Free abdominal gas on computed tomography in the emergency department: aetiologies and association between amount of free gas and mortality

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ABSTRACT

INTRODUCTION Free abdominal gas is an important finding with major clinical implications. However, data on the aetiologies and prognosis of patients with free gas are scarce. Our primary aim was to describe the sources of free abdominal gas on emergency department (ED) computed tomography (CT). The secondary aim was to evaluate the association between the amount of free gas and all-cause mortality.

METHODS All patients who underwent CT in the ED between February 2012 and February 2019 with free abdominal gas were included in the study. A scoring system was used to assess the amount of free gas: small – gas bubbles; medium – any gas pocket ≤ 2 cm in diameter; large – any gas pocket > 2 cm. Data were collected from laboratory and clinical assessment regarding the source of free gas and all-cause mortality.

RESULTS A total of 372 patients had free abdominal gas. Colonic diverticulitis was the most common aetiology among those with a small or medium amount of free gas (81/250 [32.4%] and 12/71 [16.9%] respectively). For patients with a large amount of gas, peptic disease was the most common aetiology (11/51 [21.6%]). Three-quarters of the patients (280/372, 75.2%) had the source of free gas identified during ED admission. Ninety-day mortality rates were 7.2%, 9.9% and 21.6% for patients with small, medium and large amounts of gas respectively ($p=0.007$).

CONCLUSIONS Colonic diverticulitis was the most common source of free abdominal gas and peptic disease was the most common cause of a large amount of free gas. Mortality rates correlated with the amount of gas and were significantly higher in patients with a large amount.

KEYWORDS

Computed tomography – Pneumoperitoneum – Survival – Prognosis

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Introduction

Free abdominal gas (pneumoperitoneum and pneumoretroperitoneum) is often abnormal and secondary to hollow viscus perforation, a life threatening event that commonly requires urgent abdominal surgery.¹ Such cases can carry a risk of significant mortality. For example, the in-hospital mortality rate for a perforated peptic ulcer (a common cause of pneumoperitoneum) ranges from 5% to 24% and the mortality rate for peritonitis secondary to perforation can be as high as 9.6%.^{2–5}

Plain radiography is often the initial imaging modality of choice when evaluating patients with acute abdominal pain.^{3,6} Upright plain chest radiography can detect as little as 1ml of gas with a sensitivity of up to 78% although in the emergency setting, the much less sensitive supine radiography of the chest and abdomen is used.^{7,8} However,

computed tomography (CT) has a sensitivity of up to 92% in detecting free abdominal gas, and allows better localisation and diagnosis.^{9–11} CT is therefore preferred when hollow viscus perforation is suspected.¹²

Most published studies either approach pneumoperitoneum as a secondary finding or assess pneumoperitoneum only in the context of a specific aetiology. There is a paucity of data assessing the aetiologies of free abdominal gas in the emergency department (ED) and data evaluating the prognosis of these patients are even more scarce.^{12–19} In addition, there is no universal scoring system to evaluate the amount of free peritoneal gas and various methods have been used by different authors for assessment of gas volume.^{3,11,20,21}

The primary aim of this study was to describe the sources of free abdominal gas seen on ED CT. The

secondary aim was to evaluate the association between the amount of free gas and all-cause mortality.

Methods

This was a retrospective study from a single centre approved by the institutional review board. The board committee waived the need for informed patient consent. Our academic acute care tertiary hospital has approximately 1,800 beds and 185,000 ED visits per year.

In order to identify eligible patients, the CT reports were reviewed of all patients who underwent abdominopelvic CT in the ED between February 2012 and February 2019. All CT reports in our radiology information system were searched for text including any of the following terms or term combinations: “free gas” “free air” “perforation” “extra-luminal gas” “extra-luminal air” “pneumoperitoneum” “pneumoretroperitoneum” “gas containing” and “air containing”.

CT reports with these terms were screened by one author (with oversight by a second author) and only reports conveying positive findings (ie free abdominal gas of any amount) were included in the study. Of these, the final cohort comprised only patients with free gas for whom data were available regarding subsequent hospitalisation and 90-day mortality.

CT was performed on two platforms: Brilliance 64 (Philips, Cleveland, OH, US) or Discovery 64 (General Electric, Waukesha, WI, US). Unless contraindicated, all CT included intravenous contrast. Oral contrast was administered according to the referring physician's discretion.

