication. A uniphase injection of 100 ~ 120 mL of contrast agent at a rate of 1 ~ 3 mL per second was given to the patients. The scanning was initiated at 60~80 seconds after the injection of contrast agent.

The findings of CT in 394 patients with blunt abdominal trauma were prospectively recorded. The presence or absence of intraperitoneal extraluminal air, intraperitoneal extraluminal fluid, as well as whether or not there was any associated intraperitoneal solid organ injuries were recorded by two readers in consensus without knowledge of the operative findings and outcome. The intraperitoneal extraluminal air and extraluminal fluid of which their identification on CT has little inter-observer discrepancy among different levels of emergency physicians as well as among different subspecialties. In order to increase the detection rate of free air and free fluid, we should reduce the artifact created by respiratory motion, and acquire thin CT slices. Therefore, in this study, we used a more rapid multidetector CT (MDCT) scanner and thinner CT slices (5mm thickness) as compared to the single detector CT scanner and thick slices (7mm-10mm) to screen patients for BBI. Our objective is to determine if MDCT can serve as an imaging modality of choice to screen patients for BBI based on the findings of extraluminal air, fluid, or unexplained fluid.

**Figure 1.** Abdominal computed tomography (CT) of ileum perforation demonstrated unexplained extraluminal fluid (arrow) at peritoneal cavity of right lower quadrant.

**Figure 2.** Abdominal computed tomography (CT) demonstrated extraluminal air (arrow) at right anterior peritoneal cavity of the kidney level. Terminal ileum perforation was proven by surgical laparotomy.
minal fluid of 82 patients that had no solid organ injuries was defined as unexplained fluid (Fig. 1).

A retrospective chart review of these patients for bowel injuries, choice of treatments, and final outcome was performed. The correlation of intraperitoneal perforation of bowel with CT findings of extraluminal air, extraluminal fluid, and unexplained extraluminal fluid in the absence of intraperitoneal solid organ injuries was computed using a Chi-square test or Fisher’s exact test whenever appropriate. A p-value of <0.05 was considered statistically significant. The diagnostic values and likelihood ratios of these CT findings were also determined.

RESULTS

Among CT scans of 394 patients, 22 had intraperitoneal extraluminal air (Fig. 2), 259 had intraperitoneal extraluminal fluid, and 213 had solid organ injuries. Of the 259 patients with extraluminal fluid, 82 showed no have intraperitoneal solid organ injuries, 177 had associated solid organ injuries.

Of the 394 patients, 138 underwent laparotomy. Blunt perforation of the bowel occurred in 24 (6.1%) patients. Of these 24 patients, 21 were treated with bowel repair, 3 were treated with segmental bowel resection. Among the 24 patients who underwent bowel surgery, 3 died of polytrauma, 1 died of sepsis related to bowel perforation.

As summarized in Table 1, blunt perforation of the bowel was significantly correlated with extraluminal air (68.2% vs. 2.4%, p<0.001), extraluminal fluid regardless of whether or not there was any solid organ injuries (8.9% vs. 0.7%, p=0.001), as well as unexplained fluid in the absence of intraperitoneal solid organ injuries (23.2% vs. 2.3%, p<0.001).

The sensitivities, specificities, positive predictive values, negative predictive values, accuracies, and the positive likelihood ratios were tabulated in Table 2. The likelihood ratio of positive extraluminal air, extraluminal fluid, and unexplained extraluminal fluid for bowel perforation was 32.9, 1.5, and 3.1 respectively. Extraluminal air had the highest specificity (98.1%) but low sensitivity (62.5%), extraluminal fluid had the highest sensitivity (95.8%) but low specificity (36.2%). By comparison, unexplained fluid in the absence of solid organ injury had a higher specificity than unspecified extraluminal fluid (73.3% vs. 36.2%).

### Table 1. Correlation of CT findings with surgical proven bowel perforation.

<table>
<thead>
<tr>
<th>CT findings</th>
<th>Bowel perforation</th>
<th>No perforation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraperitoneal air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>presence (N=22)</td>
<td>15 (68.2%)</td>
<td>7 (31.8%)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>absence (N=372)</td>
<td>9 (2.4%)</td>
<td>363 (97.6%)</td>
<td></td>
</tr>
<tr>
<td>Intraperitoneal fluid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>presence (N=259)</td>
<td>23 (8.9%)</td>
<td>236 (91.1%)</td>
<td>p=0.001</td>
</tr>
<tr>
<td>absence (N=135)</td>
<td>1 (0.7%)</td>
<td>134 (99.3%)</td>
<td></td>
</tr>
<tr>
<td>Unexplained fluid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>presence (N=82)</td>
<td>19 (23.2%)</td>
<td>63 (76.8%)</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>absence (N=177)</td>
<td>4 (2.3%)</td>
<td>173 (97.7%)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. The diagnostic values and positive likelihood ratios of the CT findings for blunt bowel perforation.

