Abdominal Radiology (2019) 44:2963–2970
https://doi.org/10.1007/s00261-019-02064-6

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Acute non-traumatic abdominal pain by quadrant: relative yield of CT and clinical evaluation for diagnosis in 1000 patients

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Published online: 18 May 2019

Abstract

Objective To determine the relative diagnostic yield of contrast-enhanced CT in adults presenting with symptoms referable to a specific abdominal quadrant.

Methods Electronic health records review systematically identified patients meeting the following inclusion criteria: adults (≥ 18 years) undergoing IV contrast-enhanced abdominopelvic CT for acute non-traumatic symptoms referable to a specific abdominal quadrant (RLQ/LLQ/LUQ/RUQ). The CT-based diagnosis and any clinical diagnosis in the absence of CT diagnosis were recorded. The final cohort of 1000 subjects (mean age, 48.1 years; 647F/353M) consisted of consecutive sub-cohorts of 250 patients for each abdominal quadrant. Positive oral contrast was utilized in 91.6% (916/1000) of cases.

Results A positive CT diagnosis was provided in 47.3% (473/1000) of all patients, and was highest for LLQ (58.8%) and RLQ (58.0%) symptoms, including diverticulitis and appendicitis in 23.6% and 24.8% cases, respectively. CT positivity was lower for the LUQ (34.4%) and RUQ (38.0%) ($p < 0.0001$), with no single diagnosis representing > 5% of cases. However, all quadrants provided valuable triage of 218 hospital admissions (21.8%), 83.0% were CT positive, whereas 62.7% of 782 discharged patients were CT negative. Only 7.0% of CT-negative patients were admitted. A clinical-only diagnosis was provided in 9.3% of the total cohort (93/1000), representing 17.6% of the CT-negative cohort (93/527).

Conclusion The rate of positive CT diagnosis is considerably higher for the lower abdominal quadrants, predominately due to appendicitis and diverticulitis. However, CT results (positive vs. negative) for all four quadrants strongly correlated with hospital admission versus discharge. Clinical-only diagnosis represented < 10% of all cases.

Keywords CT · Abdominal pain · Appendicitis · Diverticulitis

Introduction

Acute non-traumatic abdominal pain represents a common presenting complaint to the emergency department (ED). Due to the wide variety of potential underlying conditions, coupled with limitations related to physical examination and laboratory evaluation, a purely clinical diagnosis is often difficult. As such, abdominal imaging is commonly performed in this setting, variably consisting of radiography, ultrasound, and CT. For many situations, multi-detector CT (MDCT) is currently the diagnostic study of choice in adults, and is widely available in the ED setting. The diagnostic performance of MDCT is well established for the evaluation of acute right lower quadrant (RLQ) and left lower quadrant (LLQ) pain, particularly for appendicitis and colonic diverticulitis [1–6]. Although MDCT may also be useful in some cases of right upper quadrant (RUQ) and left upper quadrant (LUQ) symptoms, there is less published evidence of its diagnostic yield for these upper quadrants, particularly for the left. In general, we are not aware of any previous studies focusing on the yield of CT-based diagnosis according to the specific symptomatic abdominal quadrant.

The purpose of this study was to determine the relative diagnostic yield of IV contrast-enhanced CT in adults presenting to the ED with symptoms referable to a specific abdominal quadrant (i.e., RLQ, LLQ, LUQ, or RUQ). In addition, positive versus negative CT results were correlated with hospital admission versus discharge from the ED.

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Methods

Study group

This HIPAA-compliant study was approved by our institutional review board. The need for signed informed consent was waived for this retrospective investigation of our institutional PACS and EMR. The inclusion criteria for this study consisted of patients 18 years or older presenting to our ED who underwent IV contrast-enhanced MDCT evaluation for acute non-traumatic symptoms related to a specific abdominal quadrant (i.e., RLQ, LLQ, LUQ, or RUQ). A specific quadrant of symptoms as noted in the CT study indication or clinical history was required for inclusion; patients with diffuse or non-localizing abdominal symptoms, or with symptoms referable to more than one quadrant of either flank were excluded. For each abdominal quadrant, a consecutive series of 250 adult patients meeting the above inclusion criteria were enrolled, with each quadrant requiring a different interval of time to reach the required number of cases. Specifically, MDCT studies from 2017 and earlier were consecutively searched, extending back to 2009 (94 months) to reach $n = 250$ for the LUQ sub-cohort. The RUQ, RLQ, and LLQ subcohorts required 22-month, 18-month, and 9-month intervals to reach 250 subjects each, respectively. This resulted in a final study cohort of 1000 subjects, with a mean age of 48.1 years and 64.7% female. Table 1 provides more detailed demographic data of the final study cohort. The gender distribution was similar among the four quadrants (range of females, 60.8–66.8%); age distribution was also fairly similar but tended to be slightly younger for the RLQ cohort and slightly older for the LLQ cohort.

