Abdominal Radiography Findings in Small-Bowel Obstruction: Relevance to Triage for Additional Diagnostic Imaging

**OBJECTIVE.** Our aim was to determine which findings on abdominal radiography are relevant for distinguishing complete or high-grade partial small-bowel obstruction from low-grade partial or no small-bowel obstruction.

**MATERIALS AND METHODS.** Admitting abdominal radiographs with the patients in the supine and upright positions were scored for 25 different findings in 81 patients with clinically suspected small-bowel obstruction. Forty-one patients had complete or high-grade partial small-bowel obstruction, and 40 had low-grade partial small-bowel obstruction or no obstruction as determined by enteroclysis examination. Abdominal radiography findings were subjected to statistical analysis for correlation with degree of obstruction.

**RESULTS.** Of 12 radiographic findings strongly associated \((p < 0.05)\) with the severity of obstruction, two findings were found to be the most significant \((p \leq 0.0003)\) and predictive of a higher grade small-bowel obstruction: the presence of air–fluid levels of differential height in the same small-bowel loop and the presence of a mean air–fluid level width greater than or equal to 25 mm on upright abdominal radiographs.

**CONCLUSION.** When both critical findings are present, the degree of small-bowel obstruction is likely high-grade or complete. When both signs are absent, small-bowel obstruction is likely low-grade or nonexistent. Upright abdominal radiographs are important in the examination of patients with suspected small-bowel obstruction and may contribute to the imaging triage of these patients.

According to a recent report, conventional abdominal radiography remains the preferred method of initial radiologic examination of symptomatic patients suspected of small-bowel obstruction [1]. These investigators and others advocate that if further diagnostic imaging is warranted to establish a more specific diagnosis or to obtain information pertinent to the clinical treatment, the results of the abdominal radiographic examination should serve as the basis for triage [1, 2]. It is recommended that if the initial abdominal radiographs suggest a complete or high-grade partial small-bowel obstruction, CT would be the preferred additional imaging modality if surgery is not imminently planned. This approach is supported by the sensitivity of CT for establishing the diagnosis of a high-grade or complete small-bowel obstruction, reported to be 82–100%, and the potential value of CT to modify the patient’s treatment [1, 3–7]. Conversely, if the initial radiographic findings are interpreted as normal, equivocal, or suggestive of a low-grade partial small-bowel obstruction, an examination using a direct contrast material infusion of the intestinal lumen is preferred. Enteroclysis and CT enteroclysis satisfy these requirements and are recommended on the basis of their high sensitivity for the diagnosis of a less severe or low-grade small-bowel obstruction, their ability to exclude the diagnosis of obstruction, and the comparatively lower diagnostic sensitivity of conventional CT in this clinical situation [8–10].

Experienced radiologists have shown accuracy and agreement for the diagnosis of acute high-grade small-bowel obstruction on the interpretation of abdominal radiographs, but the diagnosis of low-grade obstruction is less certain [8, 11]. Additionally, no substantial data exist regarding the capability of abdominal radiography to distinguish the severity of obstruction of the small bowel. In a study of patients with a clinical suspicion of small-
bowel obstruction who were later proven to have various degrees of small-bowel obstruction or no obstruction, we objectively determined the frequency and pertinent measurement of the various findings on abdominal radiographs that are commonly used to evaluate small-bowel obstruction. Considering the implications for subsequent patient workup based on the use of abdominal radiographs as a diagnostic triage tool, we attempted to establish which findings correlated with the degree of small-bowel obstruction and to determine from those findings which were the most significant in differentiating the severity of small-bowel obstruction.

Materials and Methods

All patients were recruited retrospectively by review of the radiology clinical database according to the study requirements as follows: a diagnosis of small-bowel obstruction was suspected clinically and was the primary reason for referral for imaging, admitting abdominal radiographs were obtained with the patient in the supine and upright positions and were available for review, and an enteroclysis examination was performed within 5 days of the admitting abdominal radiography.

