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ORIGINAL ARTICLE

Risk factors for gastric distension in patients with acute appendicitis: a retrospective cohort study

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Abstract
Purpose There has been no report on risk factors for gastric distension (GD) when inducing general anesthesia in an emergency situation. The aim of this study was to clarify the risk factors for GD in patients with acute appendicitis at their hospital visit.
Methods We reviewed medical records of patients from April 2007 to March 2010 who underwent open appendectomy for acute appendicitis and were diagnosed pathologically. GD was defined as a larger anteroposterior diameter and larger lateral diameter of the stomach than those of the left kidney in computed tomography (CT) imaging. The primary outcome was the presence of GD. Candidate variables such as patient characteristics, physical findings, and CT imaging findings associated with GD were assessed. Time after beginning of abdominal pain was categorized and compared. Determinants with significant univariate association ($P < 0.20$) with the primary outcome were used to construct multivariable logistic regression models.
Results We enrolled 121 patients and divided this cohort into a GD group (44 cases, 36%) and a non-GD group (77 cases, 64%). Results of univariate analysis showed longer duration of time after beginning of abdominal pain ($P = 0.016$), younger age ($P < 0.001$), and more frequent distended small bowel ($P < 0.001$) in the GD group than in the non-GD group. In multivariate analysis, age [odds ratio (OR) = 0.939, $P = 0.002$] and time after beginning of abdominal pain (OR = 1.807, $P = 0.031$) were shown to be independent risk factors.
Conclusion Younger appendicitis patients with acute abdominal pain for 1 or more days should be treated as patients with high risk for GD.

Keywords Acute appendicitis · Gastric distension · Full stomach · Aspiration pneumonia

Introduction

When inducing general anesthesia in an emergency situation, a vital issue for anesthesiologists is whether the patient has gastric distension (GD), because regurgitated gastric contents could cause aspiration pneumonia or fatal airway obstruction. However, the frequency of such complications of rapid sequence intubation has been reported to be only 3–10 cases in 10,000 cases, and various factors are considered to be associated with these complications [1–4]. It is therefore difficult to investigate these rare but devastating complications in humans prospectively, and even the definition of GD, or full stomach, is not well documented [3, 4]. In this study, we defined GD using X-ray computed tomography (CT) imaging and conducted a retrospective observational study in patients with acute appendicitis, which is the most frequently encountered disease in acute abdomen. The aim of this investigation was to clarify risk factors for GD in patients with acute appendicitis by patient characteristics, results of physical examinations, and the first CT imaging at their hospital visit.

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Materials and methods

After approval from the Research Ethics Committee in our hospital, we reviewed medical records of patients who underwent open appendectomy for acute appendicitis and were diagnosed pathologically as having acute appendicitis during the period from 1 April 2007 to 31 March 2010. Patients were excluded if they were placed on nasogastric tube drainage before CT scanning or had a past history of gastric surgery. Because there were some periods of time in our hospital when CT imaging study was not available during night duty, patients were excluded who did not undergo CT imaging within 1 h after arrival at our hospital.

Extracted information and data included patient's demographics [gender, age, and body mass index (BMI)], physical findings (right lower quadrant pain, fever, nausea, and vomiting), time after beginning of abdominal pain, and imaging findings related to appendicitis using the initial CT (GD, free fluid, perforation, abscess, fat stranding, and distended small bowel). All CT scans were performed with 64-multidetector CT scanners (Aquilion CT scanner; Toshiba, Tokyo, Japan). These imaging findings were evaluated by a staff radiologist who did not have previous information about the patient, surgical procedure, and histological diagnosis. Primary outcome was presence of GD in initial CT at the time of the hospital visit.

Word definitions

We estimated a CT image of anteroposterior and lateral diameter of the stomach in the gastric fundus is positively correlated with the volume of gastric contents and defined GD as both anteroposterior diameter and lateral diameters of the stomach at the level of the gastric fundus larger than those of the left kidney at the level of the renal vein in the initial CT (Fig. 1). Fever was defined as body temperature more than 38.0°C at the patient's arrival. Nausea was defined positive when it was observed at the time of visiting the hospital. Vomiting was defined positive when it was observed at the time between the arrival and initial CT imaging study. Right lower quadrant pain was defined as pain at McBurney's point at the time of visiting the hospital. Time after the beginning of abdominal pain was defined as the time from the beginning of abdominal pain to the patient's hospital visit and was classified into four categorical variables (1, within 6 h; 2, 6–12 h; 3, 12–24 h; 4, more than 24 h). For the initial CT imaging findings, free fluid was defined as any amount of free fluid in the intraperitoneal cavity, perforation was defined when a gas bubble was observed in the intraperitoneal cavity, abscess was defined as fluid collection with a mass effect and enhancing rim around the appendix and cecum, fat stranding was defined as positive when it was observed in the abdominal space, and distended small bowel was defined as three or more distended small bowel loops greater than 3 cm with gas–fluid levels [5, 6].