For all patients meeting the study inclusion criteria, the final prospective CT interpretation was utilized as the ground truth for the CT-based diagnosis, if established. Furthermore, for all cases where a prospective CT diagnosis was posited, the level of diagnostic confidence was retrospectively and subjectively applied by one of the co-authors (blinded), with further input as needed by a second co-author (blinded) for equivocal cases. In addition, the EMR for each patient was extensively reviewed for data relating to the clinical assessment in the ED (including clinical diagnosis), the use of ultrasound imaging, the ultimate disposition of the patient (i.e., admitted to the hospital or discharged to home), and any relevant further work-up or treatment.

CT technique

Helical CT imaging was performed on our ED scanner (GE LightSpeed VCT, GE Healthcare) using a 64×0.625 detector configuration, pitch = 0.516, and rotation time = 0.4 s. The specific kV, mA, and scan FOV settings are based on patient size, with small, medium, and large adults defined as a combined AP plus lateral abdominal scout measurement of < 55 cm, 55–80 cm, and > 80 cm, respectively. Corresponding kV settings were 100, 120, and 140, with 120 kV in the majority of cases; Smart mA was employed with variable mA range (lowest = 50, highest = 630) and Noise Index ranged from 15 to 21. Unless contraindicated or specifically requested to withhold, 1000 ml of dilute water-soluble nonionic positive oral contrast was typically administered over a 1-h period prior to scanning in 200 ml increments. Positive oral contrast was utilized in 91.6% (916/1000) of cases. All patients received IV contrast, generally standard portal venous phase imaging with a weight-based IV contrast volume ranging from 100 to 150 ml injected at 3 ml/s, followed by a 60-ml saline chaser.

Transverse (axial) CT images were reconstructed with 5-mm slice thickness at 3-mm intervals, using a 40% ASiR blend. An additional thin-section series with 1.25-mm slice thickness at 0.625-mm intervals was also provided, as well as coronal and sagittal reformats with 5-mm slice thickness at 2.5-mm intervals. All MDCT studies were interpreted in soft-copy cine mode on a standard PACS.

Statistical analysis

Fisher's exact test was used to test for differences in categorical variables, and Student's *t* test was used to test

Table 1 Demographic characteristics of the cohort

	Total cohort	RUQ	LUQ	LLQ	RLQ
Cohort size (*n*)	1000	250	250	250	250
Female (*n*, %)	647 (64.7%)	165 (66.0%)	167 (66.8%)	152 (60.8%)	163 (65.2%)
Mean age (years)	48.1	49.4	49.1	52.2	41.6
Median age (years)	47	49	49	52	40
18-30 years (%)	18.5%	14.0%	16.0%	11.6%	32.4%
31-45 years (%)	28.3%	30.0%	28.8%	22.4%	32.0%
46-64 years (%)	35.5%	36.8%	36.4%	42.8%	26.0%
65 + years (%)	17.7%	19.2%	18.8%	23.2%	9.6%

for differences in continuous variables. A two-tailed p-value < 0.05 was used as the criterion for statistical significance.

Results

A prospective CT-based diagnosis was given in 47.3% (473/1000) of all ED patients in this cohort; the remaining cases were CT negative for a specific etiology. As shown in Fig. 1a, the rate of positive CT diagnosis was highest for the LLQ (58.5%) and RLQ (58.0%) sub-cohorts, compared with the RUQ (38.0%) and LUQ (34.4%) cohorts ($p < 0.001$). Acute appendicitis accounted for 24.8% of the entire RLQ sub-cohort, and 42.8% of those with a CT-based RLQ diagnosis. Similarly, colonic diverticulitis accounted for 23.6% of the LLQ group, and 40.1% of those with a CT-based LLQ diagnosis. In comparison, no single diagnosis comprised even 5% of cases in the upper quadrants (Table 2). Table 2 lists the additional CT-based diagnoses for each abdominal quadrant in descending order of frequency, and Figs. 2, 3, 4, and 5 show typical or interesting case examples for each quadrant.

