Computed Tomographic Diagnosis of Pneumatosis Intestinalis

Clinical Measures Predictive of the Need for Surgical Intervention

Vincent P. Duron, MD; Sandra Rutigliano, MD; Jason T. Machan, PhD; Damian E. Dupuy, MD; Peter J. Mazzaglia, MD

Objective: To determine which clinical, laboratory, and radiographic parameters predict positive operative findings in patients with pneumatosis intestinalis on computed tomography (CT).

Design: Retrospective record review.

Setting: Tertiary care hospital and affiliated community hospital.

Patients: One hundred fifty consecutive patients diagnosed as having pneumatosis intestinalis on CT.

Main Outcome Measures: Presence or absence of abdominal pathological findings at laparotomy and mortality rates.

Results: Of the 150 patients studied, 54 (36%) were managed nonoperatively, 72 (48%) were managed operatively, and 24 (16%) were considered unsalvageable and given comfort measures only. Sixty patients (47%) improved with nonoperative management or had negative intraoperative findings. In the nonoperative group, 50 (93%) improved (n=50) and 3 (5%) crossed over to surgery. One patient (2%) died. In the operative group, 63 patients (87%) had operative findings requiring intervention and 9 (13%) had negative results on exploration. Twenty-one patients (28%) died. Univariate analysis identified numerous predictors of positive intraoperative findings, including history of coronary artery disease, tachycardia, tachypnea, hypotension, peritonitis, abdominal distention, and lactic acidemia. The significant radiographic findings included dilated loops of bowel, portal venous gas, and atherosclerosis on CT. On multivariate analysis, only abdominal distention (odds ratio=13.19; \( P = .001 \)), peritonitis (odds ratio=9.35; \( P = .007 \)), and lactic acidemia (odds ratio=2.29; \( P = .02 \)) were predictive of positive intraoperative findings.

Conclusions: Many patients with pneumatosis intestinalis on CT can be successfully treated nonoperatively. In determining a management strategy, abnormal physical examination findings were more predictive of the need for surgical intervention than laboratory values or radiographic findings.

Arch Surg. 2011;146(5):506-510

PNEUMATOSIS INTESTINALIS is the result of gas infiltration into the wall of the intestine. It is not a disease, but a physical or radiographic finding that is the result of an underlying pathological process. Three mechanisms have been proposed as the source of this intestinal wall gas: (1) intrusion of intraluminal gas into the bowel wall through mucosal or immune compromise; (2) intraluminal bacterial production of gas that reaches the intramural compartment through mucosal or immune derangement; and (3) pulmonary gas from alveolar rupture, tracking through the mediastinum to the retroperitoneum and mesentery. Traditionally, pneumatosis was considered a sign of bowel wall ischemia that, without swift intervention, would lead to infarction. Portal venous gas (PVG; extension of intramural gas into the portal venous system) was considered a particularly ominous sign. Recently, however, several nonischemic causes of pneumatosis have been described, including infectious enteritis, inflammatory bowel disease, celiac disease, intestinal dilatation, ulceration, chronic obstructive pulmonary disease, connective tissue disease, AIDS, transplantation, steroids, and chemotherapy. Also, because of the improved sensitivity afforded by modern computed tomographic (CT) scanners, pneumatosis and PVG are being diagnosed more frequently. Therefore, the significance of pneumatosis now depends on the nature and severity of the underlying condition, and pneumatosis cannot
always be assumed to predict intestinal ischemia or necrosis.

Most series studying the prognostic value of pneumatosis still associate this radiographic finding with high mortality rates, ranging from 65% to 86%, especially when it is accompanied by PVG.6-9 Some recent studies, however, have shown lower mortality rates, ranging from 22% to 44% overall and 56% to 72% in patients with PVG.10-12 With a better understanding of its multiple causes, selective surgical management of pneumatosis intestinalis is becoming more frequent. However, there is still much debate over which factors distinguish urgent cases from cases in which conservative management may be acceptable.

