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• Original Article •

Changes of Clinical Practice in Gastrointestinal Perforation with the Increasing Use of Computed Tomography

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Purpose: The use of computed tomography (CT) to evaluate acute abdominal complaints has increased over the past two decades. We investigated how the clinical practice of patients with intestinal perforation has changed with the increasing use of abdominal CT in the emergency department (ED).

Methods: We compared ED arrival to CT time, ED arrival to surgical consultation time, and ED arrival to operation time according to the method of diagnosis from 2003-2004 and 2013-2014.

Results: In patients with gastrointestinal perforation, time from ED arrival to CT was shorter (111.4±66.2 min vs. 199.0±97.5 min, p=0.001) but time to surgical consultation was longer (135.1±78.8 vs. 77.9±123.7, p=0.006) in 2013-2014 than in 2003-2004. There was no statistically significant difference in time to operation for perforation confirmed either by plain film or CT between the two time periods. There was no statistically significant difference in length of hospital or ICU stay or mortality between the two groups.

Conclusion: With the increasing use of abdominal CT in ED, ED arrival to CT time has decreased and ED arrival to surgical consultation time has increased in gastrointestinal perforation. These changes of clinical performance do not delay ED arrival to operation time or adversely influence patient outcome. [J Trauma Inj 2017; 30: 25-32]

Key Words: Gastrointestinal perforation, Computed tomography, Clinical performance

I. Introduction

Abdominal pain is one of most common chief complaints in adults (≥18 years of age) evaluated in the emergency department (ED).(1-4)

Accurate and timely diagnosis of the etiology of abdominal pain poses a challenge for the emergency physician (EP). The differential diagnosis is broad, and the EP must consider contextual, comorbid, and sociologic factors; surgical causes of abdominal pain have varied and atypical presentations, often with non-specific complaints. Imaging is often used as an adjunct or as a confirmatory test, to ensure safe and appropriate disposition.

Intestinal perforations are a surgical emergency that can be catastrophic if diagnosis is delayed. Although suspicion of the diagnosis is often made on clinical grounds, simple imaging using plain film radiography can detect free air with a sensitivity of 55-85%.(5-8) Before the proliferation of computed tomography (CT), other methods were used to confirm perforation. These included repeated x-rays, contrast, or air insuf-

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flation via nasogastric tube.(9-11) In current practice, CT has obviated further testing for perforation with an accuracy of 86%.(12)

Due to its diagnostic success, CT utilization has increased dramatically over the past two decades. Korea is a major user of CT imaging among developed countries and is the third-highest user of CT imaging among members of the Organisation for Economic Co-operation and Development (OECD).(13) With the ready availability of CT imaging in Korea, the total number of abdominal CT examinations doubled from 31,472 in 2003 to 61,147 in 2007.(14)

In this study, the primary objective was how the clinical practice has changed in patients with intestinal perforation with increasing use of CT in the ED. The secondary objective was to investigate patient outcome with the changes of clinical performance.

II. Materials and Methods

1. Study subjects

Two study periods were compared: 01 January 2003 to 31 December 2004, and 01 January 2013 to 31 December 2014. We included two full years in each decade to mitigate seasonal effect. This study was performed in the ED at three hospitals affiliated with the Korea University Medical Center.

This was a retrospective cohort study of patients diagnosed with gastrointestinal perforation in the ED during the study periods. Our electronic medical record (EMR) was established in all three hospitals prior to the study periods. We searched our EMR for an ED visit that included as one of the diagnoses the following: stomach, small bowel, and/or large bowel perforation. We specifically excluded perforated appendicitis and traumatic perforation.

2. Study Design

After identification of eligible subjects by EMR, we chose all the patients who received an emergency operation during admission period. A detailed chart review was conducted by two emergency medicine specialists. We collected data on the following variables: age, sex, initial vital signs, laboratory data, symptom onset time, final diagnosis, time from ED arrival to CT, time from ED arrival to surgical consultation, time from ED arrival to operation, operative approach, site of perforation, cause of perforation, duration of surgery, diagnostic method of perforation, duration of hospital stay, duration of intensive care unit stay, and mortality.