If appendicitis and diverticulitis cases are excluded from the RLQ and LLQ cohorts, respectively, the rates of positive CT diagnosis were similar for all four quadrants (range 33.2–38.0%). Bowel inflammation or thickening related to colitis or enteritis was a relatively common CT diagnosis for all four quadrants (range 4–8%), as was excessive stool burden (range 3–6%). Other CT-based diagnoses common to three or four quadrants included diverticulitis, small bowel obstruction, symptomatic urolithiasis, pancreatitis, epiploic

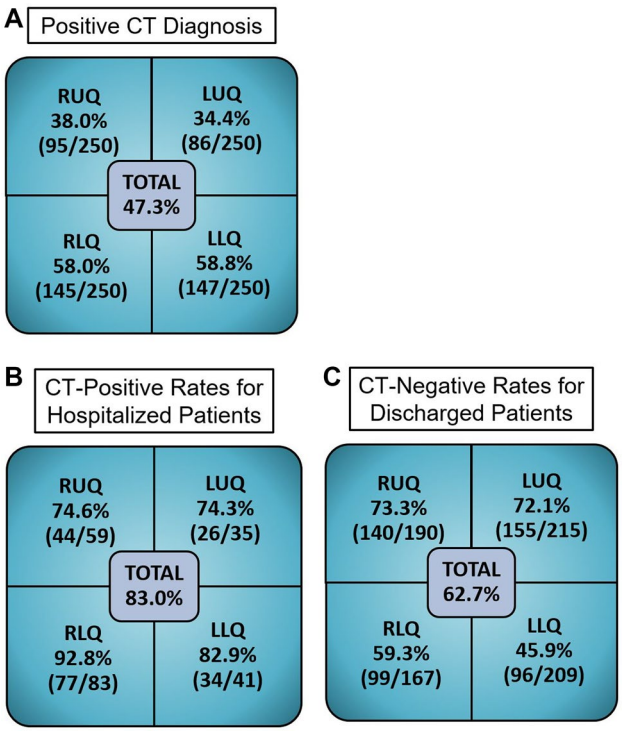

Fig. 1 CT diagnosis and patient disposition results according to the abdominal quadrant

Table 2 Most frequent CT diagnoses by abdominal quadrant

CT diagnosis	*N* (%)
Right lower quadrant (RLQ)	
CT negative (no diagnosis)	105 (42)
Appendicitis	62 (25)
Bowel inflammation or thickening	13 (5)
Excessive stool burden	11 (4)
Symptomatic right adnexal cyst	11 (4)
Left lower quadrant (LLQ)	
CT negative (no diagnosis)	103 (41)
Diverticulitis	59 (24)
Bowel inflammation or thickening	21 (8)
Excessive stool burden	15 (6)
Symptomatic urolithiasis	9 (4)
Epiploic appendagitis	8 (4)
Symptomatic left adnexal cyst	8 (4)
Small bowel obstruction	5 (2)
Left upper quadrant (LUQ)	
CT negative (no diagnosis)	164 (66)
Bowel inflammation or thickening	12 (5)
Excessive stool burden	10 (4)
Pancreatitis	7 (3)
Small bowel obstruction	5 (2)
Right upper quadrant (RUQ)	
CT negative (no diagnosis)	155 (62)
Cholecystitis or symptomatic cholelithiasis	17 (7)
Bowel inflammation or thickening	9 (4)
Pancreatitis	8 (3)
Excessive stool burden	7 (3)
Diverticulitis	5 (2)
Biliary obstruction	5 (2)
Malignant mass	5 (2)

Less frequent diagnoses (< 5 cases): RLQ—diverticulitis, lymphadenopathy, cystitis, mesenteric adenitis, small bowel obstruction, omental infarction, pancreatitis, malpositioned IUD, epiploic appendagitis, right hydronephrosis, hydrosalpinx, abdominal wall hematoma, Chilaiditi syndrome, cholecystitis, mesenteric panniculitis; LLQ—cystitis, appendicitis, symptomatic uterine fibroid, ventral hernia, abscess, pancreatitis, acute kidney injury, mesenteric volvulus, metastatic pancreatic cancer, small bowel intussusception, hydrosalpinx, rectus sheath hematoma; LUQ—gastric wall thickening, lymphadenopathy, cirrhosis, hiatal hernia, left lung base opacity, left renal mass, GERD, omental infarct, splenic infarct, uterine fibroids, left hydronephrosis, adnexal lesion, symptomatic urolithiasis, peritoneal carcinomatosis; RUQ—epiploic appendagitis, abscess, choledocholithiasis, cirrhosis, cholangitis, PUD, symptomatic urolithiasis, pyelonephritis, rectus sheath hematoma, Fitz Hugh–Curtis syndrome