<table>
<thead>
<tr>
<th>CT findings</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
<th>Likelihood ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intraperitoneal air</td>
<td>62.5%</td>
<td>98.1%</td>
<td>68.2%</td>
<td>97.6%</td>
<td>95.9%</td>
<td>32.9</td>
</tr>
<tr>
<td>Intraperitoneal fluid</td>
<td>95.8%</td>
<td>36.2%</td>
<td>8.9%</td>
<td>99.3%</td>
<td>39.8%</td>
<td>1.5</td>
</tr>
<tr>
<td>Unexplained fluid</td>
<td>82.6%</td>
<td>73.3%</td>
<td>23.2%</td>
<td>97.7%</td>
<td>74.1%</td>
<td>3.1</td>
</tr>
</tbody>
</table>

PPV=positive predictive value, NPV=negative predictive value
DISCUSSION

Using a dedicated ultrasound to assess patients of blunt abdominal trauma is time consuming and the results are always operator dependent. Consequently, a modified method of ultrasound examination is used instead. This modified method which is called the focused assessment with sonography for trauma (FAST), is an accurate and rapid test for the presence of intraperitoneal fluid. It is advocated as a valuable screening tool for unstable patient of blunt abdominal trauma [11]. However, the diagnostic value of ultrasound for BBI is low [12].

In most of the published papers, traumatic bowel perforation, bowel contusion, and mesenteric injury are always grouped together as a single disease entity [8-10, 13-15]. However, contrary to bowel contusion and mesenteric injury that may not necessarily require emergent laparotomy if the hemodynamic condition is stable, traumatic bowel perforation warrants early surgical intervention regardless of hemodynamic stability [2, 16]. Therefore in this study, by sorting out patients with traumatic bowel perforation from either bowel contusion or mesenteric injury, we can truly evaluate the diagnostic value of CT in triaging patients for emergency surgery from otherwise observation management.

In this study, we analyzed the CT findings of intraperitoneal extraluminal air, intraperitoneal extraluminal fluid, and unexplained intraperitoneal fluid for bowel perforation. Extraluminal air is an objective finding on CT and its identification among different readers has little inter-observer discrepancy. It has a high specificity of 98.1% and a negative predictive value of 97.6% for bowel perforation. A patient with CT finding of extraluminal air has 32.9 times likelihood of having bowel perforation than a patient without extraluminal air. The overall accuracy of extraluminal air in this study is 95.9%. The disadvantages of extraluminal air as a CT finding for bowel perforation are its relatively low sensitivity of 62.5%, and its correct identification must be made on images with wide window setting. The detection of extraluminal air can be improved by obtaining images of thin slice thickness [17] as well as viewing images on a work-station.

The sensitivity of extraluminal air for the detection of gastrointestinal perforation is lower in blunt trauma patients as compared to that of non-trauma patients [18]. Most of the non-traumatic perforation occurs at the high-pressure stomach or proximal duodenum whereas traumatic bowel perforation is usually found at the low-pressure proximal jejunum or distal ileum. Therefore, the air that leaks from the high-pressure hollow organ is more massive and conspicuous than that from the low-pressure organ. Because the volume of air-leak will increase over time, we can anticipate that the conspicuity and sensitivity of extraluminal air could be increased if the time lapse between injury and CT scanning was prolonged.

According to Hamilton et al., the extraluminal air of blunt trauma patients in whom bowel was intact could actually be the result of peritoneal lavage, barotrauma, pneumothorax, pneumatosis cystoides intestinalis, air entering via female genital tract [19]. In our series, 7 out of 22 patients with extraluminal air did not have bowel perforation. None of these patients received diagnostic peritoneal lavage prior to CT scan at our institution. The proposal of Hamilton et al. might well explain the extraluminal air in 6 patients. Three of them had pneumothorax, 2 had pelvic injury and open wound, 1 was a woman. However, the cause of extraluminal air in 1 patient was remained unknown.

