Original Article

Non-traumatic bladder rupture showing less than 10 Hounsfield units of ascites

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Aim: Bladder ruptures are commonly misdiagnosed as gastrointestinal perforations or intestinal ischemia. If a diagnosis is made preoperatively, conservative treatment is a safe and effective option. We evaluated the validity of using the attenuation value of ascites, measured by non-contrast computed tomography (CT), to identify patients with bladder ruptures.

Methods: A retrospective search of our hospital database identified 7 patients with confirmed bladder ruptures between 2007 and 2013. We also enrolled 18 patients with gastrointestinal perforations and 10 patients with intestinal ischemia with detectable ascites on abdominal CT that had undergone emergency exploratory laparotomy between 2007 and 2013. Between-group comparisons of attenuation values of ascites as obtained by non-contrast CT were evaluated.

Results: All attenuation values were less than 10 Hounsfield units (HU) in bladder rupture patients. Moreover, the attenuation value of ascites in cases of bladder rupture (median, 5.7; range, 3.1–6.1) was significantly lower than in cases of gastrointestinal perforation (median, 14.7; range, 4.7–25.4) and intestinal ischemia (median, 13.3; range, 6.0–18.1) ($P = 0.004$ for both comparisons).

Conclusion: Bladder rupture mimics gastrointestinal perforation and intestinal ischemia with acute kidney injury. Therefore, the diagnosis of bladder rupture using the attenuation value of ascites on non-contrast CT is both useful and highly significant. We suggest that bladder rupture be considered in the differential diagnosis of patients presenting with acute abdominal pain and attenuation values of ascites of less than 10 Hounsfield units.

Key words: Abdominal pain, ascites, diagnosis, retrospective study, urinary bladder

INTRODUCTION

BLADDER RUPTURE IS rare and difficult to diagnose.[1,2] The most common cause of bladder rupture is trauma involving fracture of the pelvis.[2–4] Patients with non-traumatic causes of bladder rupture, such as malignancy, inflammatory lesions, irradiation, neurogenic bladder, and outlet obstruction, present with acute abdominal pain. In these cases, bladder rupture is usually not considered in the differential diagnosis because of its rare incidence.[3–6] High ascitic urea and ascitic creatinine levels,[7] cystoscopy and fluoroscopic retrograde cystography,[3] as well as computed tomography (CT) with retrograde cystography[4] can be used to confirm the diagnosis of bladder rupture. Clinically, however, these examinations are not indicated for patients presenting with acute abdominal pain unless there are clear indications to suspect a rupture of the bladder.[6] Furthermore, bladder rupture causes an intraperitoneal leakage of urine that results in significant reabsorption of urea and creatinine through the peritoneum.[8,9] These clinical findings mimic gastrointestinal perforation and intestinal ischemia with acute kidney injury.[8] Although abdominal CT is the most frequently used tool for diagnosing acute abdominal pain, CT imaging cannot specifically distinguish bladder rupture from gastrointestinal perforation and intestinal ischemia. Therefore, most patients require exploratory laparotomy to confirm the diagnosis.[5,6,8] If the diagnosis is made preoperatively, conservative treatment is a safe and effective option.[5,8]

We previously reported a case of spontaneous bladder rupture and described the clinical findings that led us to suspect a bladder rupture; these findings included ammonia-smelling ascites fluid obtained by abdominocentesis, hypervolemic status of the patient, and a near-water attenuation value of ascites, recognizing that ascites fluid odor and

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hypervolemic status are only associated with massive ascites.[8] Therefore, we hypothesized that the attenuation value of ascites would be a useful marker to distinguish bladder rupture from gastrointestinal perforation and intestinal ischemia. The aim of our study was to evaluate the utility of the attenuation value of ascites as measured by non-contrast CT for identifying bladder ruptures in patients presenting with acute abdominal pain.

METHODS

Patients

WE UNDERTOOK A retrospective hospital database review and identified 7 consecutive cases of bladder rupture, including 3 cases that had undergone exploratory laparotomy, between January 2007 and December 2013 at Bellland General Hospital (Osaka, Japan). Bellland General Hospital is a secondary emergency facility with a 477-bed capacity that does not receive severely injured trauma patients.