Study patients were enrolled in a chronologically consecutive fashion until an equivalent number of patients constituted each of four groups: 21 patients had complete small-bowel obstruction, 20 had high-grade and 20 had low-grade partial small-bowel obstruction, and 20 had no obstruction. Thus, a total of 81 patients constituted the study population.

Findings at enteroclysis examination served as the basis for the assignment of patients to a study group. Enteroclysis examinations were performed by senior staff radiologists (including one of the authors) with expertise in gastrointestinal imaging or by residents directly supervised by the staff radiologist. All enteroclysis examinations were reviewed retrospectively and independently of the analysis of the abdominal radiographs and were evaluated by consensus of two senior gastrointestinal radiologists and a senior radiologist. Evaluations were made without knowledge of the corresponding enteroclysis result or the patient’s clinical outcome. The patients’ supine and upright abdominal radiographs at admission were scored with respect to 25 different variables, 17 of which involved a specific numeric measurement (continuous variable) and eight of which involved the presence or absence of a condition (categoric variable). A diagnostic interpretation of the abdominal radiographs was not performed as part of the scoring evaluation.

The specific variables scored on the supine radiograph included the number of distended (≥2.5-cm lumen diameter) or nondistended (<2.5-cm lumen diameter) gas-filled or fluid-filled small-bowel loops; the maximum and mean small bowel diameter (in millimeters); and the maximum and mean diameter (in millimeters) of various colon segments, including the cecum, ascending colon, transverse colon, descending colon, and rectum (Fig. 2). Presence of the string-of-beads sign, defined as a series of air-fluid levels individually measuring less than 10 mm in width (Fig. 4); and the presence of a distended stomach.

Statistical Analysis

Two categories of small-bowel obstruction were defined for statistical analysis of the data. A severe or higher grade group of obstruction (n = 41) included patients with complete and high-grade partial small-bowel obstruction. A less severe or lower grade group (n = 40) included patients with low-grade partial small-bowel obstruction and patients with no obstruction.

In the initial screening process, each scored radiographic finding or variable was examined on a univariate basis to evaluate its individual importance. During this screening, Fisher’s exact test was used for the categoric variables. For the continuous (numeric) variables, t tests were performed. All variables, categoric or continuous, yielding univariate p values of less than 0.3 were considered relevant and potentially significant in determining the severity of small-bowel obstruction.

To transform significant continuous (numeric) variables into more clinically applicable radiographic findings, cut-points (threshold values) were generated using tree-based modeling [12]. This method identified the optimal threshold value for continuous variables that would yield the best possible statistical separation between the categories of higher grade and lower grade small-bowel obstruction. Variables transformed in this manner would then be more appropriate for use in predicting the severity of small-bowel obstruction.

Finally, a backward elimination logistic regression model was used to eliminate relevant variables that contained similar or noncontributory information [13, 14]. All explanatory variables (p < 0.3) were initially included in the model, and nonsignificant variables were removed one at a time until only significant variables remained. The process optimally generates a concise final version of the predictive statistical model.

All methods of statistical analysis were performed using S-Plus (StatSci, a division of MathSoft, Seattle, WA) and SAS (SAS Institute, Cary, NC) software.

Results

Enteroclysis examinations were performed within the first 72 hr of admission in 34 (83%) of 41 patients in the higher grade category of obstruction and in 35 (88%) of 40 patients in the lower grade category of obstruction. Only 15% (12/81) of enteroclysis examinations were performed on either the
fourth or fifth day after the patient’s admitting abdominal radiographs.

Of the 41 patients in the higher grade category of obstruction, the cause of the obstruction was adhesions in 28 patients, neoplasm in six, ischemic stricture in three, hernia in two, intussusception in one, and perforated appendicitis in one patient. Of the 40 patients in the lower grade category of obstruction, low-grade partial obstruction was due to adhesions in 19 patients and Crohn’s disease in one patient, whereas patients without small-
bowel obstruction showed either nonobstructive adhesions (6 patients) or various conditions including enteritis in five patients, chronic abdominal pain in four, gastroparesis in two, adynamic ileus associated with medication or electrolyte imbalance in two, and transient intussusception in one patient.