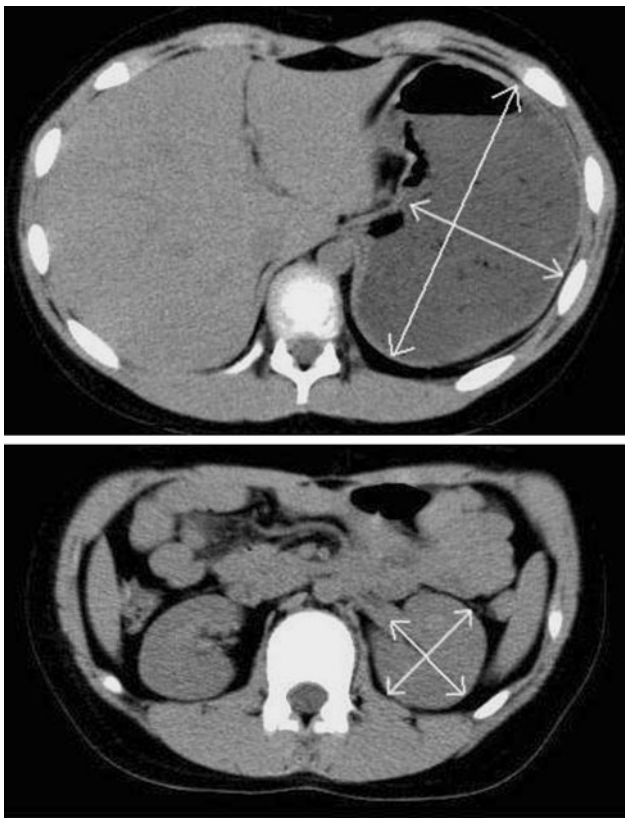

Fig. 1 Evaluation of gastric distension in computed tomography (CT). Maximal anteroposterior and transverse diameters of the stomach at the level of the gastric fundus are compared with those of the left kidney at the renal vein level (*arrows*)

Statistical analysis

The association between the presence and absence of GD was first quantified using univariate analysis. Candidate variables (patient's demographics, time after beginning of abdominal pain, physical findings, and CT findings) were selected. Determinants with significant univariate association ($P < 0.20$) with the primary outcome were used to construct multivariable logistic regression models, presented as adjusted odds ratios with 95% confidential intervals (CI). Interactions between the variables were systematically searched, and colinearity was considered when $r > 0.8$ by Spearman coefficient matrix correlation. Discrimination of the final models with and without GD was assessed by likelihood ratio χ^2 statistics. Calibration of models was tested using the Hosmer–Lemeshow statistic.

Data are expressed as mean ± SD for Gaussian distribution. Comparison of two means was performed using Student's *t* test, comparison of two medians was performed

Table 1 Patient characteristics and findings on admission

	Gastric distension (GD) group	Non-GD group	*P*
n (male:female)	44 (17:27)	77 (35:42)	0.59
Age (year)	18 ± 11	29 ± 14	<0.001
Body mass index (kg/m^2)	21.5 ± 3.0	22.5 ± 3.6	0.14
Right lower quadrant pain	42 (95%)	71 (92%)	0.77
Fever	35 (80%)	58 (75%)	0.7
Nausea	27 (61%)	42 (55%)	0.53
Vomiting	0	0	
Time after beginning of abdominal pain, *n* (%)			0.016
1	6 (14%)	19 (25%)	
2	18 (41%)	39 (51%)	
3	17 (39%)	17 (22%)	
4	3 (7%)	2 (3%)	
CT findings			
Free fluid	20 (45%)	24 (31%)	0.12
Perforation	6 (14%)	6 (8%)	0.23
Abscess	5 (11%)	6 (8%)	1
Fat stranding	29 (66%)	56 (73%)	0.53
Distended small bowel	26 (59%)	21 (27%)	<0.001

Values are presented as mean ± SD or *n* (%). Time after beginning of abdominal pain was classified into four categorical variables (1, within 6 h; 2, 6–12 h; 3, 12–24 h; 4, over 24 h) and displayed as *n* (%)

CT computed tomography, *GD* gastric distension

using the Mann–Whitney *U* test, and comparison of two proportions was performed using Fisher's exact test. We used the R statistical package (version 2.12.1, statistical package, http://www.R-project.org; Free Software Foundation's GNU General Public License, Wien, Austria) to perform all analyses in this study.

Results

Of 139 patients enrolled in this study, 121 patients (87%) fulfilled our criteria with an initial CT within 1 h after visiting the hospital. Of the excluded patients, 2 patients were excluded because they were placed on nasogastric tube drainage. No patient vomited at the time from their arrival to the CT imaging study. Patients were divided into a GD group (44 cases, 36%) and a non-GD group (77 cases, 64%). Patient characteristics and results of univariate analysis are shown in Table 1. Patients in the GD group had a significantly longer duration of time after beginning of abdominal pain ($P = 0.016$) and significantly younger age ($P < 0.001$) than those of patients in the non-GD group. In CT imaging, only distended small bowel was significantly more frequent in the GD group than in the non-GD group ($P < 0.001$). Subsequent multivariate analysis revealed the risk factors for GD (Table 2). Variables with $P < 0.20$ in univariate analysis that were included in the multivariate analysis were age, BMI, time after beginning of abdominal pain, free fluid, and distended small bowel. Multivariate analysis showed that age [odds ratio (OR) = 0.939, $P = 0.002$] and time after beginning of abdominal pain (OR = 1.807, $P = 0.031$) were independent risk factors for GD. No colinearity between the variables was found. Discrimination of the final models assessed by the likelihood ratio χ^2 statistics was significant ($P < 0.001$). Calibration of models tested using the Hosmer–Lemeshow statistic was not significant ($P = 0.457$).

