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Focused CT for the evaluation of suspected appendicitis

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Abstract

Purpose To determine the diagnostic accuracy of focused appendiceal CT as a feasible alternative to the standard CT of the abdomen and pelvis (CT-AP) in patients with suspected acute appendicitis.

Methods Retrospective review of 200 adults with suspected acute appendicitis between January and October 2016 were included in this study. Each patient underwent CT-AP with oral and intravenous (IV) contrast. A subset of axial images starting at the top of L4 vertebral body to the roof of the acetabula were obtained from each study which served as the focused appendiceal CT. After review of the focused CTs, the non-focused CT-AP scans were reviewed, each patient acting as their own control. Images were assessed for ability to identify the appendix, assess for appendicitis, or identify alternative diagnoses that could account for the presenting symptoms.

Results Of 200 cases, the appendix was visualized in the focused CT in 191 patients. In nine studies, the appendix was not visualized in focused or standard CT-AP. Using focused CT, 42 cases were positive for acute appendicitis. This result was identical when reviewing standard CT-AP. Alternative diagnoses were present in 38 patients. Using focused CT, 14 of these were not fully covered but the readers were able to make the diagnoses confidently on the focused CTs. Only one patient had acute non-appendiceal pathology mostly outside of the field of view.

Conclusions Focused appendiceal CT with IV and oral contrast in the setting of clinically suspected appendicitis is a suitable alternative to conventional CT-AP.

Keywords Appendicitis · Computed tomography (CT) · Dose reduction

Introduction

Acute appendicitis is one of the most common diagnoses in acute care surgery with an incidence of 84.2 per 100,000 [1]. It is thought to be caused by obstruction of the appendiceal lumen that leads to intraluminal hypertension, bacterial proliferation, vascular compromise, necrosis, and subsequent perforation [2]. Typical clinical presentation of acute appendicitis includes abdominal pain which is initially periumbilical and subsequently becomes well-defined, localizing to the right lower quadrant. It is often associated with loss of appetite, fever, nausea, vomiting and leucocytosis. However, presentation can often be non-specific and the clinical signs equivocal which can lead to delay in diagnosis which in turn can lead to perforation and increased patient morbidity [3]. Although history and physical examination is the cornerstone of diagnosis, imaging now plays a crucial role in the assessment of acute appendicitis. From 1998 to 2007, there was a steady decrease in the number of negative appendectomies, which are not without morbidity, suggesting a possible correlation with increased use of diagnostic imaging [4]. Multiple subsequent studies including a study by Drake et al. showed decreased rates of negative appendectomies with increasing use of diagnostic imaging with no significant change in rates of perforation from 2006 to 2011 [5].

The main imaging modalities used in diagnosing acute appendicitis is ultrasound (US) and computed tomography (CT). Extensive work has been done to compare specificity and sensitivity between these two modalities which have demonstrated that CT is superior to US in most cases [6, 7]. CT is especially useful in identifying alternative diagnoses in the setting of suspected acute appendicitis [8] and is now the test of choice in the most recent American College of

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Radiology (ACR) Appropriateness Criteria evidence-based guidelines for suspected acute appendicitis [9]. The most commonly used protocol is CT of the entire abdomen and pelvis (CT-AP) with intravenous (IV) and oral contrast [10].

A major drawback of CT is ionizing radiation. Improvements in CT technology have resulted in decreased radiation dosages with better diagnostic yield. In the setting of suspected acute appendicitis, in efforts to further reduce radiation exposure, focused appendiceal CT has been suggested with variable results [11–14].

The purpose of this study was to evaluate whether focused appendiceal CT with oral and IV contrast is a feasible alternative to the standard CT-AP in adult patients who presented with suspected acute appendicitis.

Materials and methods

Institutional review board approval was obtained and informed consent was waived due to the retrospective nature of the study.