The frequency of various (categoric) radiographic findings in the two defined categories of small-bowel obstruction is summarized in Table 1. Table 2 summarizes the means and standard deviations of the numeric variables scored for each of the two categories.

Table 3 lists the results of the initial screening process. Twelve variables were strongly associated with each group, including the maximum small-bowel diameter, the mean air–fluid level width, and the presence of a differential air–fluid level. All variables had p values of less than 0.05. One finding, the string-of-beads sign, was marginally associated with each group, which in this study was defined as a p value greater than 0.05 and equal to or less than 0.15. Twelve other variables, including the number of air–fluid levels, the measurements of colon size, the presence of colonic gas or feces, and any specific ratio of the maximum small-bowel diameter to maximum colon diameter, had no significant correlation with the two groups (p > 0.3).

Table 4 lists the threshold values generated for each of the significant continuous (numeric) variables. The p values listed are an approximate measurement of the statistical separation the threshold value creates between the two groups.

Of the thirteen variables that passed the initial statistical screening process (p < 0.3, Table 3), two were determined by logistic regression analysis to be the most significant predictors between the two categories of severity of small-bowel obstruction. These were the presence of air–fluid levels of differential height in the same bowel loop and the presence of a mean air–fluid level width greater than or equal to 25 mm. Their strength as markers of a small-bowel obstruction of higher grade can be expressed as an odds ratio. The ratio is 7.2 for a mean air–fluid level width of 25 mm or greater, and the ratio is 4.5 for the presence of a differential air–fluid level.

Table 5 presents the data for the association of the two most significant radiographic findings with the category of obstruction. The presence of both findings meant an almost 86% chance that the patient had a high-grade partial or complete obstruction.
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small-bowel obstruction, because 18 of the 21 patients who showed the concurrent presence of both significant findings on abdominal radiographs were in the category of higher grade obstruction. When neither finding was present there was an 83% chance that the patient had a low-grade partial small-bowel obstruction or no obstruction, because 24 of the 29 patients who had neither finding on radiographs were in the lower grade category. Both or neither of these findings was seen in 50 (62%) of 81 cases.

Overall, the presence of a differential air-fluid level on the upright abdominal radiograph was noted in 56% (45/81) of patients. A mean air-fluid level width greater than or equal to 25 mm was noted on the upright radiograph in 35% (28/81) of patients.

Discussion
Abdominal radiographs provide valuable cost-effective information in the early examination of patients with various abdominal symptoms and disorders, particularly intestinal obstruction. Limitations in the diagnosis of small-bowel obstruction are recognized, however, because the intestinal gas pattern upon which the interpretation of radiographs is largely based varies with certain characteristics such as the severity, level, and duration of the obstruction. In patients for whom abdominal radiographs are insufficient to confidently establish a diagnosis of small-bowel obstruction or to reasonably assess the severity of obstruction, additional diagnostic imaging becomes necessary.

The methodology in this study of combining symptomatic patients into two functional categories of obstruction was based on the appropriateness of the additional imaging evaluation as related to its sensitivity for the diagnosis of small-bowel obstruction and the implications for subsequent clinical management [1–7].

The grouping of patients with low-grade partial small-bowel obstruction with patients with no obstruction into a lower grade obstruction category is justified on the basis of their presenting symptoms being consistent with intestinal obstruction and on the basis that the recommended method of additional radiologic workup is similar for these patients. Although patients with low-grade partial small-bowel obstruction usually present with abnormal abdominal radiographic findings diagnostic of obstruction, approximately 40% of such patients have normal or equivocal findings [1, 8]. Similarly, even symptomatic patients who are eventually shown to have no small-bowel obstruction may have equivocal radiographic findings suggestive enough to warrant further imaging to exclude obstruction. The sensitivity and accuracy of enteroclysis for defining a minimal degree of obstruction and establishing small-bowel normality supports the use of this technique for the further examination of patients in either group [8].