We also retrospectively reviewed the records of 1,541 patients who had received emergency surgery for acute abdominal pain at our institution between January 2007 and December 2013. Of these, a total of 46 patients who had undergone exploratory laparotomy for possible gastrointestinal perforation and intestinal ischemia were identified. Surgical indications for exploratory laparotomy in these 46 cases were as follows: 31 cases presented with little intraperitoneal air bubbles on CT but an unknown site of perforation, and 15 cases of possible intestinal ischemia presented with gut distention but an unknown site of obstruction and no signs of ischemia on CT. Of these cases, laparotomy findings confirmed 21 cases of gastrointestinal perforation, 10 cases of intestinal ischemia, 3 cases of bladder rupture, and 12 cases of other disease. Bladder rupture accounted for 0.19% (3/1,541) of emergency surgeries for acute abdominal pain and for 6.5% (3/46) of exploratory laparotomies. We excluded 3 cases of gastrointestinal perforation where ascites were not detected on non-contrast abdominal CT.

The final analysis included data from 7 patients with diagnoses of bladder rupture, 18 patients with diagnoses of gastrointestinal perforation, and 10 patients with diagnoses of intestinal ischemia, all presenting with ascites on non-contrast abdominal CT on admission (Table 1). For the total set of 35 cases, patient data were obtained from individual medical records, surgery records, and the diagnostic reports database. The study protocol was approved by the institutional ethics committee of Bellland General Hospital.

Table 1. Etiology of patients with bladder rupture (n = 7), gastrointestinal perforation (n = 18), and intestinal ischemia (n = 10)

Etiology	No. of patients
Bladder rupture (n = 7)	
Interstitial cystitis	2
Neurogenic bladder	2
Radiation cystitis	2
Bladder cancer	1
Gastrointestinal perforation (n = 18)	
Peptic ulcer	7
Small intestinal perforation	5
Colon cancer with perforation	4
Sigmoid diverticulitis	2
Intestinal ischemia (n = 10)	
Closed-loop obstruction	10

Evaluation of CT attenuation values of ascites

All CT scans were carried out using a 16-row multidetector CT scanner (SOMATOM Sensation Cardiac, Siemens, Forchheim, Germany), with 5-mm slices, 120 kVp, and 200 mA. Attenuation values (Hounsfield units, HU) were measured for all patients using the Picture Archiving and Communication System (Centricity RA1000, GE Healthcare, Buckinghamshire, UK). All ascites attenuation value measurements were undertaken in a similar manner using a single axial slice image showing the greatest fluid accumulation on non-contrast CT. To assess the HU value, a polygonal region of interest was placed along the fluid accumulation to the maximum possible extent (Fig. 1). All measurements were made independently by two surgeons who were blinded to patient information. The average of two independent measurements was used for our analysis.

Statistical analysis

All statistical analyses were carried out with EZR (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface developed for R (The R Foundation for Statistical Computing, Vienna, Austria).[10] Independent HU measurements were compared to evaluate inter-observer agreement using Spearman's rank correlation coefficient. All multiple comparisons were evaluated using Steel's test for multiple comparisons. All statistical tests were two-sided, and P-values ≤0.05 indicated statistical significance.

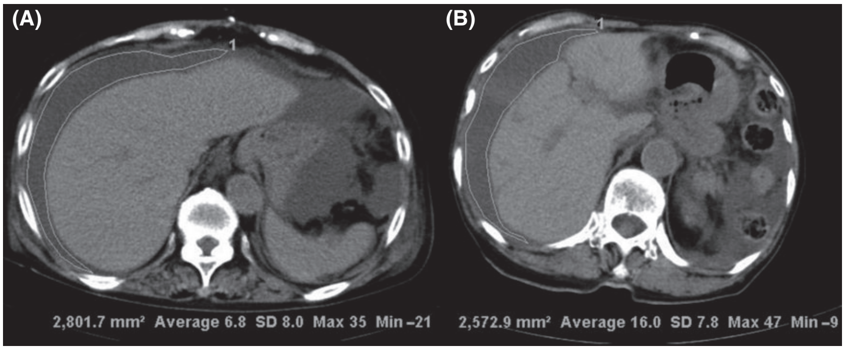

Fig. 1. Measurement of attenuation values of ascites. Attenuation values of ascites were measured using a polygonal region of interest on non-contrast axial computed tomography (CT). A, Axial CT image of a bladder rupture with an attenuation value of 6.8 Hounsfield units (HU). B, Axial CT image of intestinal ischemia with an attenuation value of 16.0 HU.