Most published studies on pneumatosis are case reports with literature reviews or small case series. The 2 largest series currently in the literature reviewed fewer than 100 patients. Hawn et al 12 looked at 86 patients and evaluated whether age, serum creatinine level, or lactic acid level correlated with worse outcomes. They concluded that lactic acid level significantly correlated with mortality in patients with pneumatosis. The mortality rate of patients presenting with pneumatosis was 42%. Morris et al 11 looked at 97 patients. They focused on overall mortality rates and associated laboratory values, comparing surgical vs non-surgical mortality rates. They concluded that approximately half of patients with pneumatosis could be successfully managed nonoperatively. The mortality rate of patients presenting with pneumatosis in this study was 22%.

In light of these findings, our study was designed to incorporate a more extensive analysis of which clinical signs and symptoms, laboratory values, and accompanying radiologic findings predict positive intraoperative findings requiring surgical intervention. We also looked to identify which factors’ absence can predict a successful nonoperative approach.

Three management groups were defined: operative, nonoperative, and futile. The futile group consisted of patients whose prognosis was so poor that intervention was deemed futile and comfort measures were ordered. The main study outcomes were presence or absence of intra-abdominal pathological findings at laparotomy (as documented on the surgeon’s operative note) and mortality. Positive intraoperative findings were defined as those mandating intervention, ie, mesenteric ischemia, obstruction, or an incarcerated hernia. Negative results on exploratory laparotomy were defined as nothing requiring intervention being identified. Patients who were classified under the futile category either died or were discharged to hospice, which was counted as a death.

A total of 30 clinical, laboratory, and radiographic findings were analyzed, and significance for predicting the presence of intra-abdominal pathological findings requiring surgical intervention was determined. We selected parameters likely to be associated with ischemia or positive intraoperative findings in patients with pneumatosis on CT. All parameters except laboratory values were recorded in binary form. Laboratory values were recorded as continuous values, except for abnormal liver function test results, which were labeled as normal or elevated.

We performed a univariate analysis on each parameter using logistic regression to determine statistical significance. Laboratory values were analyzed with logistic regression, also plotting receiver operating characteristic curves and signal detection theory. Statistically significant parameters with a high likelihood of colinearity were combined into summary indices. These summary indices were then included in a multivariate analysis. Statistical analysis was performed using SAS version 9.2 statistical software (SAS Institute, Inc, Cary, North Carolina).

RESULTS

Of the 150 patients, 54 (36%) were initially managed nonoperatively. Fifty patients (93%) improved clinically and were discharged from the hospital, and 3 (5%) crossed over to the surgical arm. One patient who underwent nonoperative management died of unrelated causes 240 days into his hospitalization. Seventy-two patients (48%) were managed operatively. Of these patients, 63 (87%) had positive intraoperative findings and 9 (13%) had negative intraoperative findings. Twenty-four patients (16%) were classified as futile because they were determined to be unsalvageable (Figure).

Mortality rates were 2% (n=1) for the nonoperative group, 28% (n=21) for the operative group, and 100% (n=24) for the futile group. Patients in the futile group were excluded from further analysis owing to our inabil-

Figure. Patient distribution.
ity to confirm ischemia or abdominal pathological findings. In all, 60 of the 126 patients (47%) assigned to treatment either improved with nonoperative management or had negative intraoperative findings.

On univariate analysis, historical parameters that correlated with positive intraoperative findings included being older than 60 years and having history of coronary artery disease or cerebrovascular accident. Presenting symptoms of diarrhea, emesis, and abdominal pain as well as history of diabetes, atrial fibrillation, malignant neoplasm, or recent steroid use were not statistically significant (Table 1). Seven physical examination parameters, including occult blood–positive stool, tenderness to palpation, peritonitis (defined as rebound tenderness or involuntary guarding), abdominal distention, tachycardia, tachypnea, and hypotension, were significant. Presence of fever or hypothermia was not significant (Table 2).