The diagnosis of gastrointestinal perforation was determined by any of the following: free air on plain radiography; free air, air bubble, or discontinuity of the bowel wall on CT in the radiology report; and/or the documentation of gastrointestinal perforation in the surgical report. Time from ED arrival to surgical consultation was based on the consult time recorded by electronic call system; time to operation was based on the first surgical incision time documented by the operation record. If the two chart reviewers were presented with conflicting data for continuous variables, the mean value was used. For conflicting data with categorical variables, a third investigator reviewed the charts and determined which data were to be used.

3. Analyses

An independent sample t-test was used to compare the mean value of the continuous variables; the Mann-Whitney test was used to compare continuous variables that did not show a normal distribution. Chi-squared analysis or Fisher's exact test was used for the categorical variables using the SPSS Statistics for Windows 17.0 software package (SPSS 17.0, IBM, Chicago, USA). Continuous variables are presented as mean±standard deviation.

4. Ethics statement

This study was carried out after receiving approval from the institutional review board of our hospital information system (IRB No.: KUGH15101).

III. Results

The use of abdominal CT in the ED almost doubled in all three study hospitals between study periods (Fig. 1). All CTs for this indication were performed with IV contrast on a 16-slice CT scanner.

Ninety eight patients were diagnosed with gastrointestinal perforation in the 2003–2004 period. Among them, 70 patients were diagnosed by simple X-ray, 20 patients by CT scan, and 8 patients by operation. There were 99 patients in the 2013–2014 cohort. Among them, 48 patients were diagnosed as gastrointestinal perforation by simple X-ray, 47 patients by CT scan, and 4 patients by operation (Fig. 2).

Laparotomy rates decreased and laparoscopy rates increased between the study periods. The vast majority (94.9%) patients received laparotomy in 2003–2004. In the 2013–2014 time period, 45 (45.5%) patients received laparotomy, 30 (30.3%) patients received laparoscopy, and 25 (25.3%) patients were converted from laparoscopy to laparotomy in 2013–2014 (Table 1).

Table 2 shows the comparison of clinical practice in patients with gastrointestinal perforation according to the diagnostic methods in periods of 2003–2004 and 2013–2014. In patients with gastrointestinal perforation confirmed by X-ray, ED arrival to CT time was significantly shorter in 2013–2014 than in 2003–2004 (111.4±66.2 min vs. 199.0±97.5 min, p=0.001); ED arrival to surgical consultation time was significantly longer in 2013–2014 than in 2003–2004 (135.1±78.8 vs. 77.9±123.7, p=0.006); ED arrival time to operation was shorter in 2003–2004 than in 2013–2004 without statistical difference. In patients with gastrointestinal perforation confirmed by CT, ED arrival to CT time was significantly shorter in 2013–2014 than in 2003–2004 (156.0±81.7 min vs. 298.6±158.5 min, p=0.000); ED arrival to surgical consultation time was significantly longer in 2013–2014 than in 2003–2004 (213.2±109.7 vs. 98.7±72.7, p=0.000); ED arrival time to operation was shorter in 2013–2014 than in 2003–2004 without statistical difference.

Site of detected perforation was different by modality (Table 3). Perforation of the stomach and the first part of duodenum were more frequently diagnosed on simple X-ray than by CT (67.8% vs. 38.8%, p<0.01); jejunum/ileum were the more frequent site of perforation diagnosed by CT than simple X-ray (23.9% vs. 11.0%, p=0.021). Ulcer was more frequent cause of perforation diagnosed by simple X-ray than by CT (65.3% vs. 38.8%, p=0.000); cancer and non-specific inflammation were more frequent cause of perforation diagnosed by CT than simple X-ray (14.9% vs. 5.9%, p=0.042) (19.4% vs. 5.9%, p=0.005).

Patients in whom perforation was confirmed by surgical exploration had varied etiologies (Table 4).