RESULTS

THE ETIOLOGY AND characteristics of patients with bladder rupture, gastrointestinal perforation, and intestinal ischemia with detectable ascites on non-contrast CT are listed in Tables 1 and 2. Non-contrast CT was always carried out prior to contrast CT. No patients had recently received prior contrast material administration. In all cases, ascites were detected in areas of the pelvic floor including Douglas' pouch, the vesicouterine pouch, and the rectovesical pouch. The sites of greatest fluid accumulation were as follows: for bladder rupture, the pelvic floor (in 4 cases), the right subphrenic space (in 2 cases), and the right paracolic gutter (in 1 case); for gastrointestinal perforation, the pelvic floor (in 10 cases), the right subphrenic space (in 3 cases), the right paracolic gutter (in 3 cases), the left subphrenic space (in 1 case), and the left paracolic gutter (in 1 case); and for intestinal ischemia, the pelvic floor (in 4 cases), the right subphrenic space (in 3 cases), the left subphrenic space (in 2 cases), and the left paracolic gutter (in 1 case).

Detailed characteristics for the 7 patients with bladder ruptures are listed in Table 3. None of these patients experienced bladder rupture as a result of blunt trauma. Review of the diagnostic records for these patients indicated that 5 of the 7 patients had received a false diagnosis based on contrast and non-contrast CT results (Table 3).

The attenuation values of ascites on non-contrast CT as independently evaluated by two different observers are shown in Figure 2. The inter-observer agreement for attenuation value was 0.98, indicative of excellent reliability. Therefore, the average of two independent measurements was used for between-group comparisons.

The attenuation values of ascites in patients with bladder rupture, gastrointestinal perforation, and intestinal ischemia

Table 2. Characteristics of patients with bladder rupture (*n* = 7), gastrointestinal perforation (*n* = 18), and intestinal ischemia (*n* = 10)

	Bladder rupture (*n* = 7)	Gastrointestinal perforation (*n* = 18)	Intestinal ischemia (*n* = 10)
Age, years	81 (71–88)	74 (18–87)	76 (57–94)
Male	4 (57.1)	7 (38.9)	2 (20.0)
eGFR <45	5 (71.4)	12 (66.7)	6 (60.0)
Contrast CT	2 (28.6)	13 (72.2)	8 (80.0)
Free air	3 (42.8)	17 (94.4)	None
Massive ascites	2 (28.6)	7 (38.9)	6 (60.0)
Ascites <10 HU	7 (100.0)	3 (16.7)	1 (10.0)
HU value of ascites	5.7 (3.7–6.1)	14.7 (4.7–25.4)	13.3 (6.0–18.1)

Massive ascites were defined as ascites located at least 1.5 cm from the peritoneal wall that were easily punctured. Data are reported as number (%) or median (range).
CT, computed tomography; eGFR, estimated glomerular filtration rate; HU, Hounsfield units.

Table 3. Characteristics of patients with bladder rupture ($n = 7$)

Case	Etiology	CT diagnosis	Contrast CT	Free air	Massive ascites	Diagnostic method	Treatment
1	Radiation cystitis	Bladder rupture	No	Yes	No	CT cystoscopy	Conservative
2	Neurogenic bladder	Bladder rupture	No	No	No	CT cystoscopy	Conservative
3	Bladder cancer	Gastrointestinal perforation	No	Yes	No	Operation	Operative
4	Interstitial cystitis	Gastrointestinal perforation	Yes	Yes	No	Operation	Operative
5	Interstitial cystitis	Intestinal ischemia	No	No	No	Operation	Operative
6	Neurogenic bladder	Cholecystitis	No	No	Yes	Paracentesis Cystography	Conservative
7	Radiation cystitis	Ascites of unknown origin	Yes	No	Yes	Paracentesis Cystography Cystoscopy	Conservative

Massive ascites were defined as ascites located at least 1.5 cm from the peritoneal wall that were easily punctured. Operation indicates exploratory laparotomy.
CT, computed tomography.