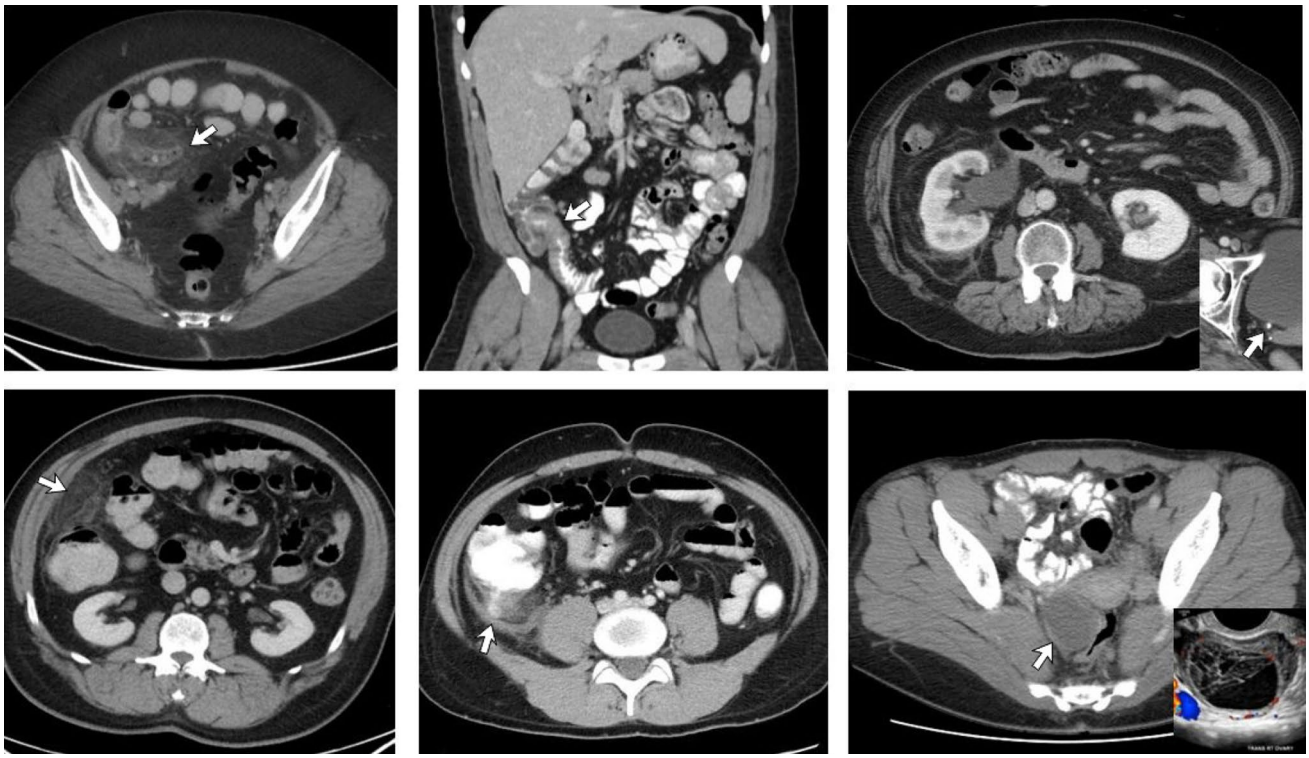

Fig. 2 Examples of positive CT diagnosis in adults presenting with non-traumatic RLQ pain. Collage of contrast-enhanced CT images from adults presenting to the ED with acute RLQ symptoms shows uncomplicated appendicitis (upper left; arrow), new Crohn's ileitis (upper middle; arrow), obstructing right ureteral calculus (upper right; arrow on inset), omental infarct (lower left, arrow), right-sided colonic diverticulitis (lower middle; arrow), and right ovarian hemorrhagic cyst (lower right; arrow, US inset)

appendagitis, abdominal wall hematoma, and malignant tumors (primary or metastatic).

After retrospective review of CT-positive interpretations, the assigned diagnostic confidence level was considered high in 84.4%, intermediate in 14.3%, and low in 1.3% of all cases. A clinical-only diagnosis was provided in 9.3% of the total cohort (range 7.6–11.2% among quadrants), representing 17.6% of the CT-negative cohort (93/527). Ultrasound imaging was performed in addition to CT in 14.7% (147/1000) of patients. Ultrasound utilization was highest for patients with right-sided symptoms (23.2% for both the RUQ and RLQ sub-cohorts) and was lowest for the LUQ group (4.8%). Ultrasound was performed in only 7.6% of the LLQ group.

A total of 218 patients (21.8%) were admitted to the hospital from the ED, with an average hospital stay of 3.0 ± 4.1 days. Among hospitalized patients, 83.0% (181/218) had a positive diagnosis at CT (Fig. 1b), including a high of 92.8% (77/83) for those admitted with RLQ symptoms and somewhat lower rates for the upper abdomen (74.3% for LUQ and 74.6% for RUQ). Conversely, among patients discharged from the ED, 62.7% (490/782) were negative at CT (Fig. 1c), with the highest CT-negative rates in the upper abdomen (73.3% for RUQ and 72.1% for LUQ) and lowest in the LLQ (45.9%). Put another way, hospital admission was significantly more frequent ($p < 0.001$) in CT-positive patients (38.2%; range 23.1–53.1% among quadrants) compared with CT-negative patients (7.0%; range 5.5–9.7%) ($p < 0.001$), resulting in an overall odds ratio of 5.5.