Among the radiographic parameters studied, the findings of PVG, atherosclerosis, free fluid, or dilated loops of bowel were statistically significant. Free air, location of pneumatisis in small bowel, and bowel wall thickening were not significant (Table 3). Interestingly, of the 41 patients presenting with PVG, 25 underwent an operation, 11 were considered nonsalvageable, and 5 had nonoperative management. Eight (28%) had either successful nonoperative management or negative intraoperative findings.

Of the laboratory values analyzed as continuous variables, only lactic acid levels were statistically significant. Presence of abnormal liver function test results was also predictive of positive intraoperative findings. White blood cell count, number of bands, and bicarbonate, creatinine, and glucose levels, however, did not correlate with intraoperative findings (Table 3).

In all, the univariate analysis revealed that 14 parameters were statistically significant in predicting positive intraoperative findings. Not all parameters were submitted to multivariate analysis owing to concerns of multicolinearity and sample size. Rather, only the parameters felt to be most physiologically and clinically indicative of intra-abdominal pathological findings were included. Parameters that shared common physiological mechanisms or were highly correlated were combined into several mechanistically independent summary indices. These included the following: (1) coronary artery disease or cerebrovascular accident and a CT finding of atherosclerosis; (2) abdominal distention and a CT find-

---

**Table 1. Univariate Analysis of History of Present Illness and Medical History**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Patients, %</th>
<th>Operative</th>
<th>Nonoperative</th>
<th>Positive Operative Findings, OR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present Illness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diarrhea or emesis</td>
<td>59</td>
<td>62</td>
<td></td>
<td>0.99 (0.48-2.08)</td>
<td>.98</td>
</tr>
<tr>
<td>Abdominal pain</td>
<td>91</td>
<td>79</td>
<td></td>
<td>2.68 (0.87-8.26)</td>
<td>.09</td>
</tr>
<tr>
<td>Aged &gt;60 y</td>
<td>78</td>
<td>63</td>
<td></td>
<td>2.88 (1.27-6.50)</td>
<td>.01</td>
</tr>
<tr>
<td>Medical history</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>24</td>
<td>15</td>
<td></td>
<td>1.57 (0.65-3.79)</td>
<td>.32</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>24</td>
<td>20</td>
<td></td>
<td>1.84 (0.77-4.38)</td>
<td>.17</td>
</tr>
<tr>
<td>CAD or CVA</td>
<td>51</td>
<td>35</td>
<td></td>
<td>2.20 (1.07-4.54)</td>
<td>.03</td>
</tr>
<tr>
<td>Malignant neoplasm</td>
<td>29</td>
<td>33</td>
<td></td>
<td>0.92 (0.43-1.95)</td>
<td>.82</td>
</tr>
<tr>
<td>Recent steroid use</td>
<td>13</td>
<td>13</td>
<td></td>
<td>0.68 (0.24-1.96)</td>
<td>.48</td>
</tr>
</tbody>
</table>