Patients

A computer-based imaging database (Montage™) was used to retrospectively identify 200 consecutive patients (117 female and 83 male; mean age, 44 years; age range, 16–92 years) that were referred from the Emergency Department with suspected acute appendicitis (i.e. the clinical history provided in the requisition indicated that appendicitis was the primary differential consideration) between January 2016 and October 2016. Patients less than 18 years old and patients with pre-existing Crohn's disease were excluded from the study.

CT technique

All patients underwent routine CT-AP with oral and IV contrast which was considered the gold standard. The scan spanned from the diaphragm to the ischial tuberosities. Contrast preparation involved oral administration of 500 cc diluted Gastrografin 37% Solution (Bracco Diagnostic) which was administered 1 h prior to the scan, as well as IV contrast material (80 cc Visipaque 270). The CT-AP examinations were performed in the supine position with MDCT scanner (LightSpeed 64 and Optima 64, General Electric Medical Systems, Milwaukee, WI). A subset of axial images from the standard CT-AP, starting at the top of L4 vertebral body to the roof of the acetabula (approximately 15 cm field of view) was obtained from each study. Sagittal and coronal reformats through the same region were also included. These images served as the focused appendiceal CT.

Imaging analysis

All 200 focused appendiceal CT studies were anonymized and interpreted by a fellowship-trained abdominal radiologist (P.A.V. with 13 years experience) and radiology resident (M.T. with 2 years experience) independently. The radiologists were blinded to the electronic health records, including laboratory findings, surgical notes, pathology results and CT reports.

The studies were evaluated for visualization of the appendix (indicating yes or no), whether it was visualized in its entirety or partially, and for features of acute appendicitis. The scans were also assessed for the ability to detect any acute pathology other than appendicitis that could account for the presenting symptoms such as enteritis, colitis, ureteric calculi etc. The focused appendiceal CT was considered positive for appendicitis if the appendix had thickened wall and was dilated with a maximum diameter greater than 6 mm, with or without associated peri-appendiceal inflammatory changes such as stranding, phlegmon or collections. The CT was considered negative for appendicitis if the appendix was thin walled, measured less than 6 mm in diameter and there was no peri-appendiceal inflammation. When the appendix was not visualized, absence of peri-appendiceal inflammation was also interpreted as negative for appendicitis.

In a separate reading session, the CTs of the entire abdomen and pelvis were analyzed and the findings were again recorded independently. Any pathology related to the patient's clinical findings identified outside of the aforementioned focused assessment was considered a missed diagnosis. Data from the focused and standard CT examinations were compared. Although the hospital course of patients was reviewed through the electronic medical record, including operative reports, surgical pathology results and follow-up clinic notes, our focus was not to test the diagnostic accuracy of CT in the evaluation of suspected appendicitis but to compare diagnostic reports of focused appendiceal CT with those of the standard and most commonly used protocol, full abdominopelvic CT with IV and oral contrast.

Results

Visualization of the appendix

Of the 200 cases, the appendix was identified in 191 (96%) patients with focused appendiceal CT. The appendix was fully visualized in 186 of these patients and partially visualized in 5 patients. Of note, the resident did not visualize

the appendix in two of the studies, however, both studies were considered to be negative for appendicitis. In these two cases, consensus was reached between the two readers regarding the presence of the appendix. None of the partially visualized appendices were inflamed. The appendix was not identified in nine patients, even after review of the images encompassing the entire abdomen (Fig. 1).

Diagnostic accuracy

Of the 200 focused scans, 42 (21%) were interpreted positive for acute appendicitis and 158 were interpreted negative (79%). Of the 42 cases of appendicitis, the inflamed appendix was partially visualized in three patients. In these three cases, only a few millimetres of the appendix were not included and no important additional findings such as free air or abscess were present outside the scanning field upon review of the CT-AP. Standard CT-AP revealed appendicitis in the same 42 patients. Histopathologic confirmation of acute appendicitis was obtained in 26 of 42 cases who underwent surgical management. The 16 remaining cases of appendicitis were managed conservatively. There were no cases where a normal appendix was removed.

