

Intraluminal Air within an Obstructed Appendix:

A CT Sign of Perforated or Necrotic Appendicitis

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Rationale and Objectives: The aim of this study was to evaluate the predictive value of intraluminal air for appendiceal necrosis and/or perforation when not apparent on imaging. Additional factors of intraluminal appendicoliths, age, and gender were also assessed.

Materials and Methods: Patients with pathologically proven appendicitis who underwent multidetector computed tomographic imaging over a 3-year period ($n = 487$) were retrospectively reviewed. Those with imaging evidence for perforation were excluded to create a study population of apparent uncomplicated acute appendicitis ($n = 374$). Each scan was assessed for intraluminal appendiceal air and appendicoliths on multidetector computed tomography and compared against surgical and pathologic results for appendiceal necrosis and/or perforation.

Results: Image-occult necrosis or perforation was present in 17.4% (65 or 374) of the study cohort. Intraluminal air and appendicoliths were predictive variables by univariate logistic regression ($P = .001$ and $P \leq .001$, respectively), with odds ratios of 2.64 (95% confidence interval, 1.48–4.73) for intraluminal air and 2.67 (95% confidence interval, 1.55–4.61) for appendicoliths. Both remained independent variables on multivariate modeling despite multicollinearity. Increasing age was also predictive (odds ratio, 1.25; 95% confidence interval, 1.09–1.44; $P = .002$), whereas gender was not ($P = .472$).

Conclusions: Intraluminal appendiceal air in the setting of acute appendicitis is a marker of perforated or necrotic appendicitis. Recognition of this finding in otherwise uncomplicated appendicitis at imaging should raise suspicion for image-occult perforation or necrosis.

Key Words: Appendicitis; perforation; necrosis; intraluminal air; CT.

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Acute appendicitis is the most common abdominal surgical emergency in the United States, with >250,000 new cases diagnosed each year (1). Computed tomographic (CT) imaging has emerged as the preferred imaging modality for the diagnosis of appendicitis, especially in adults, because of its high accuracy, widespread availability, and lack of operator dependence (2,3). A recent study documented the increased utilization of CT imaging in adult patients with suspected appendicitis from 19% in 1998 to 93% in 2007 (4). CT imaging has an excellent performance profile, with sensitivities and specificities ranging from 94% to 98% for the diagnosis of acute appendicitis (5–10), and is accurate in the differentiation of perforated from nonperforated appendicitis (11).

Prompt diagnosis of acute appendicitis is critical, because treatment of appendicitis before perforation significantly decreases morbidity and mortality (12). In our experience, the

presence of intraluminal air within the appendix may be helpful in this regard, because it represents a finding that suggests necrosis and perforation that may otherwise be unapparent at imaging. Although some studies have pointed to an association between intraluminal air and acute appendicitis (13), its relationship to a more serious situation has not been widely recognized to our knowledge, either clinically or in the literature (aside from a sporadic case report) (14). Indeed, the presence of intraluminal air has been used as a feature to argue against the diagnosis of acute appendicitis by confirmation of luminal patency. However, this represents a distinctly different situation whereby the appendix is otherwise normal in appearance without evidence of obstruction or inflammation. The primary purpose of this study was to evaluate the predictive value of intraluminal appendiceal air in the setting of acute appendicitis for the presence of appendiceal necrosis and/or perforation when not otherwise apparent at imaging. The secondary aims included investigating other potential predictive factors, including demographic variables of age and gender and the CT feature of the presence of an intraluminal appendicolith.

MATERIALS AND METHODS

Institutional review board approval was obtained for this Health Insurance Portability and Accountability Act–compliant, retrospective study. The requirement for informed consent was waived.

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Patient Population

The pathology database at our tertiary referral center (including both pediatric and adult patients) was queried for all histologically proven cases of appendicitis over a 3-year period from January 1, 2006, to December 31, 2008 ($n = 799$). Eight patients had pathologic findings of appendicitis attributable to alternative diagnoses, such as Crohn's disease or infectious colitis, and were excluded in the analysis. Those patients with preoperative CT studies for review within 48 hours of surgery at our institution were then extracted ($n = 487$). From this group, patients with imaging evidence of perforation on CT imaging by the criteria listed below ($n = 113$ [23.2%]) were then identified, leaving a study cohort of 374 individuals to address the main focus of the study. The main study cohort thus consisted of individuals with pathologically proven acute appendicitis without evidence of perforation by imaging prior to surgery. Figure 1 summarizes the study population determination.