The grouping of patients with high-grade partial or complete small-bowel obstruction into a category of higher grade obstruction is based on the premise that no substantive differences exist in the imaging evaluation or clinical management of these two patient groups [2, 7]. CT is sensitive and highly accurate for the diagnosis of severe grades of small-bowel obstruction and is a technically optimal method of examining these patients [1, 3–7].

If abdominal radiography is to function as a decision tool or triage point for the direc-
Statistical Association of Abdominal Radiography Findings for Association of the Two Most Significant Abdominal Radiography Findings

Note.—Findings include categoric and continuous (numeric) variables. Higher grade category (n = 41) includes high-grade partial and complete obstruction, lower grade category (n = 40) includes low-grade partial obstruction and no obstruction. The following findings are not associated (p > 0.3) with distinguishing grade of obstruction: distended stomach, number of air–fluid levels, small bowel–to-colon ratio > 1.0, and ratio of small-bowel diameter to colon diameter.

<table>
<thead>
<tr>
<th>Finding</th>
<th>p</th>
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<tbody>
<tr>
<td>Strongly associated (p &lt; 0.05)</td>
<td></td>
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<tr>
<td>Maximum small-bowel diameter</td>
<td>0.0001a</td>
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<tr>
<td>Mean air-fluid level width</td>
<td>0.0001a</td>
</tr>
<tr>
<td>Presence of differential air-fluid levels</td>
<td>0.0003b</td>
</tr>
<tr>
<td>No. of gas-filled small-bowel loops &gt; 2.5 cm</td>
<td>0.0005a</td>
</tr>
<tr>
<td>Mean small-bowel diameter</td>
<td>0.0007a</td>
</tr>
<tr>
<td>No. of fluid-filled small-bowel loops &gt; 2.5 cm</td>
<td>0.0007a</td>
</tr>
<tr>
<td>Stretch sign</td>
<td>0.001b</td>
</tr>
<tr>
<td>Maximum air-fluid level width</td>
<td>0.001a</td>
</tr>
<tr>
<td>No. of gas- or fluid-filled small-bowel loops &lt; 2.5 cm</td>
<td>0.008a</td>
</tr>
<tr>
<td>Maximum differential air-fluid level height</td>
<td>0.17a</td>
</tr>
<tr>
<td>Mean differential air-fluid level height</td>
<td>0.024a</td>
</tr>
<tr>
<td>Small bowel–colon ratio &gt; 0.5</td>
<td>0.035b</td>
</tr>
<tr>
<td>Marginally associated (p ≤ 0.15)</td>
<td>0.15b</td>
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Valid correlations also require an objective recording of the radiographic findings. Abdominal radiograph interpretations were therefore conducted randomly and by a consensus of observers who were unaware of the corresponding enteroclysis diagnosis. In some cases, particularly patients with radiographs showing numerous distended small-bowel loops, a precise accounting of the number of loops and the measurement of all loop diameters could not be made with absolute certainty. Determining the margins of predominantly fluid-filled small-bowel loops for diameter measurement is more difficult than determining the margins of gas-filled loops, and measurement of fluid-filled loops could be underestimated in comparison. Appreciating the presence of differential air-fluid levels can also be difficult in cases with overlapping bowel loops and these levels are potentially misrepresented, probably underestimated, when interpreting upright abdominal radiographs. In most instances, however, we believe that scoring the various findings was straightforward and seldom problematic with careful scrutiny of the radiographs. The extensive data collected, the calculations of individual measurements, and an equivalent number of radiographs being scored from the different groups, are factors that may minimize the effect that potential inaccuracies in data collection would have on results.
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In our clinical setting—a large primary care and tertiary referral center—the number of symptomatic patients encountered with either low-grade partial obstruction or no obstruction is considerably greater than the number of patients having a high-grade partial or complete small-bowel obstruction. Given the quantity of the data collected and analyzed, the arbitrary enrollment of an equivalent number of patients in each study group was considered a reasonable approach to time and cost considerations of the study and a satisfactory approach for valid statistical comparisons between the groups.