Diagnostic accuracy for non-appendiceal pathologies

Acute pathology other than appendicitis was identified in 38 patients (19% of 200 patients and 24% of 158 patients without appendicitis). The diagnoses included colitis in 13 patients, diverticulitis in seven patients, epiploic appendagitis in four patients, enteritis/ileitis in three patients, urinary tract pathology in five patients and gynecological pathology in four patients (Fig. 2). There was one case of cecal carcinoma and one instance of iliopsoas abscess, as outlined in Table 1. The exact etiology of the iliopsoas abscess was never identified and the appendix was normal on this scan.

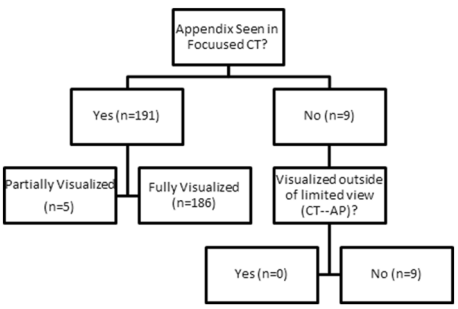

Fig. 1 Visualization of the appendix in focused appendiceal CT versus CT-AP. *CT-AP* CT of the abdomen and pelvis

Of the five cases with urinary tract pathology, two had right ureterovesical junction stone, one patient had cystitis and two patients had thickening and hyperenhancement of the ureter with associated peri-ureteric stranding, presumably secondary to recent passage of a stone. In these two cases, a ureteric stone was not identified either in the focused or CT-AP studies. The four cases with gynecological findings included two cases of tubo-ovarian abscess and two cases of ovarian lesion which were further evaluated with transvaginal US.

The non-appendiceal acute diagnoses were accurately made using focused appendiceal CT in 37 (97%) of these cases. In 14 patients, the pathology extended cranial to the focused CT field (above the superior endplate of L4); however, focused CT assessment secured the diagnosis regardless of partial visualization. In a single case, focused appendiceal CT identified free fluid and stranding around the hepatic flexure, however, the segment of thickened colon was outside the scanning field, this case was considered a missed diagnosis (Fig. 3). No patient had acute pathology exclusively outside the boundaries of the focused appendiceal CT. There were no discrepancies between the readings of the two radiologists although it took the resident approximately three times longer to interpret the scans.

Discussion

Appendectomy is the most common emergency abdominal surgery in North America with over 300,000 cases in the United States alone in 2010 based on Centers for Disease Control and Prevention (CDC) data [15]. The estimated incidence of appendiceal perforation in acute appendicitis is between 20 and 35 per 100,000 [1–16]. Prompt diagnosis of appendicitis has been shown to decrease morbidity, length of hospital stay, and cost [3]. The increased use of diagnostic imaging in the setting of suspected acute appendicitis over the past 25 years stems from limited diagnostic accuracy achievable from patient history, physical examination and laboratory values alone. False-positive appendectomy rates of up to 25% were reported [17], with increased morbidity and cost associated with unnecessary surgical intervention. Part of the reason for accepting this high false-positive rate was to avoid delayed diagnosis of appendicitis which had been shown to result in higher rates of perforation and associated complications [3, 18].