IV. Discussion

Many factors influence the decision to perform advanced imaging in the ED. These include comorbid disease, advancing age, time constraints, and patient and family expectations, among others. Emergency

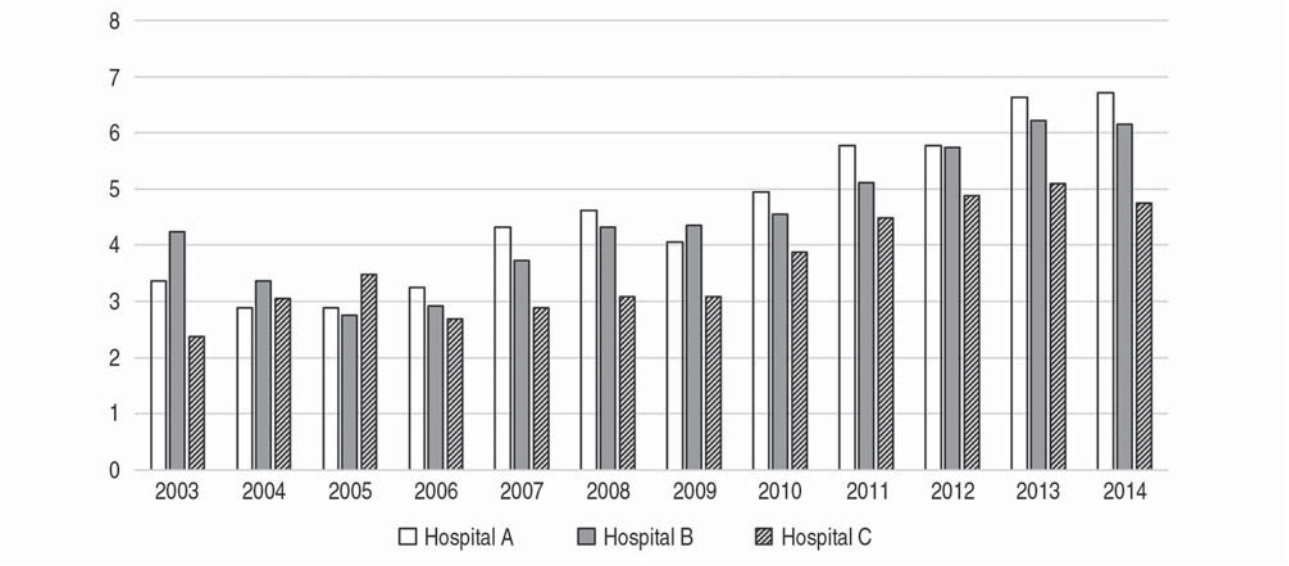

Fig. 1. Number of abdominal computed tomography scans per annual number of patients in the emergency department of the three hospitals.

physicians are faced daily with the challenge of separating acute surgical emergencies from more common benign etiologies of abdominal pain. Many patients with acute abdominal pain present with atypical symptoms that can lead to ambiguous diagnosis; over 25% of patients with abdominal pain are diagnosed as "nonspecific" or "undifferentiated".(4,15-17) A rapid and accurate diagnosis of an abdominal surgical emergency remains difficult, as patients are living longer with more chronic medical burden. Although plain X-ray provides a sensitivity of only 30% overall for diagnosing most causes of the acute abdomen, CT scan has 96% sensitivity.(18) Therefore, the number of CT scans for diagnosing acute abdomen has increased by 141% between 1996 and 2005.(19) Our study at three main campuses of a major medical center in Korea also shows a near doubling of CT utilization rate.

We found an increase in CT utilization between time periods, even for those patients diagnosed by plain films. ED arrival to CT time was more decreased and ED arrival to surgical consultation time was more increased in 2013-2014 than in 2003-2004. This means that if a patient was suspected of gastrointestinal perforation on physical exam, surgical con-