Discussion

The high utilization rates and positive clinical impact of abdominopelvic CT in adults presenting to the ED with unexplained pain have been established for decades [7–9]. These features are inter-related since the high clinical yield of CT is likely a primary driver for its high utilization. Previous studies have typically demonstrated changes in both clinical diagnosis and clinical management in 40–50% of cases after abdominal CT [10–13]. Based on the subjective opinion of ED providers, one study found that abdominal CT was the most useful diagnostic test (by far) in the setting of non-traumatic abdominal pain (followed by urinalysis) [14]. CT results have also been shown to heavily influence decision-making on the need for hospital admission [11, 12]. However, these studies tend to be dominated by

Fig. 3 Examples of positive CT diagnosis in adults presenting with non-traumatic LLQ pain. Collage of contrast-enhanced CT images from adults presenting to the ED with acute LLQ symptoms shows uncomplicated sigmoid diverticulitis (upper left; arrow), large rectus sheath hematoma (upper middle), small bowel intussusception (upper right; arrowheads), epiploic appendagitis (lower left, arrow), left-sided ischemic colitis (lower middle; arrowheads), and obstructing left ureteral calculus (lower right; arrow)

lower abdominal pain, where appendicitis in the RLQ and diverticulitis in the LLQ account for a substantial fraction of cases. This provided some of the motivation for our quadrant study, which normalized each quadrant to equal numbers. Not surprisingly, the lower frequency of performing CT for pain in the upper abdominal quadrants is demonstrated by the fact it took an order of magnitude longer (> tenfold) to accrue the 250-patient LUQ cohort compared with the LLQ cohort. The order of prevalence for symptoms by quadrant in our study (LLQ > RLQ > RUQ > LUQ) matches that from a prior clinical study in a smaller cohort [14]. Although many previous works and reviews have focused on the RLQ differential diagnosis [15–17], we are not aware of other studies that compared the relative yield of CT according to the symptomatic abdominal quadrant.

Our study revealed some interesting similarities among the four abdominal quadrants. In terms of demographic composition, the female predominance was remarkably similar (range 60.8–66.8%), and mean age was also quite similar, especially after accounting for older patients with suspected diverticulitis in the LLQ and younger patients with suspected appendicitis in the RLQ. Furthermore, if one excludes these two common diagnoses, the resulting CT-positive rates are all within 5% of each other (33.2–38.0%). Beyond appendicitis and diverticulitis, the wide array of CT-based diagnoses demonstrates the versatility of this comprehensive imaging test in the ED setting. The impact of CT on clinical decision-making and patient management is evidenced by the uniformly high rates of positive CT diagnosis among patients admitted, and the CT-negative results for the majority who are discharged. One exception is seen in the LLQ, where uncomplicated diverticulitis is often managed conservatively on an outpatient basis. Such influence on patient care may justify its high-volume usage in the ED setting. In comparison, clinical diagnosis was uncommon in the absence of a CT diagnosis.

CT of the abdomen and pelvis with IV contrast receives the highest rating for both RLQ (suspected appendicitis)