are shown in Figure 3. All attenuation values of urinary ascites were less than 10 HU. Attenuation values less than 10 HU with massive ascites were identified in 4 cases of gastrointestinal perforation and intestinal ischemia. The HU value of ascites in patients with a bladder rupture (median, 5.7; range, 3.1–6.1) was significantly lower than that in patients with gastrointestinal perforation (median, 14.7; range, 4.7–25.4) or intestinal ischemia (median, 13.3; range, 6.0–18.1) ($P = 0.004$ for both comparisons). The sensitivity, specificity, and accuracy of bladder rupture diagnosis according to an attenuation value of ascites less than 10 HU were 100.0% (95% confidence interval [CI], 47.3–100.0%), 85.7% (95% CI, 67.3–96.0%), and 88.6% (95% CI, 73.3–96.8%), respectively.

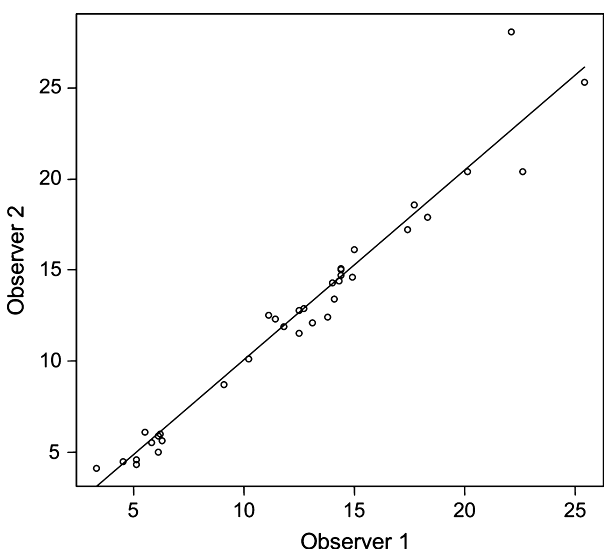

Fig. 2. Scatterplot of attenuation values of ascites. Scatterplot of attenuation values of ascites as measured by two independent observers.

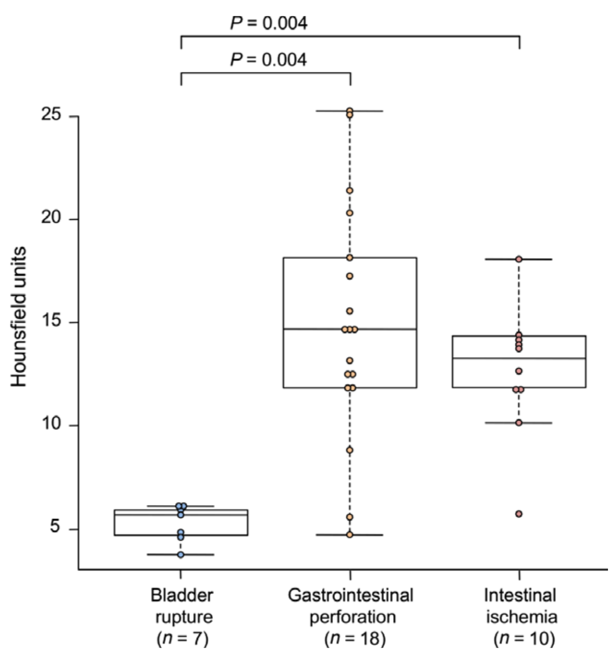

Fig. 3. Attenuation values of ascites in patients with bladder rupture, gastrointestinal perforation, and intestinal ischemia. The horizontal line within each box is the median; the upper and lower bounds of each box represent the 75th and the 25th quartiles, respectively. The whiskers on either side represent the last data points that lie within 1.5 box heights from the 75th and 25th percentile points. Dots represent individual attenuation values.

DISCUSSION

IN THIS STUDY, two important clinical observations were made: urinary ascites had near water attenuation values, and the attenuation value of ascites was useful for distinguishing bladder rupture from gastrointestinal perforation and intestinal ischemia.