As there is no standardised scoring system for assessing the amount of free abdominal gas, we chose to adopt a scoring system used previously to assess the amount of free gas on CT in cases of acute complicated diverticulitis.^{22,25} A small amount of gas was defined as bubbles without an

obvious gas pocket (Fig 1) while any gas pocket up to 2cm in longest diameter was deemed a medium amount (Fig 2) and any gas pocket larger than 2cm was judged as a large amount (Fig 3). One author, blinded as much as possible to the source of free gas, reviewed all ED CT for included patients and assigned a gas amount score for each individual.

The initial CT findings and all clinical data available on ED presentation were combined to assess whether the aetiology of free abdominal gas was evident in the ED. If the cause of free gas was not readily evident, this was noted, and the patient's medical records and subsequent

Figure 2 Medium amount of free gas appearing as a collection measuring 1.4cm in maximal diameter in a patient with a perforated sigmoid colon tumour (not shown)

Figure 1 Small amount of free gas (arrows) appearing as a few gas bubbles in a postoperative patient

Figure 3 Large amount of free gas (arrows) measuring >2cm in maximal diameter in a patient with small bowel perforation due to a foreign object (not shown)

surgical reports (if any) were accessed to evaluate whether a source of free gas was found during the patient's stay in hospital.

Electronic medical records provided laboratory results in the ED as well as information on clinical follow-up review, which included clinical assessment as to the aetiology of free abdominal gas. Mortality rates were retrieved from the Ministry of Interior's records and the time from ED admission to death was calculated, up to 90 days from admission.

Statistical analysis

All statistical analysis was conducted using statistical packages in Python™ version 3.6.5 (Python Software Foundation, Wilmington, DE, US). Statistical significance was established with a two-sided *p*-value of <0.05. Cumulative survival was analysed using the Kaplan–Meier method with evaluation of the differences in survival between patients with small, medium and large amounts of free abdominal gas up to 90 days following admission to the ED. A chi-squared test was employed to evaluate the significance of differences in survival rates.

Results

Between February 2012 and February 2019, 48,425 patients underwent abdominopelvic CT in our ED. Of these, 372 had CT reports mentioning evidence of free abdominal gas and these comprised our final study cohort.

The mean patient age was 57.0 years (standard deviation: 18.4 years). Over half of the cohort was male (208/372, 56%). Table 1 summarises the demographic and clinical data at presentation to the ED. Colonic diverticulitis (27.4%), normal postoperative free gas (13.2%) and anastomotic leak (10.5%) were the most common causes of free gas. Table 2 presents the aetiologies for the different amounts of free gas and whether the source of perforation was evident during ED presentation. For three-quarters (75.2%) of the patients, the source of extraluminal gas was evident during their ED admission.

Figures 4–6 present the five leading aetiologies of free abdominal gas for small, medium and large amounts of gas. For those with a small amount, the two most common aetiologies were colonic diverticulitis (81/250, 32.4%) and normal postoperative free gas (42/250, 16.8%). In the medium amount group, the two main causes were colonic diverticulitis (12/71, 16.9%) and anastomotic leak (10/71, 14.1%). Among patients with a large amount of free gas, the two leading aetiologies were peptic disease (11/51, 21.6%) and colonic diverticulitis (9/51, 17.6%).

Table 3 shows mortality rates at 7, 30 and 90 days from admission to the ED. Patients with free air due to bowel ischaemia had the highest mortality (3/6, 50% at 90 days), followed by those with extraluminal gas due to tumour related perforation (10/28, 35.7% at 90 days).

The 90-day mortality rates were 7.2%, 9.9% and 21.6% for patients with small, medium and large amounts

Figure 4 Five main aetiologies for small amount of free gas

Table 1 Patient demographics and clinical findings on emergency department presentation