The aim of the statistical analysis of the data was to determine from the large number of scored radiographic findings the most significant findings that might be used to differentiate the grade of small-bowel obstruction. Initially, a critical \( p \) value of 0.3 was chosen to limit further analysis to the findings (variables) that showed an association with obstruction category. A lower cut-off \( p \) value, such as the traditional 0.05, was not used because we did not want to prematurely eliminate radiographic findings (variables) that were potentially important once other variables were taken into consideration. In essence, the value of the univariate screening process was to identify findings likely to be significant while reducing the number of total variables for the final statistical analysis.

Because the use of radiographic findings characterized by a numeric measurement (termed a continuous variable in this analysis) would be difficult to implement clinically, it was necessary to transform these variables. The generation of cut-points by tree-based modeling accomplishes an appropriate modification of the continuous variables by defining a specific threshold value which, by its presence or absence, represents a more clinically usable finding to distinguish between the higher grade and lower grade obstructions.

In the final analysis, a logistic regression model was used to determine the most significantly predictive radiographic findings. Logistic regression is appropriate for identifying predictors when the dependent variable—in this study, the degree of obstruction—is in itself categorical in nature. All relevant variables with an initial \( p \) value of less than 0.3 were included in the model and then were removed individually if they did not contribute significantly to the prediction of the obstruction. For example, it would be unlikely for the maximum and mean air–fluid level widths to both be necessary as predictors. If both are necessary, the logistic regression model would use both; otherwise, the model would choose the more significantly informative one. After all noninformative variables were eliminated, the resulting version of the statistical model was used for prediction of the grade of small-bowel obstruction.

Results of this study show that abdominal radiographs can provide a distinction between these groups of patients in most cases. Of the 25 radiographic findings studied, several anticipated findings were by association significant in allowing distinction between higher and lower grades of obstruction such as small-bowel distention, with the maximally dilated loops averaging 36 mm in diameter and exceeding a size ratio of 0.5 with the colon, and a nearly 2.5 times increase in the number of distended loops in the abdomen.

These findings could be expected, given the nature of bowel obstruction, in that abnormal distention of either gas-filled or fluid-filled intestine, or both, occurs proximally to the site of obstruction and with relative collapse of the more distal intestine.

In particular, two findings derived from the upright abdominal radiograph were found to be the most significant and most predictive of the higher grades of small-bowel obstruction: the presence of differential air–fluid levels and a mean width of air–fluid levels measuring greater than or equal to 25 mm. Differential air–fluid levels were present in 56% of all patients and were observed with greater frequency on the radiographs of patients in the higher grade than in the lower grade category of obstruction, 76% versus 35%, respectively.

The measured differential height of these air–fluid levels was also notably increased with the greater severity of obstruction. We did not show in these data a significant threshold height of the differential air–fluid levels as a discriminating diagnostic finding, as has been reported by others [15]. In 1993, Harlow et al. [15] showed that the specificity for the diagnosis of mechanical bowel obstruction increased, and diagnostic sensitivity decreased, as the threshold height defining a differential air–fluid level increased. A critical differential air–fluid level height of greater than or equal to 20 mm was associated with a high positive predictive value (88%) for the diagnosis. Although the study by Harlow et al. involved a radiographic comparative analysis of 62 episodes of mechanical bowel obstruction with 38 episodes of adynamic obstruction (ileus) as determined largely by clinical information, our study involved only two patients with a clinical diagnosis of an adynamic obstruction. Perhaps these differences in the patient populations being compared, including differences in clinical presentation, account for the differences observed regarding a significant predictive height of differential air–fluid levels.