Attenuation values represent the relative densities of tissues in the body. On this scale, air has a value of −1,000 HU while water, at a specific gravity of 1.000, has a value of 0 HU. Attenuation value is related to the specific gravity of a tissue. For example, fat with a specific gravity of approximately 0.92 and muscle with a specific gravity of approximately 1.06 have values of −90 HU and 50 HU, respectively.[11] The specific gravity of a fluid is proportional to its protein content. Therefore, the density of the ascitic fluid increases with increasing protein content and exudates.[12] Ascitic fluid is traditionally classified as being transudative or exudative based on its protein concentration. The attenuation value of transudative ascites (total protein <2.5 g/dL, specific gravity <1.015) is less than 10 HU.[13] In our patient group, all attenuation values for urinary ascites were less than 10 HU. Urinary ascites were therefore likely to be transudative ascites, as urine does not normally contain protein and urinary protein concentrations are typically below 2.5 g/dL, even in cases of proteinuria related to a urinary tract infection.[14] In 2 cases in our series, ascitic protein concentrations as obtained by abdominocentesis were less than 2.5 g/dL. In case 6, with an ascitic protein concentration of 1.0 g/dL and a specific gravity of 1.009, the attenuation value was 4.5 HU, and for case 7, with an ascitic protein concentration of 1.5 g/dL and a specific gravity of 1.011, the value was 5.8 HU.

In this study, the attenuation value of ascites was useful for distinguishing bladder rupture from gastrointestinal perforation and intestinal ischemia. Exudative fluids, resulting from abscess, pancreatitis, peritonitis, bowel ischemia, or bowel perforation, typically have a total protein concentration ≥2.5 g/dL and a specific gravity ≥1.015. Seishima *et al.*[15] reported a mean attenuation value of ascites in patients with colorectal perforation of 22.5 HU, and values of 16.5 HU for perforation at other sites. For pleural effusions, Çullu *et al.*[16] also reported the mean attenuation value of exudates (12.5 HU) to be significantly higher than the value for transudates (5 HU). In our study, the attenuation values of exudative ascites (gastrointestinal perforation and intestinal ischemia) were significantly higher than values for transudative ascites (bladder rupture). However, attenuation values less than 10 HU were identified in 4 cases of gastrointestinal perforation and intestinal ischemia (Fig. 3). In addition, values less than 10 HU were also identified in cases with transudative ascites associated with conditions other than bladder rupture; these conditions included closed-loop obstruction and malnutrition with serous ascites, peptic ulcer associated with liver cirrhosis, sigmoid diverticulitis in a patient in congestive heart failure with pleural effusions, and small intestinal perforation in a patient on dialysis. The attenuation value of ascites alone was not useful for distinguishing bladder rupture from these 4 cases; however, these exceptional cases had massive ascites that were easily punctured, such that ascites color,[17] odor,[8] and creatinine concentration[7] as obtained by abdominocentesis would have been helpful in the differential diagnosis.

In this study, all attenuation values of ascites were measured using non-contrast CT. Bladder rupture often increases the serum concentration of creatinine in a process known as pseudorenal failure.[8] In fact, 5 of the 7 bladder rupture cases in this study had estimated glomerular filtration rate values <45 mL/min/1.73 m^2. Therefore, the observation that bladder rupture can be diagnosed using attenuation values of ascites on non-contrast CT is highly significant. However, physicians should be aware of any recent contrast material administration when measuring the attenuation values of ascites with this method; a retrospective study showed that delayed contrast enhancement of ascites is common in patients after recent prior i.v. contrast material administration, especially within 3 days after administration.[18] In our study, non-contrast CT was always carried out prior to contrast CT, and we confirmed that patients had not recently been given contrast material.

There were three main limitations in this study. First, the sample size of bladder rupture patients was small; however, this was in agreement with a previously reported low incidence of 0.002% in emergency departments.[1] Second, we did not identify any cases of bladder rupture associated with blunt trauma, despite the fact that blunt trauma is the most common cause of bladder rupture. In such cases, we would expect the HU value to be higher, given that hemorrhagic ascites are typically exudative. Finally, the region of interest of greatest fluid accumulation may have been subject to sampling bias, especially in cases of protein-rich exudative ascites that may have had inhomogeneous attenuation correction such as gravity-dependent layering.

Our study provides evidence that the attenuation value of ascites may be useful for distinguishing bladder rupture from gastrointestinal perforation and intestinal ischemia, with urinary ascites having attenuation values in the range of transudative ascites. We suggest that bladder rupture be considered in the differential diagnosis of patients presenting with acute abdominal pain and attenuation values of ascites of less than 10 HU.

CONFLICT OF INTEREST

NONE DECLARED.

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