Aetiology for free gas	Frequency	Mean age (years)	Male sex	Mean temperature (°C)	Mean systolic blood pressure (mmHg)	Mean white blood count (x 10 ⁹ /l)	Mean lactate (mg/dl)
Colonic diverticulitis	102/372 (27.4%)	58.0 (SD: 14.4)	57/102 (55.9%)	37.1 (SD: 0.6)	131.2 (SD: 20.6)	14.0 (SD: 4.9)	19.6 (SD: 8.1)
Postoperative (normal amount)	49/372 (13.2%)	51.7 (SD: 18.8)	25/49 (51.0%)	37.1 (SD: 0.8)	124.8 (SD: 24.5)	12.8 (SD: 6.3)	24.6 (SD: 19.7)
Anastomotic leak	39/372 (10.5%)	55.5 (SD: 16.4)	23/39 (59.0%)	37.0 (SD: 0.6)	121.2 (SD: 20.2)	15.1 (SD: 6.8)	24.7 (SD: 12.2)
Appendicitis	39/372 (10.5%)	48.8 (SD: 20.0)	24/39 (61.5%)	37.3 (SD: 0.6)	125.7 (SD: 12.8)	15.8 (SD: 5.5)	19.4 (SD: 6.6)
Tumour related perforation	28/372 (7.5%)	64.8 (SD: 17.1)	14/28 (50.0%)	37.0 (SD: 0.4)	120.3 (SD: 24.1)	13.7 (SD: 7.4)	30.2 (SD: 17.9)
Peptic disease	26/372 (7.0%)	56.7 (SD: 22.7)	17/26 (65.4%)	36.7 (SD: 0.3)	125.2 (SD: 20.8)	13.6 (SD: 6.5)	25.7 (SD: 10.4)
Post-colonoscopy	15/372 (4.0%)	61.9 (SD: 14.0)	5/15 (33.3%)	37.0 (SD: 0.5)	135.2 (SD: 29.0)	14.1 (SD: 6.4)	21.5 (SD: 6.9)
Crohn's disease	13/372 (3.5%)	46.1 (SD: 19.9)	10/13 (76.9%)	37.0 (SD: 0.6)	117.8 (SD: 18.0)	14.6 (SD: 7.1)	21.1 (SD: 9.8)
Unknown cause	12/372 (3.2%)	59.0 (SD: 21.2)	8/12 (66.7%)	37.0 (SD: 0.6)	126.6 (SD: 17.1)	12.2 (SD: 5.0)	21.2 (SD: 13.2)
Small bowel perforation of unknown cause	9/372 (2.4%)	74.3 (SD: 15.9)	4/9 (44.4%)	37.0 (SD: 0.9)	129.3 (SD: 25.1)	12.9 (SD: 4.3)	36.0 (SD: 27.4)
Colitis	8/372 (2.2%)	71.6 (SD: 21.0)	2/8 (25.0%)	36.9 (SD: 0.5)	123.0 (SD: 20.7)	14.8 (SD: 6.3)	33.3 (SD: 13.2)
PEG related perforation	8/372 (2.2%)	63.6 (SD: 17.4)	5/8 (62.5%)	37.4 (SD: 1.0)	111.6 (SD: 24.1)	8.5 (SD: 4.6)	28.6 (SD: 19.5)
Bowel ischaemia	6/372 (1.6%)	68.8 (SD: 20.9)	2/6 (33.3%)	36.7 (SD: 0.3)	112.3 (SD: 34.0)	12.3 (SD: 5.3)	36.4 (SD: 37.2)
Meckel's diverticulitis	5/372 (1.3%)	37.2 (SD: 17.6)	5/5 (100%)	37.0 (SD: 0.6)	133.0 (SD: 5.3)	16.6 (SD: 5.1)	45.2 (SD: 34.0)
Peritoneal dialysis	3/372 (0.8%)	49.3 (SD: 4.2)	2/3 (66.7%)	36.5 (SD: 0.8)	141.0 (SD: 10.0)	8.8 (SD: 2.3)	Not measured
Postoperative abscess	3/372 (0.8%)	62.3 (SD: 9.0)	2/3 (66.7%)	36.7 (SD: 0.1)	132.3 (SD: 15.4)	13.3 (SD: 5.2)	14.0 (SD: 6.1)
Small bowel diverticulitis	3/372 (0.8%)	58.7 (SD: 25.1)	2/3 (66.7%)	36.8 (SD: 0.2)	125.0 (SD: 24.3)	12.6 (SD: 5.8)	24.5 (SD: 20.5)
Foreign body	2/372 (0.5%)	83.5 (SD: 14.8)	0/2 (0%)	37.1 (SD: 0.4)	126.0 (SD: 0.0)	16.4 (SD: 8.7)	18.0 (SD: 7.9)
Enema related perforation	1/372 (0.3%)	60	1/1 (100%)	37.2	141	9.0	14
Colonic perforation of unknown cause	1/372 (0.3%)	69	0/1 (0%)	37.0	103	24.9	23