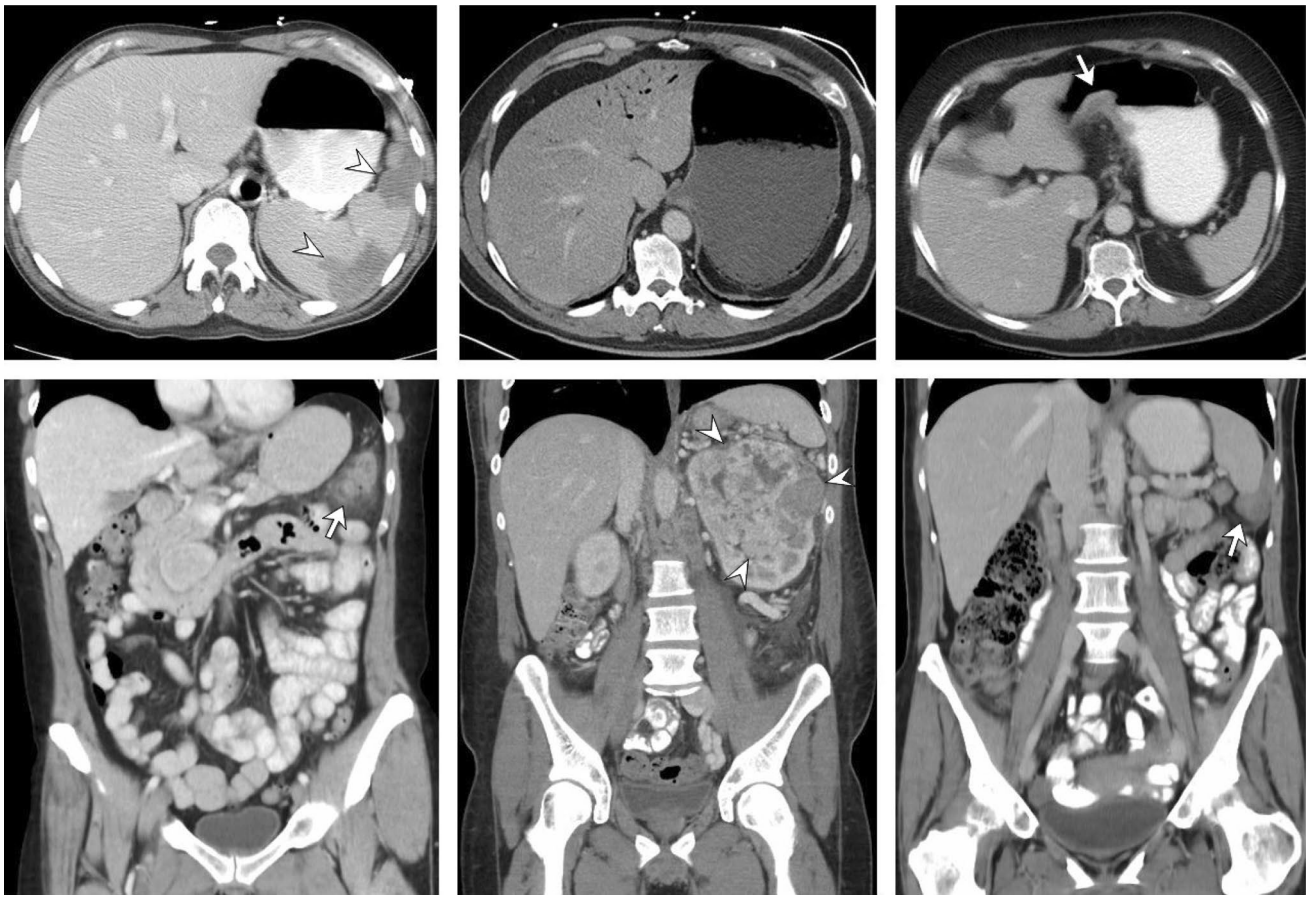

Fig. 4 Examples of positive CT diagnosis in adults presenting with non-traumatic LUQ pain. Collage of contrast-enhanced CT images from adults presenting to the ED with acute LUQ symptoms shows multiple splenic infarcts (upper left; arrowheads), emphysematous gastritis (upper middle), gastric adenocarcinoma (upper right; arrow), splenic flexure diverticulitis (lower left, arrow), left renal cell carcinoma (lower middle; arrowheads), and splenic injury in patient who underwent colonoscopy 10 days earlier (lower right; arrow)

and LLQ pain (suspected diverticulitis) in the published ACR Appropriateness Criteria [3, 4]. However, for RUQ pain, CT is rated below US, and also below MR for most clinical scenarios [18]. To our knowledge, no such appropriateness ratings exist for LUQ pain, in part due to its lower prevalence. However, our results suggest that CT appears to be quite valuable for both RUQ and LUQ pain. Unlike US imaging, which is particularly useful for specific indications (e.g., cholecystitis and the female pelvis), CT is more versatile for non-specific cases where the clinical differential is broad [19]. Like CT, MR imaging also has the potential to diagnose a wide array of acute abdominopelvic conditions beyond appendicitis [20, 21], but there are issues of availability in the ED, as well as higher cost and interpretive complexity. Beyond abdominal radiography, which is a low yield examination in this setting [7], the utility of abdominal cross-sectional imaging over clinical and laboratory evaluation is quite apparent.

We acknowledge some limitations to our study. Given the infrequent indication of LUQ pain, we derived a retrospective cohort to achieve our planned cohort size. However, we feel that utilizing the actual unbiased CT interpretation may better reflect standard clinical practice than an artificial clinical trial setting. The subjective nature of retrospective scoring of CT diagnostic confidence is a drawback, and is largely why we did not emphasize these findings. Assessment of clinical-only diagnoses was likely even more subjective. Not all diagnoses were subsequently confirmed beyond the initial CT and clinical assessment. The frequent use of positive oral contrast in this ED cohort is likely divergent from many current practices where its use has been abandoned, largely for perceived "throughput" issues. However, we continue to believe in the added value of positive oral contrast for abdominal CT, and this remains an active area of investigation for our group. However, we do not feel that the high utilization of positive oral contrast significantly impacted our general findings. We also excluded cases without IV contrast; a separate study focusing on such cases might be of interest. Finally, by definition we excluded patients with