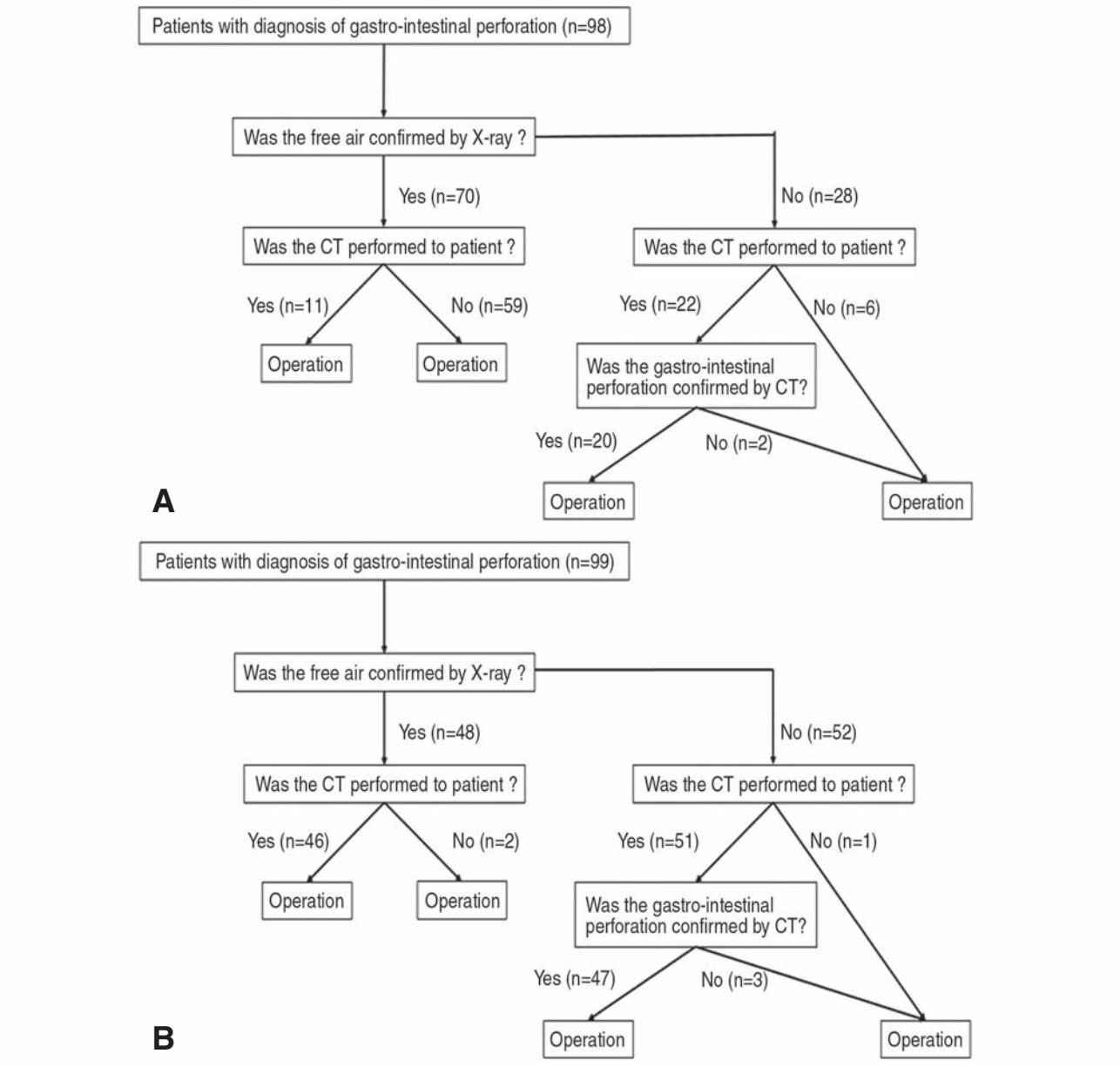

Fig. 2. Patient flow diagram in 2003-2004 (**A**) and 2013-2014 (**B**).

sultation overrode further evaluation for effective process leading to definitive treatment in 2003-2004. This practice has been changed with easy use of CT in ED. As providing more information of patients to surgeon has become easier, surgical consultation is usually done after finishing further evaluation such as CT.