Unlike extraluminal air that is specific for bowel perforation, there are many possible causes for extraluminal fluid, such as hemoperitoneum as a result of mesenteric injury, serosal tear, visceral solid organs injury, or even intraperitoneal rupture of a urinary bladder [12]. Therefore, its specificity and positive predictive value for bowel perforation are as low as, 36.2% and 8.9% respectively. However, extraluminal fluid is a valuable screening criterion because of its high sensitivity and negative predictive value, 95.8% and 99.3% respectively. We can improve the accuracy of extraluminal fluid for bowel perforation if we exclude hemoperitoneum that is caused by solid organs injury. By contrast, the unexplained extraluminal fluid has a higher specificity (73.3% vs. 36.2%) and accuracy (74.1% vs. 39.8%) for bowel perforation than unspecified extraluminal fluid regardless of whether or not there is associated solid organs injury. Patients with unexplained extraluminal fluid are 3.1 times more likely to have bowel perforation than patients without this finding. Exploratory laparotomy is often suggested when unexplained fluid is identified on CT [20, 21], while yields only low positive predictive value (23.2%). We would recommend that CT finding of unexplained fluid can be used as a screening criterion for performing a complementary diagnostic peritoneal lavage test.

Among 259 patients who had extraluminal fluid in this study, 24 had bowel perforation, but 4 other
patients were found to have intraperitoneal rupture of the urinary bladder. One of the 4 patients had associated solid organ injury, unexplained extraluminal fluid were therefore present in 3 patients. Because both traumatic bowel perforation and intraperitoneal rupture of the urinary bladder would result in peritonitis and sepsis if not adequately treated, these injuries require early exploratory laparotomy [16, 22]. Therefore, by adding these 28 patients (bowel perforation and intraperitoneal rupture of the urinary bladder) together as a single surgery group, the overall accuracy of extraluminal fluid for surgery would increase from 39.8% to 40.4%. Likewise, the overall accuracy of unexplained extraluminal fluid would increase from 74.1% to 75.3%, and the likelihood ratio would increase from 3.1 to 3.3.

The main limitation of this study is the small population number of patients with bowel perforation. Moreover, the high specificity of extraluminal air for bowel perforation derives from the fact that true negative figure far outnumbers the false positive figure. In this study, we did not specify the anatomic location as well as the quantity of extraluminal fluid because of the small sample size. The correlation of these two parameters with bowel perforation is to be investigated in a larger population basis.

In conclusion, the presence of extraluminal air or fluid on MDCT is significantly correlated with blunt bowel perforation. Extraluminal air is a specific finding and warrants immediate surgical attention, whereas unexplained fluid should initiate aggressive work-up such as diagnostic peritoneal lavage for clarifying bowel perforation.

**REFERENCES**

腹部創傷病患的多層螺旋電腦斷層：腹腔腸道外空氣，液體以及來源無法解釋的液體和腹部鈍傷造成腸穿孔的相互關係

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長庚大學 林口長庚紀念醫院 急重症影像診療科¹ 外傷急症外科³

比較腹部鈍傷造成的腸穿孔與電腦斷層上顯示腹腔腸道外空氣，液體以及在沒有腹部臟器受傷情況下來源無法解釋的液體的相關性。

在30個月的期間，總共記錄了394位腹部創傷病患的CT表現，並且進一步回顧這些病患的腸道損傷、治療的選擇及預後。然後把腹部鈍傷造成的腸穿孔與電腦斷層上顯示腹腔腸道外的空氣，液體以及來源無法解釋的液體之相互關係做進一步的分析，並計算出各項電腦斷層影像的診斷價值和概似比。

在394個電腦斷層掃描中，22人有腸道外的空氣，259人有腸道外的液體以及82人有不能解釋的腸道外的液體。腹部鈍傷造成的腸穿孔出現在24位病人，和電腦斷層檢查腸道外出現空氣在統計學上有顯著的相關性（p<0.001），而且和腸道外液體（p=0.001）以及來源無法解釋的液體（p<0.001）也有統計學上有顯著的相關性。腹腔腸道外的空氣，液體以及來源無法解釋的液體的概似比分別是32.9，1.5和3.1。腸道外的空氣有最高的特異性（98.1%）但敏感性（62.5%）低。腹腔腸道外的液體有最高的敏感性（95.8%）但特異性（36.2%）低，比較起來，在腹部臟器沒有受傷情況下，出現在腹腔內不能解釋的液體比單純的腹腔腸道外液體有著更高的特異性（73.3% vs. 36.2%）。

在螺旋電腦斷層掃描中出現腹腔腸道外空氣或是液體和腹部鈍傷造成的腸穿孔有顯著的相關。腹腔內出現腸道外空氣是一項特異的指標且需要立即進行外科手術治療，而出現在不能解釋的腹腔內液體則應該進一步評估，例如進行診斷性腹膜灌洗術以進一步評估是否有腸穿孔。