That a critical width of air–fluid levels was found to be highly significant likely reflects its association with the greater degree of abnormal distention of the small-bowel loops seen in higher grades of obstruction. Long air–fluid levels observed in cases of obstruction have also been thought to correlate with the amount of luminal fluid present, which is especially increased in obstructed loops of distal jejunum or ileum [16]. In our study, we did not determine the anatomic level of the small-bowel obstruction, so we are unable to additionally comment on this feature. Corroborating the presence of distended loops with copious luminal fluid was the significant occurrence of the stretch sign evident on supine radiographs. Interestingly, air–fluid levels of small width (<10 mm) or the radiographic string of beads, was only marginally associated with obstruction severity. Although this sign is considered an important indicator of the presence of fluid-filled bowel, its frequent presence in both higher and lower grades of obstruction suggests that its occurrence is perhaps independent of luminal distention or is quite readily perceived on upright radiographs.

Considerable material has been published about the sensitivity of various radiographic findings in the diagnosis of small-bowel obstruction, particularly in regard to air–fluid levels and the importance of the upright abdominal radiograph. The early observations of Frimann-Dahl [17] on the pertinence of air–fluid levels in distinguishing adynamic obstruction or ileus (nonobstructive distension) and mechanical obstruction lacked consistent substantiation in subsequent literature. Some studies showed the relative nonspecificity and insensitivity of these findings in establishing the diagnosis of small-bowel obstruction, although the significance of air–fluid levels as an indicator of small-bowel luminal stasis is widely accepted [18–21]. The presence of differential air–fluid levels on abdominal radiographs has also been regarded as an insensitive diagnostic finding in differentiating the mechanical versus functional nature of an intestinal obstruction because of their potential occurrence in both of these conditions [15].

Other researchers have even recommended that the upright radiograph be eliminated from...
the acute abdominal radiographic series because of its inability to substantially alter the sensitivity of the examination in the diagnosis of small-bowel obstruction [22, 23]. However, in those studies the patient populations were nonuniform and included patients with a wide variety of abdominal complaints and conditions such as abdominal pain, dynamic ileus, acute surgical abdomen, small-bowel obstruction, and colon obstruction. Few patients with a diagnosis of small-bowel obstruction were involved in the one study [22], whereas in the other the upright and supine radiographs were not evaluated independently of each other [23]. Citing such limitations and further recognizing the need to render as rapid and accurate a diagnosis as possible, other researchers have maintained support for the value of upright abdominal radiographs [24].

Unlike these previous reports, our analysis focuses on an issue other than diagnostic sensitivity: the relevance of radiographic findings in distinguishing the severity of small-bowel obstruction, because we think this distinction has important ramifications for the practical imaging examination of symptomatic patients in whom obstruction is clinically suspected by the findings of physical examination and pertinent history. The two radiographic findings considered of greatest significance as predictors of the severity of obstruction were findings seen only on the upright abdominal radiograph. When both of these radiographic findings are considered, their combined presence or absence in any given case is a strong positive (86%) or negative (83%) indicator of the degree of patency of the small-bowel lumen. Although upright radiographs alone may not be particularly sensitive in the detection of small-bowel obstruction, they may be of value in distinguishing patients with either a high-grade or a complete obstruction from those with a low-grade partial obstruction or those who are symptomatic but have no obstruction.

The information obtained from the upright radiograph makes it an integral part of abdominal radiographic examinations in patients with suspected small-bowel obstruction by helping to direct, if needed, the additional imaging method that is appropriate for further workup. The results of this study validate prior recommendations to use abdominal radiographs as a practical tool in the radiologic management of small-bowel obstruction [2]. This issue is important because the erroneous application of diagnostic procedures not only adds to health care costs but also may delay diagnosis and adversely affect patient treatment decisions.

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