We analyzed whether this changed practice led to delays in operation or not. Table 1 shows that ED

Table 1. Clinical features of study subjects

	2003-2004 (N=98)	2013-2014 (N=99)	*p*-value
Age (years)	51.6±18.8	61.8±16.7	0.000
Sex (M:F)	75:23	70:29	0.299
Vital signs			
SBP (mmHg)	126.0±21.2	123.8±24.5	0.499
DBP (mmHg)	79.4±15.0	74.7±17.9	0.051
Pulse rate (per min)	87.6±19.0	89.9±18.2	0.386
Respiratory rate (per min)	22.6±4.5	21.6±3.6	0.085
Body temperature (°C)	36.5±3.8	36.3±3.8	0.747
Hemoglobin (g/dL)	13.4±2.6	13.1±2.8	0.528
WBC ($10^3/\mu L$)	11.7±5.2	11.0±6.0	0.397
Platelet ($10^3/\mu L$)	268.6±94.1	265.2±116.8	0.823
CRP (mg/dL)	37.1±55.6	59.6±85.8	0.178
ESR (mm/hr)	41.9±39.7	37.2±30.3	0.493
Symptom onset time (days)	1.0±1.6	1.5±3.4	0.253
Operative approach (n, %)			0.000
Laparotomy	93 (94.9)	45 (45.5)	
Laparoscopy	0	30 (30.3)	
Conversion	5 (5.1)	24 (24.2)	
ED arrival to computed tomography time (min)	263.4±142.6	131.6±77.0	0.000
ED arrival to surgical consultation time (min)	80.8±109.3	173.1±101.0	0.000
ED arrival to operation time (min)	378.4±317.6	415.3±205.0	0.332
Duration of surgery (min)	148.1±74.7	131.5±73.7	0.117
Duration of hospital stay (day)	17.9±26.1	18.5±19.2	0.871
Duration of intensive care unit stay (day)	10.0±9.8	9.0±12.7	0.716
Mortality (n, %)	6 (6.1)	8 (8.1)	0.254

* Numerical data are presented with mean±standard deviation.

SBP: systolic blood pressure, DBP: diastolic blood pressure, WBC: white blood cell, CRP: C-reactive protein, ESR: erythrocyte sedimentation rate, ED: emergency department

Table 2. Comparison of clinical performance in patients with gastro-intestinal perforation according to the diagnostic methods in periods of 2003-2004 and 2013-2014

	2003-2004	2013-2014	*p*-value
Confirmed by X-ray	n=70	n=48	
ED arrival to computed tomography time (min)	199.0±97.5	111.4±66.2	0.001
ED arrival to surgical consultation time (min)	77.9±123.7	135.1±78.8	0.006
ED arrival to operation time (min)	289.5±242.6	354.3±172.4	0.114
Confirmed by computed tomography	n=20	n=47	
ED arrival to computed tomography time(min)	298.6±158.5	156.0±81.7	0.000
ED arrival to surgical consultation time (min)	98.7±72.7	213.2±109.7	0.000
ED arrival to operation time (min)	551.2±330.9	472.0±218.5	0.252

* Numerical data are presented with mean±standard deviation.

ED: emergency department

arrival to operation time was not increased. Although ED arrival to operation time was shorter in patients with perforation confirmed by simple X-ray in 2003-2004 than in 2013-2014 (without statistical signifi-

Table 3. Site and cause of gastro-intestinal perforation by diagnostic modality

	X-ray (N=118)	CT (N=67)	*p*-value
Site of perforation (n, %)			
Stomach and first part of the duodenum	80 (67.8)	26 (38.8)	0.000
Second-fourth part of the duodenum	0 (0)	1 (1.5)	0.362
Jejunum/ileum	13 (11.0)	16 (23.9)	0.021
Ascending/descending colon	6 (5.1)	7 (10.4)	0.170
Transverse colon/sigmoid colon	18 (15.3)	14 (20.9)	0.330
Rectum	1 (0.8)	3 (4.5)	0.136
Cause of perforation (n, %)			
Ulcer	77 (65.3)	25 (37.3)	0.000
Cancer	7 (5.9)	10 (14.9)	0.042
Iatrogenic	14 (11.9)	5 (7.5)	0.343
Non-specific inflammation	7 (5.9)	13 (19.4)	0.005
Tuberculosis	2 (1.7)	0 (0)	0.535
Crohn's disease	1 (0.8)	0 (0)	1.000
Diverticulitis	3 (2.5)	5 (7.5)	0.141
Miscellaneous	7 (5.9)	9 (13.4)	0.081