CT Technique

Diagnostic CT examinations were all performed using multi-detector CT scanner. The adult patients were scanned using one of the following CT scanners: SOMATOM Sensation 64, SOMATOM Sensation Open 40, SOMATOM Sensation 16, or Volume Zoom 4 (all from Siemens Healthcare, Erlangen, Germany). Most pediatric patients were scanned using a SOMATOM Sensation 16 (Siemens Healthcare). The following CT parameters were used: effective section thickness, 0.6 to 5 mm; reconstruction interval, 1 to 5 mm; gantry rotation time, 0.5 seconds; tube current–time product, 240 reference mAs, with online real-time angular dose modulation technique (CARE Dose4D; Siemens Healthcare); and tube voltage, 120 kVp. CT parameters for pediatric patients used a tube voltage of 120 kVp and a tube current–time product of 50 to 150 mAs, on the basis of patient weight. The use of both oral and/or intravenous contrast varied and was based on radiologist preference, patient renal function, the presence of a contrast allergy, and patient body habitus. When used, 20 oz oral contrast (MD-Gastroview; Mallinckrodt, Inc, St Louis, MO) or 100 to 125 mL intravenous contrast (Optiray 350; Mallinckrodt, Inc) was given. For pediatric patients, a lower ionic contrast agent was used (Optiray 320; Mallinckrodt, Inc). Rectal contrast and/or air was not used at our institution. Images were obtained from the diaphragm through the lesser trochanter of the femur. All CT examinations were displayed in the axial plane.

Image Analysis

Each CT study was independently analyzed by four reviewers. Two of the reviewers were board-certified abdominal radiologists, the third an abdominal fellow, and the fourth a senior radiology resident. The reviewers were blinded to the operative note and pathologic report. Each CT study was reviewed on a picture archiving and communication system worksta-

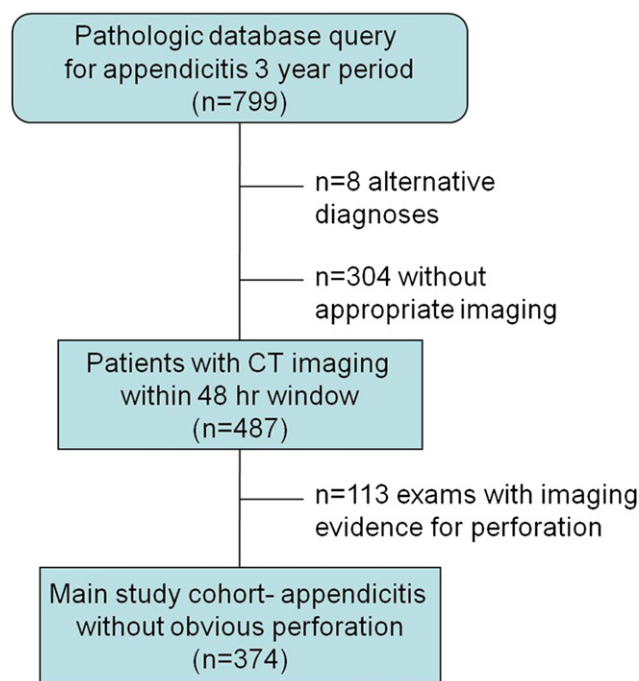


Figure 1. Study group determination flowchart. CT, computed tomographic.

tion using the axial image data set, and when necessary, coronal and sagittal reformats were obtained. Discordant cases were reviewed as a group and resolved by consensus read. Ultimately, 10.5% (51 of 487) of intraluminal air determinations and 14.6% (71 of 487) of intraluminal appendicolith determinations were discordant, requiring consensus read.

The CT examinations were initially analyzed for imaging evidence of perforation. Perforation was defined as the presence of any one of five criteria (periappendiceal phlegmon, abscess, extraluminal gas, extraluminal appendicolith, or focal wall defect; Fig 2) (11,15). These criteria have been shown to have high sensitivity and specificity ($\geq 95\%$) for the detection of appendiceal perforation. For this identified cohort, evaluation for the presence of intraluminal air was undertaken in the manner discussed in the following paragraphs. These patients with imaging evidence for perforation were then extracted from the overall study population. The remaining group constituted the main study cohort and was composed of those patients with acute appendicitis without imaging criteria for perforation. The evaluation for intraluminal air and/or appendiceal calculus was also undertaken in this group.

Intraluminal appendiceal air was classified as present if a focus or foci of air were identified within an obstructed portion of the appendix (Fig 3). The segment was deemed obstructed if three criteria were fulfilled: (1) the lumen was distended (≥ 6 mm in diameter) (16), (2) fluid filled, and (3) the distended fluid-filled segment extended in a contiguous fashion between two boundaries. Potential boundaries included between the tip of the appendix and the base of the appendix, between the tip of the appendix and an

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