Table 2 Multivariate logistic regression analysis of independent risk factors for gastric distension

Variables	Odds ratio	95% confidence interval	*P*
Age (years)	0.939	0.904–0.977	0.0017
Body mass index (kg/m^2)	0.928	0.812–1.061	0.2739
Time after beginning of abdominal pain	1.807	1.056–3.093	0.0310
Free fluid	1.046	0.416–2.631	0.9237
Distended small bowel	2.191	0.860–5.581	0.1000

Calibration of models was tested using the Hosmer–Lemeshow statistic ($P = 0.457$). Time after beginning of abdominal pain was classified into four categorical variables (1, within 6 h; 2, 6–12 h; 3, 12–24 h; 4, over 24 h)

Discussion

The main finding of this study was that time after beginning of abdominal pain and age of each patient were independent risk factors for GD in multivariate logistic

regression analysis. Younger appendicitis patients with acute abdominal pain for 1 or more days should be treated as patients with high risks of GD and aspiration pneumonia during anesthesia. We considered that evaluation of GD before induction of general anesthesia would contribute to safe anesthetic management. Small-scale animal studies have shown that the intragastric volume required to produce regurgitation under general anesthesia is 0.4–20.8 ml/kg [4, 7]. In critical care patients, the amount of intragastric volume that relates to an increased risk of aspiration pneumonia has been reported as low as 50 ml and more than 500 ml [8–10]. Ljungqvist and Søreide [11] have shown that a minimum of 200 ml fluid gastric volume probably needs to be current to induce passive regurgitation and pulmonary aspiration. We used this definition of GD primarily because comparison of gastric volume and the left kidney in CT imaging is so simple and an easy way. Calculating some lengths with several CT images to evaluate accurate intragastric volume involved too many psychomotor steps and is considered to be unrealistic. Moreover, as the volume of the left kidney is about 133 ml in human adults, and the size is correlated with patient height [12, 13], if we find an obviously larger gastric volume than the left kidney in CT images, the gastric content is thought to be more than 150–200 ml. In most cases, we believe our definition would satisfy the evidence that Ljungqvist and Søreide reported.

In this study, patients with longer time duration after the beginning of abdominal pain and younger patients showed a higher incidence of GD. It is understandable that a longer period of appendicitis leads to a poorer abdominal condition. Animal studies have shown that intraperitoneal *Escherichia coli* infection caused delayed gastric emptying and altered small intestinal transit [14, 15]. Moreover, these changes were observed in a dose-dependent fashion [15]. Intraabdominal infection causes a large amount of free fluid in the abdominal space, abscess around the appendicitis, distended small bowel and GD, and finally leads to secondary peritonitis, which worsens the general condition.

However, the rates of abscess and perforation, which were considered to be related to severe intraabdominal infection, did not show a significant difference between the GD group and non-GD group in our study. Given that it may be because of lack of power, we think further study is needed.

Age was also found to be an independent risk factor for GD. It is well known that diagnosis of appendicitis in pediatric patients is difficult because 33–50% of pediatric patients present atypical symptoms and easily progress to peritonitis by appendiceal perforation [16–19]. The omentum in children has not grown to a sufficient size to completely enwrap an appendiceal perforation [20]. The perforation rate is 10–20% in 10- to 17-year-old patients and is increased to 80–100% in children less than 4 years of age [19–21]. Perforation leads to secondary peritonitis and can result in decreased gastrointestinal motility. These factors delay appropriate initial therapy and lead to GD at a higher frequency in younger patients.

There are some limitations in our study. First, we did not evaluate effects of medication before the visit to our hospital. Especially, antibiotics modulate duration of time after beginning of abdominal pain and intraabdominal infection and inflammation. Second, although we tried to choose a better cutoff value of GD in CT imaging, it was based on little evidence because of difficulty in investigating aspiration pneumonia or fatal airway obstruction prospectively. Finally, because there were few data of older patients with appendicitis and our data were based on a younger population, our result that younger age was an independent risk factor for GD may not be directly applicable to older patients. It is clear that morbidity and mortality rates are greater in elderly patients with appendicitis, who often have delayed and atypical presentations [22].

In conclusion, we studied the risk factors of GD and found that time after beginning of abdominal pain and age were independent risk factors for GD. Understanding the tendency of GD can help predict aspiration pneumonia or fatal airway obstruction, leading to prevention of these devastating complications by emergent induction of general anesthesia.

Conflict of interest We had neither a funding source nor source of support in the form of equipment, drugs, or grants. We had no published material that required written permission of authors and publishers.

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