Table 4. Characteristics of patients with gastro-intestinal perforation diagnosed on operation

No.	Year of visit	Sex	Age	ED arrival to CT	ED arrival to surgical consultation	ED arrival to operation	Site of perforation	Cause of perforation
1	2013-2014	F	86	N/A	60 min	285 min	ileum	Strangulation due to hernia
2	2013-2014	M	56	89min	185 min	842 min	Descending colon	Cancer
3	2013-2014	M	41	24 min	173 min	560 min	First part of duodenum	Ulcer
4	2013-2014	F	82	103 min	147 min	347 min	Rectum	Stercoral perforation
5	2003-2004	M	62	N/A	50 min	994 min	ileum	Strangulation due to adhesion
6	2003-2004	F	88	228 min	50 min	460 min	Ascending colon	Diverticulitis
7	2003-2004	F	56	N/A	28 min	75 min	Sigmoid colon	Iatrogenic
8	2003-2004	M	87	N/A	120 min	490 min	Sigmoid colon	Non-specific inflammation
9	2003-2004	M	41	N/A min	52 min	1073 min	First part of duodenum	Ulcer
10	2003-2004	M	42	240 min	60 min	1016 min	Ascending colon	Diverticulitis
11	2003-2004	M	36	N/A	170 min	260 min	Stomach	Ulcer
12	2003-2004	M	42	N/A	110 min	1426 min	Cecum	Diverticulitis

cance, Table 3), it may be because many cases in 2003-2004 were transferred to the operation room without additional CT. We put much weight on the results of patients with perforation confirmed by CT. In these patients, although not statistically significance, ED arrival to operation time was decreased despite the increased surgical consult time. It means that the effort to make a definite diagnosis in patient with suspicious gastrointestinal perforation by CT does not cause a delay, or even shorten, in ED arrival to operation time. There were also no changes in duration of surgery, hospital length of stay, ICU stay, or mortality between cohorts in this study.

In this study, the stomach and first part of the duodenum were the most frequent perforation sites in patients with perforation confirmed by simple X-ray; small bowel was more frequent in patients with perforation confirmed by CT than by simple X-ray (Table 3). This may be due to the difference in location or amount of air leakage. Air leakage from stomach or duodenum is abundant and its location is around liver and stomach in general, which makes it possible to easily confirm free air in these perforations by simple X-ray.(12,19-21) On the contrary, free air in small bowel perforation is not so abundant as to be detected more frequently by CT than by simple X-ray.

Table 4 lists the cases with gastrointestinal perforation diagnosed on operation. This group of patients, if physical examination was not obvious, might make the emergency physicians to have a trouble in whether seeking emergent surgical consultation or not. They might pose a challenge to the surgeon in deciding on an emergent operation. Eight of these patients (66%) received operation after 6 hours of their ED arrival; five had surgery 12 hours after their arrival.

V. Limitations

This study has several limitations inherent to most retrospective analyses. The data of this study were limited to three medical centers, which might generate a bias of faulty generalization in other hospitals with different environment. The other limitation is that there are many other factors influencing clinical performance in ED such as medical resources, hospital volumes/crowding, and baseline patient characteristics, however, all of which we did not consider in this study. We also included only those who were diagnosed with perforation. We do not know about those in whom the diagnosis was missed and we do not speak to overall utilization of abdominal CT.

VI. Conclusion

With the increasing use of abdominal CT in ED, ED arrival to CT time has been decreased and ED arrival to surgical consultation time has been increased in gastrointestinal perforation. These changes of clinical performance does not cause delay of ED arrival to operation time or adverse patient outcome.