Clinical diagnosis is also made more difficult in situations where variable presentations of other acute gastrointestinal and gynecological pathologies mimic appendicitis. Conversely, the variable orientation and length of the appendix can cause pain in areas that mimic other acute gastrointestinal and gynecological conditions such as acute diverticulitis,

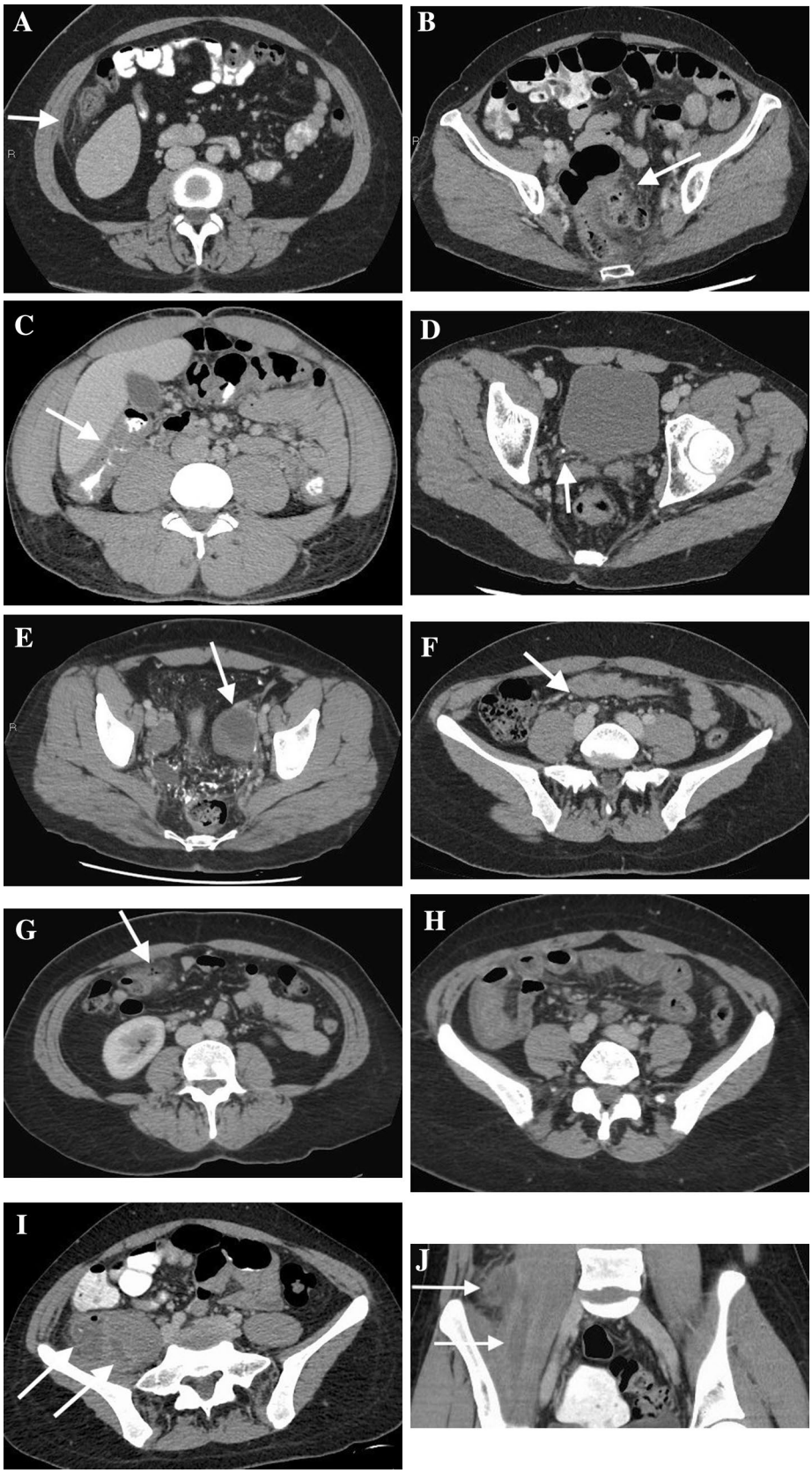

Fig. 2 **a** Right-sided epiploic appendagitis, **b** Acute sigmoid diverticulitis, **c** Right-sided colitis, **d** Right UVJ stone, **e** Left tubo-ovarian abscess, **f**—Right-sided ureteritis, **g** Right-sided colonic diverticulitis, **h** Acute enteritis, **i** Right-sided iliopsoas abscess, axial and **j** Coronal CT