**Table 2. Univariate Analysis of Vital Signs and Physical Examination Findings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Patients, %</th>
<th>Operative</th>
<th>Nonoperative</th>
<th>Positive Operative Findings, OR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital signs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body temperature &lt;36°C or &gt;38°C</td>
<td>17</td>
<td>8</td>
<td></td>
<td>2.46 (0.73-8.30)</td>
<td>.15</td>
</tr>
<tr>
<td>Heart rate &gt;90 beats/min</td>
<td>56</td>
<td>25</td>
<td></td>
<td>3.18 (1.49-6.78)</td>
<td>.003</td>
</tr>
<tr>
<td>Respiratory rate &gt;20 breaths/min</td>
<td>27</td>
<td>2</td>
<td></td>
<td>6.63 (1.80-24.02)</td>
<td>.004</td>
</tr>
<tr>
<td>Systolic blood pressure &lt;100 mm Hg</td>
<td>28</td>
<td>7</td>
<td></td>
<td>4.38 (1.52-12.65)</td>
<td>.006</td>
</tr>
<tr>
<td>Physical examination finding</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occult blood–positive stool</td>
<td>23</td>
<td>9</td>
<td></td>
<td>4.30 (1.11-16.63)</td>
<td>.03</td>
</tr>
<tr>
<td>Tenderness to palpation</td>
<td>86</td>
<td>62</td>
<td></td>
<td>5.55 (2.05-15.07)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Peritonitis, rebound tenderness, or guarding</td>
<td>33</td>
<td>8</td>
<td></td>
<td>4.44 (1.64-12.01)</td>
<td>.003</td>
</tr>
<tr>
<td>Abdominal distention</td>
<td>63</td>
<td>21</td>
<td></td>
<td>4.78 (2.20-10.38)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: CAD, coronary artery disease; CI, confidence interval; CVA, cerebrovascular accident; OR, odds ratio.
ing of dilated loops of bowel; and (3) tachycardia, hypotension, and tachypnea.

On multivariate analysis, only 3 parameters retained statistical significance as predictors of positive operative findings. They included the following: (1) the summary index of abdominal distention on physical examination and dilated loops of bowel on CT; (2) lactic acidemia; and (3) peritonitis (Table 4). These findings were uncommon in patients successfully managed nonoperatively: abdominal distention on examination and/or dilated loops of bowel on CT in 18%, lactic acid level greater than 2.5 mg/dL (to convert to millimoles per liter, multiply by 0.111) in 11%, and peritonitis in 8%.

Further analysis was performed to determine the predictive value of having any of these 3 factors vs none of them. For this purpose, we divided patients according to lactic acid level being less than 2.5 mg/dL vs 2.5 mg/dL or higher, the standard cutoff above which the lactic acid level is considered elevated. Using this value, the odds ratio of having positive intraoperative findings if a patient had abdominal distention or dilated loops of bowel, lactic acidemia, or peritonitis was 10.24 (P=.001).

### Results

Results from this study demonstrate that nearly half (47%) of patients with pneumatosis intestinalis on CT were successfully managed nonoperatively. Similar findings have been reported in previous series.\(^\text{11,12}\) This study included a more comprehensive array of parameters in an effort to establish criteria that could be used to assign patients to operative vs nonoperative management. The 2 largest retrospective studies in the literature to date analyzed only a limited number of parameters. Hawn et al\(^\text{12}\) looked at 3 parameters—age, creatinine level, and lactic acid level—and separated study groups by location of pneumatosis, which was found not to be clinically relevant. They concluded that a lactic acid level higher than 2 mg/dL significantly correlates with mortality in patients with pneumatosis intestinalis. Morris et al\(^\text{11}\) looked at laboratory values (pH, white blood cell count, hematocrit, creatinine level, total bilirubin level, lactic acid level) and compared mortality rates between surgical and nonsurgical groups. They found that pH and creatinine, total bilirubin, and lactic acid levels were significant in predicting mortality on univariate analysis.

While numerous findings on historical, physical, laboratory, and radiographic assessment were significant in the univariate analysis (Table 1, Table 2, and Table 3), only 3 major findings remained significant after multivariate analysis (Table 4). On physical examination, these were peritonitis and abdominal distention. Of all the laboratory and radiographic assessments studied, only dilated loops of bowel on CT and lactic acidemia remained significant. The radiographic finding of dilated loops of bowel was combined with the physical examination finding of abdominal distention, as they are highly correlated. Lactic acidemia, reflective of anaerobic metabolism due to mesenteric ischemia, proved to be a reliable predictor of life-threatening intra-abdominal processes.
Some parameters that have traditionally signaled a worse prognosis did not significantly correlate with the presence of intra-abdominal pathological findings requiring operative intervention. Many of them, when present, are often weighted heavily in favor of surgical intervention; in light of our findings, though, their importance needs to be reevaluated. These parameters include fever or hypothermia, leukocytosis, atrial fibrillation, and history of known malignant neoplasm. Surprisingly, free air, normally signaling a perforated viscus and mandating a trip to the operating room, was not significant. This was likely owing to the fact that postoperative patients and postendoscopy patients can have free air and benign pneumatisis. In fact, all of our 5 patients with pneumatisis on CT after colonoscopy or esophagogastroduodenoscopy were successfully treated nonoperatively.