PEG = percutaneous endoscopic gastrostomy; SD = standard deviation

Table 2 Aetiologies for different amounts of free abdominal gas

Aetiology for free gas	Frequency	Small amount	Medium amount	Large amount	Cause identified on CT
Colonic diverticulitis	102/372 (27.4%)	81/102 (79.4%)	12/102 (11.8%)	9/102 (8.8%)	88/102 (86.3%)
Postoperative (normal amount)	49/372 (13.2%)	42/49 (85.7%)	5/49 (10.2%)	2/49 (4.1%)	43/49 (87.8%)
Anastomotic leak	39/372 (10.5%)	23/39 (59.0%)	10/39 (25.6%)	6/39 (15.4%)	29/39 (74.4%)
Appendicitis	39/372 (10.5%)	34/39 (87.2%)	4/39 (10.3%)	1/39 (2.6%)	37/39 (94.9%)
Tumour related perforation	28/372 (7.5%)	11/28 (39.3%)	9/28 (32.1%)	8/28 (28.6%)	16/28 (57.1%)
Peptic disease	26/372 (7.0%)	6/26 (23.1%)	9/26 (34.6%)	11/26 (42.3%)	17/26 (65.4%)
Post-colonoscopy	15/372 (4.0%)	11/15 (73.3%)	2/15 (13.3%)	2/15 (13.3%)	11/15 (73.3%)
Crohn's disease	13/372 (3.5%)	11/13 (84.6%)	2/13 (15.4%)	0/13 (0%)	10/13 (76.9%)
Unknown cause	12/372 (3.2%)	7/12 (58.3%)	4/12 (33.3%)	1/12 (8.3%)	0/12 (0%)
Small bowel perforation of unknown cause	9/372 (2.4%)	5/9 (55.6%)	4/9 (44.4%)	0/9 (0%)	6/9 (66.7%)
Colitis	8/372 (2.2%)	4/8 (50.0%)	2/8 (25.0%)	2/8 (25.0%)	1/8 (12.5%)
PEG related perforation	8/372 (2.2%)	1/8 (12.5%)	2/8 (25.0%)	5/8 (62.5%)	5/8 (62.5%)
Bowel ischaemia	6/372 (1.6%)	2/6 (33.3%)	2/6 (33.3%)	2/6 (33.3%)	4/6 (66.7%)
Meckel's diverticulitis	5/372 (1.3%)	3/5 (60.0%)	1/5 (20.0%)	1/5 (20.0%)	3/5 (60.0%)
Peritoneal dialysis	3/372 (0.8%)	3/3 (100%)	0/3 (0%)	0/3 (0%)	3/3 (100%)
Postoperative abscess	3/372 (0.8%)	1/3 (33.3%)	2/3 (66.7%)	0/3 (0%)	2/3 (66.7%)
Small bowel diverticulitis	3/372 (0.8%)	2/3 (66.7%)	1/3 (33.3%)	0/3 (0%)	3/3 (100%)
Foreign body	2/372 (0.5%)	2/2 (100%)	0/2 (0%)	0/2 (0%)	0/2 (0%)
Enema related perforation	1/372 (0.3%)	1/1 (100%)	0/1 (0%)	0/1 (0%)	1/1 (100%)
Colonic perforation of unknown cause	1/372 (0.3%)	0/1 (0%)	0/1 (0%)	1/1 (100%)	1/1 (100%)
Total	372/372 (100%)	250/372 (67.2%)	71/372 (19.1%)	51/372 (13.7%)	280/375 (75.2%)

CT = computed tomography; PEG = percutaneous endoscopic gastrostomy

of free abdominal gas respectively. The mortality rate was significantly higher ($p=0.007$) for those with a large amount of free air (Fig 7). After excluding patients with normal postoperative extraluminal gas, there

remained a difference in mortality, with 90-day mortality rates of 6.7%, 10.6% and 22.4% for small, medium and large amounts respectively ($p=0.008$) (Fig 8).

Figure 5 Five main aetiologies for medium amount of free gas

Figure 6 Five main aetiologies for large amount of free gas
PEG = percutaneous endoscopic gastrostomy

Figure 7 Kaplan–Meier curve for 90-day survival for all patients with free abdominal gas, grouped by amount of gas ($n=372$)

Figure 8 Kaplan–Meier curve for 90-day survival, excluding patients with a normal postoperative amount of free abdominal gas, grouped by amount of gas ($n=315$)