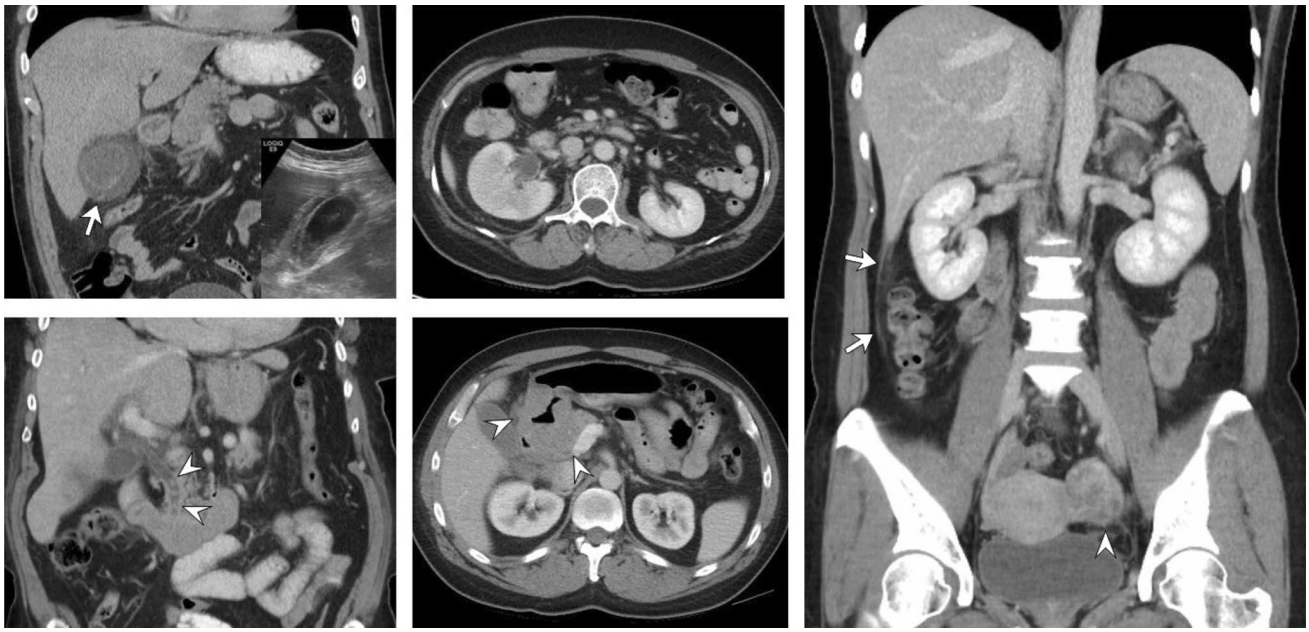

Fig. 5 Examples of positive CT diagnosis in adults presenting with non-traumatic RUQ pain. Collage of contrast-enhanced CT images from adults presenting to the ED with acute RUQ symptoms shows acute cholecystitis (upper left; arrow and US inset), right pyelonephritis (upper middle), choledocholithiasis (lower left, arrowheads), gastroduodenal lymphoma (lower middle; arrowheads), and chlamydial PID with Fitz Hugh–Curtis presentation (right image; arrows and arrowhead)

diffuse, multi-quadrant, flank, or non-localized abdominal complaints, which compromises a large subset. This likely impacted our diagnostic milieu and probably excluded a number of patients with small bowel obstruction, peritonitis, peptic ulcer disease (PUD), and urolithiasis, among other conditions. Interestingly, one ED series that included all patients with non-traumatic abdominal or flank pain reported that PUD was the most common diagnosis, followed by symptomatic urolithiasis [14]. We have noted an increasing rate of PUD diagnosis at abdominal CT in our ED practice [22].

In conclusion, the overall diagnostic yield of CT was high for all abdominal quadrants, with added value not only for positive diagnoses, but likely also for many cases where CT excludes significant pathology. Not surprisingly, appendicitis (RLQ) and colonic diverticulitis (LLQ) accounted for nearly one-quarter of all patients for their respective quadrant. For the upper quadrants, no single CT diagnosis accounted for > 5% of cases. When abdominal CT is negative in this ED setting, very few patients will receive an alternative clinical diagnosis for their symptoms. The CT results for all four abdominal quadrants effectively triaged ED patients in terms of subsequent discharge or hospital admission, demonstrating the added value of this commonly used imaging study.

Compliance with ethical standards

Conflict of interest Relationships with industry: Dr. Pickhardt—advisor to Bracco; shareholder in SHINE, Elucent, and Cellectar. Dr. Nelson declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was waived for this retrospective study.