REFERENCES

1) Brewer BJ, Golden GT, Hitch DC, Rudolf LE, Wangensteen SL. Abdominal pain. An analysis of 1,000 consecutive cases in a University Hospital emergency room. Am J Surg 1976; 131: 219-23.
2) Powers RD, Guertler AT. Abdominal pain in the ED: stability and change over 20 years. Am J Emerg Med 1995; 13: 301-3.
3) Sanson TG, O'Keefe KP. Evaluation of abdominal pain in the elderly. Emerg Med Clin North Am 1996; 14: 615-27.
4) Kamin RA, Nowicki TA, Courtney DS, Powers RD. Pearls and pitfalls in the emergency department evaluation of abdominal pain. Emerg Med Clin North Am 2003; 21: 61-72, vi.
5) Kumar A, Muir MT, Cohn SM, Salhanick MA, Lankford DB, Katabathina VS. The etiology of pneumoperitoneum in the 21st century. J Trauma Acute Care Surg 2012; 73: 542-8.
6) Levine MS, Scheiner JD, Rubesin SE, Laufer I, Herlinger H. Diagnosis of pneumoperitoneum on supine abdominal radiographs. AJR Am J Roentgenol 1991; 156: 731-5.
7) Shaffer HA, Jr. Perforation and obstruction of the gastrointestinal tract. Assessment by conventional radiology. Radiol Clin North Am 1992; 30: 405-26.
8) Baker SR. Imaging of pneumoperitoneum. Abdom Imaging 1996; 21: 413-4.
9) Coleman JA, Denham MJ. Perforation of the peptic ulceration in the elderly. Age Ageing 1980; 9: 257-61.
10) Kane E, Fried G, McSherry CK. Perforated peptic ulcer in the elderly. J Am Geriatr Soc 1981; 29: 224-7.
11) Upadhye AS, Dalvi AN, Nair HT. Nasogastric air insufflation in early diagnosis of perforated peptic ulcer. J Postgrad Med 1986; 32: 82-4.
12) Hainaux B, Agneessens E, Bertinotti R, De Maertelaer V, Rubesova E, Capelluto E, et al. Accuracy of MDCT in predicting site of gastrointestinal tract perforation. AJR Am J Roentgenol 2006; 187: 1179-83.
13) OECD (2011) Health at a Glance 2011: OECD Indicators,

OECD Publishing, Paris. DOI: http://dx.doi.org/10.1787/health_glance-2011-en.
14) Lee W. Current status of medical radiation exposure and regulation efforts. J Korean Med Assoc 2011; 54: 1248-52.
15) Irvin TT. Abdominal pain: a surgical audit of 1190 emergency admissions. Br J Surg 1989; 76: 1121-5.
16) Jess P, Bjerregaard B, Brynitz S, Holst-Christensen J, Kalaja E, Lund-Kristensen J, et al. Prognosis of acute nonspecific abdominal pain. A prospective study. Am J Surg 1982; 144: 338-40.
17) Lukens TW, Emerman C, Effron D. The natural history and clinical findings in undifferentiated abdominal pain. Ann Emerg Med 1993; 22: 690-6.
18) MacKersie AB, Lane MJ, Gerhardt RT, Claypool HA, Keenan S, Katz DS, et al. Nontraumatic acute abdominal pain: unenhanced helical CT compared with three-view acute abdominal series. Radiology 2005; 237: 114-22.
19) Levin DC, Rao VM, Parker L, Frangos AJ, Sunshine JH. Ownership or leasing of CT scanners by nonradiologist physicians: a rapidly growing trend that raises concern about self-referral. J Am Coll Radiol 2008; 5: 1206-9.
20) Kim SH(1), Shin SS, Jeong YY, Heo SH, Kim JW, Kang HK. Gastrointestinal tract perforation: MDCT findings according to the perforation sites. Korean J Radiol 2009; 10: 63-70.
21) Furukawa A, Sakoda M, Yamasaki M, Kono N, Tanaka T, Nitta N, et al. Gastrointestinal tract perforation: CT diagnosis of presence, site, and cause. Abdom Imaging 2005; 30: 524-34.