Table 1 Acute alternative diagnoses in patients without appendicitis

Diagnosis	Number of patient ($n=38$)
Colitis	13
Diverticulitis	7
Epiploic appendagitis	4
Enteritis/ileitis	3
Cystitis/ureteritis	3
Tubo-ovarian abscess	2
Ovarian mass	2
Ureteric stone	2
Cecal cancer	1
Iliopsoas abscess	1

colitis, enteritis, ovarian torsion, pelvic inflammatory disease, which could lead to delayed diagnosis.

Given these issues, it is not surprising that diagnostic imaging in the form of US and especially CT, which offer high diagnostic accuracy, have been adopted as they have decreased the latency to diagnosis (reducing complications), and dramatically reduced the number of unnecessary surgical interventions [3, 18–20]. These two imaging modalities are now the standard of care in most centers when acute appendicitis is clinically suspected [21].

CT has been shown to be more accurate and consistent than US in large meta-analyses spanning medical literature from 1986 to 2004, citing pooled sensitivity of 94 versus 84% and pooled specificity of 94 versus 93% in CT versus US [6]. This is likely in part due to operator variability inherent in US imaging, anatomical variation of the location of the appendix, body habitus, excessive bowel gas and severe abdominal pain [22–24]. CT also covers other areas in the abdomen that are not always well seen on US, for example the retroperitoneal structures, which can be important in pathologies that mimic appendicitis. Although CT is the mainstay of diagnostic imaging recommendations in the workup of suspected appendicitis, the optimal CT technique for appendicitis remains controversial [19] and proposed CT protocols include a combination of CT of the abdomen and pelvis or focused CT alone with oral and IV contrast (traditional protocol), unenhanced CT, CT with oral contrast only, with oral and rectal contrast, with rectal contrast only or with IV contrast alone [9, 25, 26].

The main drawback of CT utilization is the concern associated with risks due to radiation exposure, the most important of which is increased risk of cancer [27–30]. Multiple methods to decrease radiation dose have been proposed, primarily reducing the field of view of the CT examination.

Several authors have argued that focused appendiceal CT could effectively diagnose acute appendicitis. Rao et al. prospectively examined 100 patients suspected of having acute appendicitis that underwent focused CT with oral and rectal contrast but no IV contrast, through a 12–15 cm region, centered approximately 3 cm above the cecum. They found that focused CT had a sensitivity of 100%, a specificity of 95%, a positive predictive value of 100% and overall accuracy of 98% [12]. Fefferman et al. examined 93 pediatric patients with right lower quadrant pain using CT-AP with oral and IV contrast, dividing the CT into three regions (above the lower pole of the right kidney, between lower pole and iliac crest, and below the iliac crest). They cite a sensitivity of