References

1. Pickhardt PJ, Lawrence EM, Pooler BD, Bruce RJ. Diagnostic Performance of Multidetector Computed Tomography for Suspected Acute Appendicitis. Annals of Internal Medicine 2011;154:789-U38
2. Rao PM, Rhea JT, Novelline RA, Mostafavi AA, McCabe CJ. Effect of computed tomography of the appendix on treatment of patients and use of hospital resources. New England Journal of Medicine 1998;338:141-6
3. Smith MP, Katz DS, Lalani T, et al. ACR Appropriateness Criteria(R) Right Lower Quadrant Pain--Suspected Appendicitis. Ultrasound quarterly 2015;31:85-91

4. Balfe DM, Levine MS, Ralls PW, et al. Evaluation of left lower quadrant pain. American College of Radiology. ACR Appropriateness Criteria. Radiology 2000;215 Suppl:167-71.
5. Ambrosetti P, Grossholz M, Becker C, Terrier F, Morel P. Computed tomography in acute left colonic diverticulitis. British Journal of Surgery 1997;84:532-4
6. Rao PM, Rhea JT, Novelline RA, et al. Helical CT with only colonic contrast material for diagnosing diverticulitis: Prospective evaluation of 150 patients. American Journal of Roentgenology 1998;170:1445-9
7. Ahn SH, Mayo-Smith WW, Murphy BL, Reinert SE, Cronan JJ. Acute nontraumatic abdominal pain in adult patients: Abdominal radiography compared with CT evaluation. Radiology 2002;225:159-64
8. Rosen MP, Sands DZ, Longmaid HE, Reynolds KF, Wagner M, Raptopoulos V. Impact of abdominal CT on the management of patients presenting to the emergency department with acute abdominal pain. American Journal of Roentgenology 2000;174:1391-6
9. Larson DB, Johnson LW, Schnell BM, Salisbury SR, Forman HP. National Trends in CT Use in the Emergency Department: 1995-2007. Radiology 2011;258:164-73
10. Pescatori LC, Brambati M, Messina C, et al. Clinical impact of computed tomography in the emergency department in nontraumatic chest and abdominal conditions. Emerg Radiol 2018;25:393-8
11. Abujudeh HH, Kaewlai R, McMahon PM, et al. Abdominopelvic CT increases diagnostic certainty and guides management decisions: a prospective investigation of 584 patients in a large academic medical center. AJR American journal of roentgenology 2011;196:238-43
12. Pandharipande PV, Reisner AT, Binder WD, et al. CT in the Emergency Department: A Real-Time Study of Changes in Physician Decision Making. Radiology 2016;278:812-21
13. Rosen MP, Siewert B, Sands DZ, Bromberg R, Edlow J, Raptopoulos V. Value of abdominal CT in the emergency department for patients with abdominal pain. Eur Radiol 2003;13:418-24
14. Nagurney JT, Brown DF, Chang Y, Sane S, Wang AC, Weiner JB. Use of diagnostic testing in the emergency department for patients presenting with non-traumatic abdominal pain. The Journal of emergency medicine 2003;25:363-71
15. Pooler BD, Lawrence EM, Pickhardt PJ. Alternative Diagnoses to Suspected Appendicitis at CT. Radiology 2012;265:733-42
16. Macari M, Balthazar EJ. The acute right lower quadrant: CT evaluation. Radiol Clin North Am 2003;41:1117-36
17. Purysko AS, Remer EM, Filho HM, Bittencourt LK, Lima RV, Racy DJ. Beyond appendicitis: common and uncommon gastrointestinal causes of right lower quadrant abdominal pain at multidetector CT. Radiographics 2011;31:927-47
18. Yarmish GM, Smith MP, Rosen MP, et al. ACR appropriateness criteria right upper quadrant pain. Journal of the American College of Radiology : JACR 2014;11:316-22
19. van Randen A, Lameris W, van Es HW, et al. A comparison of the accuracy of ultrasound and computed tomography in common diagnoses causing acute abdominal pain. Eur Radiol 2011;21:1535-45
20. Pooler BD, Repplinger MD, Reeder SB, Pickhardt PJ. MRI of the Nontraumatic Acute Abdomen: Description of Findings and Multimodality Correlation. Gastroenterology clinics of North America 2018;47:667-90
21. Repplinger MD, Pickhardt PJ, Robbins JB, et al. Prospective Comparison of the Diagnostic Accuracy of MR Imaging versus CT for Acute Appendicitis. Radiology 2018;288:467-75
22. Kitchin DR, Lubner MG, Menias CO, Santillan CS, Pickhardt PJ. MDCT diagnosis of gastroduodenal ulcers: key imaging features with endoscopic correlation. Abdom Imaging 2015;40:360-84