Table 3 All-cause mortality by free gas aetiology

Aetiology for free gas	7-day mortality	30-day mortality	90-day mortality
Colonic diverticulitis	0/102 (0%)	3/102 (2.9%)	5/102 (4.9%)
Postoperative (normal amount)	0/49 (0%)	3/49 (6.1%)	4/49 (8.2%)
Anastomotic leak	0/39 (0%)	2/39 (5.1%)	4/39 (10.3%)
Appendicitis	0/39 (0%)	0/39 (0%)	0/39 (0%)
Tumour related perforation	2/28 (7.1%)	6/28 (21.4%)	10/28 (35.7%)
Peptic disease	0/26 (0%)	1/26 (3.8%)	4/26 (15.4%)
Post-colonoscopy	0/15 (0%)	0/15 (0%)	0/15 (0%)
Crohn's disease	0/13 (0%)	0/13 (0%)	0/13 (0%)
Unknown cause	0/12 (0%)	1/12 (8.3%)	1/12 (8.3%)
Small bowel perforation of unknown cause	1/9 (11.1%)	1/9 (11.1%)	2/9 (22.2%)
Colitis	0/8 (0%)	1/8 (12.5%)	1/8 (12.5%)
PEG related perforation	1/8 (12.5%)	2/8 (25.0%)	2/8 (25.0%)
Bowel ischaemia	2/6 (33.3%)	3/6 (50.0%)	3/6 (50.0%)
Meckel's diverticulitis	0/5 (0%)	0/5 (0%)	0/5 (0%)
Peritoneal dialysis	0/3 (0%)	0/3 (0%)	0/3 (0%)
Postoperative abscess	0/3 (0%)	0/3 (0%)	0/3 (0%)
Small bowel diverticulitis	0/3 (0%)	0/3 (0%)	0/3 (0%)
Foreign body	0/2 (0%)	0/2 (0%)	0/2 (0%)
Enema related perforation	0/1 (0%)	0/1 (0%)	0/1 (0%)
Colonic perforation of unknown cause	0/1 (0%)	0/1 (0%)	0/1 (0%)

PEG = percutaneous endoscopic gastrostomy

Discussion

Free abdominal gas is an important finding on CT. When it is secondary to gastrointestinal tract perforation, it often carries significant morbidity and requires surgical treatment.²⁴ Most published studies focus on the ability of CT to identify free gas or assess a single pathology causing hollow viscus perforation.^{2-4,11,16,17,19,21,25} The aim of the present study was to describe all the different aetiologies for free abdominal gas, and to evaluate whether there was an association between the amount of gas and all-cause mortality. To our knowledge, this is the largest study to date that assesses the various aetiologies of free gas and the resulting mortality.

The most common overall source of free abdominal gas was colonic diverticulitis (27.4%), which was also the most common cause for small and medium amounts of free gas. Other authors have reported similar findings, listing diverticulitis and appendicitis as leading causes.^{3,18,24} However, in our study, the most common aetiology for a large amount of free gas was peptic disease (11/51, 21.6%); other studies have found colonic perforation to be the main cause.²

When taking into account the patient's history (prior surgery, oncological background) and CT findings, the

majority of the patients (280/375, 75.2%) had the source of free abdominal gas identified during the initial ED assessment. This is likely to be of benefit to patients as a prompt treatment plan can be devised, targeting the specific pathology, although this would need further investigation in future studies.

All-cause mortality at 7, 30 and 90 days was significantly higher in patients with a large amount of free abdominal gas than in the small and medium groups. Our study did not examine potential explanations for this finding as some common causes for free gas among patients with a large amount of gas can carry high mortality (eg peptic disease and tumour related bowel perforation),^{2,26-28} which may account for the differences observed between the patient groups. Our results suggest that individuals with a large amount of free abdominal gas should be treated the same as patients with significant life threatening disease, especially as most patients have the source of free gas readily identified on initial assessment.^{11,16,29,30}

One of the strengths of our study was that all patients presenting to the ED of a large tertiary hospital over a seven-year period were included. This search paradigm encompassed all potential cases. Furthermore, any amount of free gas was included and of any cause, thereby encompassing all possible aetiologies.

Nevertheless, there are limitations to our study. Patients were identified from their initial ED CT reports and so it is possible that a few potential cases could have been missed. A further limitation is the simple scoring system devised for assessing the amount of free abdominal gas as there is no agreed system in the literature. While a different method of scoring might have produced different results, the significant difference in mortality between the small, medium and large amount groups suggests that our choice of scoring the free gas volume may have clinical value, and is therefore robust. This system would benefit from confirmation in future studies.

Finally, there may be factors other than the amount of free gas that can explain the differences in mortality rates between the various groups, factors that were not explored in our current study. However, this study shows that the amount of free abdominal gas on initial CT could serve as an important marker during patient management and work-up in the ED.

Conclusions

Colonic diverticulitis was the most common source of free abdominal gas and peptic disease was the most common cause of a large amount of free gas. Mortality rates correlated with the amount of gas, with significantly higher mortality rates seen in patients with a large amount of free abdominal gas.

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