Also, patients with a CT finding of PVG, which is commonly interpreted as a sign of severe mesenteric ischemia and in the past was taken as a clear indication for surgical intervention, were successfully managed nonoperatively or had negative intraoperative findings in almost a third of cases. We conclude that although the presence of PVG should heighten concern, it is not always a mandate for surgery.

As stated previously, several parameters found to significantly predict positive intraoperative findings on univariate analysis were not included in our multivariate analysis owing to concerns of multicolinearity and sample size. Age older than 60 years was not included because it was felt that age covaries with multiple parameters. Stool studies for occult blood were performed in only 67 patients, thus limiting the power of this parameter. Tenderness to palpation covaries with multiple parameters and was thought to be nonspecific. Free fluid was also thought to be nonspecific and may be physiological in women. Presence of abnormal liver function test results was thought to be indirectly linked to hypoperfusion and so was not included.

There were several limitations to the study. First, because it was impossible to confirm the presence or absence of ischemia or intra-abdominal pathological findings in patients triaged to the futile group, these patients were excluded from further analysis. Exclusion of these patients, who almost certainly had an abdominal catastrophe, may have biased findings in favor of nonoperative management, increasing the possibility of type I error. Conversely, the true pathological findings of patients triaged to the nonoperative group were also unavailable. These patients may have had unidentified ischemia at some point during their disease course. Also in this group, because pathological or surgical examination results of the specimen were unavailable and because the cause of pneumatisis may have been multifactorial, definitive diagnosis of the primary cause of pneumatisis often could not be ascertained. Finally, some patients who underwent exploration and had minimal findings that were counted as positive may in fact have had resolution nonoperatively, such as the single adhesive band causing a low-grade obstruction or the early ischemic colitis.

In conclusion, this study confirms that the performance of an accurate physical examination remains the most important component in the assessment and management of patients with pneumatisis intestinals. The physical examination findings of peritonitis and abdominal distention are most significant in predicting the need for surgery. Dilated loops of bowel on CT and elevated lactic acid level are the objective parameters that maintained statistical significance for predicting positive intraoperative findings. If none of these findings are present in a patient diagnosed with pneumatisis on CT, a nonoperative management approach should be strongly considered.

Accepted for Publication: December 28, 2010.
Correspondence: Vincent P. Duron, MD, Department of Surgery, Rhode Island Hospital, 593 Eddy St, APC 415, Providence, RI 02903 (vincent_duron@brown.edu).

Author Contributions: Study concept and design: Duron, Dupuy, and Mazzaglia. Acquisition of data: Duron and Rutigliano. Analysis and interpretation of data: Duron, Machan, and Mazzaglia. Drafting of the manuscript: Duron, Rutigliano, and Mazzaglia. Critical revision of the manuscript for important intellectual content: Duron, Machan, Dupuy, and Mazzaglia. Statistical analysis: Duron, Machan, and Mazzaglia. Administrative, technical, and material support: Duron, Rutigliano, Dupuy, and Mazzaglia. Study supervision: Duron, Dupuy, and Mazzaglia.

Financial Disclosure: None reported.

Previous Presentation: This paper was presented at the 91st Annual Meeting of the New England Surgical Society; October 30, 2010; Saratoga Springs, New York.

REFERENCES