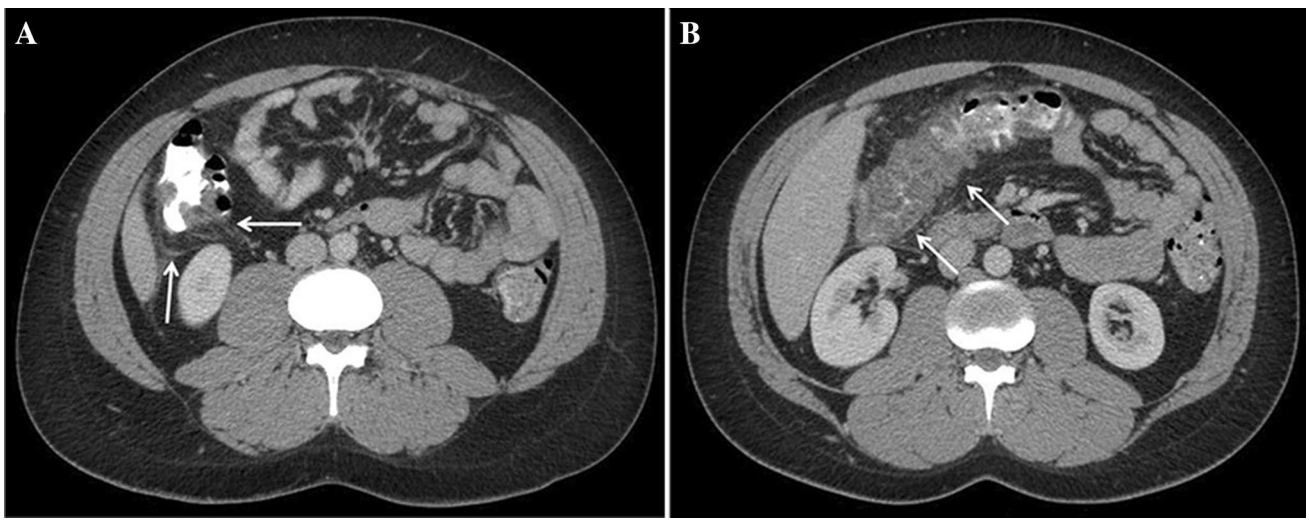

Fig. 3 **a** Focused appendiceal CT reveals fluid around the tip of the right hepatic lobe and partially imaged colonic wall thickening (arrows). **b** CT-AP above the focused scan reveals colitis affecting the hepatic flexure and proximal transverse colon (arrows). *CT-AP* CT of the abdomen and pelvis

97% and specificity of 93% for the region below the right lower pole [13]. Lane et al. studied 300 patients referred from the departments of surgery and emergency medicine with suspected acute appendicitis with focused unenhanced CT from T12 vertebra to the pubic symphysis with a sensitivity of 96%, specificity of 99%, and accuracy of 97% [31]. Finally, Wijetunga et al. studied 100 patients in the emergency setting referred by surgery with equivocal signs and symptoms of appendicitis. They underwent focused CT with oral contrast of a 12–15 cm region of the right lower quadrant using the distended cecum as a landmark, with 93% sensitivity, 97% specificity, and 96% accuracy [32].

Some authors on the contrary, have suggested that the sensitivity and specificity of focused CT, as well as the possibility of missing important alternative diagnoses outside of the scanning field is too significant to adopt focused appendiceal CT. For example, Jacobs et al. assessed 228 patients with clinically suspected appendicitis. They performed focused appendiceal CT (with oral contrast alone, scanning 15 cm of the right lower quadrant centered over the inferior third of the cecum) followed immediately by standard CT-AP with oral and IV contrast. Their specificity and sensitivity for appendicitis was found to be greater in CT-AP with oral and IV contrast, with four cases of appendicitis that would have been missed using focused CT [10]. Kamel et al. analyzed 100 patients with right lower quadrant pain considered to have an atypical presentation of appendicitis. These patients underwent CT-AP with oral and IV contrast, as well as CT of the pelvis alone, with an overall sensitivity of 88% [14].

Based on the past literature summarized above, further investigation was felt necessary for several reasons. The clinical criteria for subject inclusion in these studies were heterogeneous. Some studies considered only patients with clinically suspected appendicitis, while others selected patients with right lower quadrant pain, and others considered only atypical presentation for suspected appendicitis. The referral patterns also varied, some from emergency physicians, others from medicine and surgery, and some only from surgeons. The selection of contrast for the CT examinations was heterogeneous, including unenhanced, oral contrast only, oral and rectal contrast only, and oral and IV contrast. The region of interest also varied from a region around the proposed location of the cecal pole, various regions using the lower pole of the kidney as a landmark, from the T12 vertebra to pubic rami, and the pelvis alone. Finally, most of the studies for focused appendiceal CT are also greater than 15 years old, with advances in CT technology in the interim.

Our study showed that focussed CT starting at the top of L4 vertebral body to the level of the roof of the acetabula has a high diagnostic accuracy for acute appendicitis with sensitivity and specificity of 100%. Comparing the gold standard CT-AP with focused appendiceal CT, there was no difference in the ability to visualize the appendix. Using focused CT technique, there were no cases where the appendix was completely outside the margins of the scans and only three cases where part of the appendix was not included, by a few millimetres. There was also no difference in the diagnostic accuracy i.e. there were no cases where appendicitis was missed. Of the three cases where the inflamed appendix was not fully included in the field of view of focused appendiceal CT, no additional significant findings were seen in the CT-AP (no abscesses local or distant, and no extra-luminal free air).

Our results also demonstrate that focused CT confidently established an alternate diagnosis in 37 out of 38 patients that did not have acute appendicitis. In 14 of these patients, the pathology was partially visualized; however, it did not change the diagnostic accuracy. In one patient however, the upper limit of the focused appendiceal CT revealed free fluid, stranding around the hepatic flexure, and subtle thickening in the colon wall, however, the thickened segment of colon was not included in the field of view, which qualifies as a missed diagnosis of colitis (Fig. 3). In this case, it stands to reason that when non-specific abnormal findings or incomplete pathology is identified in focused CT, we advise extending the field of scanning to provide full coverage of the abdomen and pelvis. This requires immediate review of the focused CT or recall of the patient.

The rate of incidental findings outside the area of focused CT was not assessed here as the focus was on findings that would explain the patients' acute presentation. However, this has been investigated in previous studies and the majority of incidental findings were of little clinical significance [33].

We also believe that the fixed bony landmarks used in our study (superior endplate of L4 and roof of acetabulum) are much easier to identify on the scout topograms compared to other studies using the cecum as a landmark which may not be gas filled and the renal shadow which could be obscured by bowel gas when planning the CT scan.

Comparison of our results with prior literature is difficult because of inhomogeneous scan protocols and heterogeneity in patient selection. For example, in a study by Malone et al. they elected to exclude patients with strong suspicion of appendicitis and included patients with lower abdominal pain in whom the diagnosis was not obvious [34]. Similarly, in a retrospective study by Kamel et al. looking at the value of non-focused CT versus focused appendiceal imaging, patients with symptoms equivocal for appendicitis were also included in the study population [14]. Our selection criteria were meant to mimic the most common clinical presentation in that most patients with suspected appendicitis are triaged and imaged after initially assessment in the emergency department, rather than after consultation with other services. Thus, the accuracy of limited CT in patients

referred by the surgeon on call rather than the emergency physicians was not ascertained.

We chose to include radiology resident reviews in the study as opposed to only experienced abdominal radiologists, again to provide the most realistic representation of a radiology department where a subspecialized radiologist may not always be available.

Specific analysis of the reduction of exposure to ionizing radiation was not performed in our study. Nonetheless, it has been estimated that CT of the pelvis alone has an effective dose of less than half that of CT of the abdomen and pelvis [35]. For the purposes of this study, we estimate the focused appendiceal CT dose is approximately half that of CT-AP. Therefore, in this cohort of 200 patients, an equivalent dose of approximately 100 CTs would be spared.

A similar estimated savings in time taken to interpret the CT and cost for interpretation of the CT would also be expected. This has been modeled in previous studies and showed to represent a potential for significant cost savings to the healthcare system [36].

In conclusion, accurate diagnosis of acute appendicitis is possible with focused appendiceal CT of the abdomen and pelvis with IV and oral contrast, specifically limited to the area between the top of L4 vertebral body and the roof of the acetabulum, which is the most limited scanning field of view in studies of this kind. Moreover, this strategy ensures adequate visualization of other pathologies that mimic acute appendicitis. This presents a possibility to decrease radiation exposure to the patient, decrease in CT reading time, and decrease cost, without compromising accuracy.

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