Relative CT number of periappendiceal fat stranding may be an applicable index for estimating the severity of acute appendicitis

XINHONG SONG, MINGQI SHI, WEI LIU, YANSONG GE and PEIYUAN WANG, MD, PhD

Department of Radiology, Yantai Affiliated Hospital of Binzhou Medical University, No 717 Jinbu Road, Yantai, Shandong 264100, PR China

Address correspondence to: Mr Peiyuan Wang
E-mail: wangpeiyuan1640@163.com

The authors Xinhong Song and Mingqi Shi contributed equally to the work.

Objectives: To investigate the feasibility of relative CT numbers to periappendiceal fat attenuation as an applicable index for estimating the severity of acute appendicitis.

Methods: In total, 308 consecutive surgery-confirmed acute appendicitis patients and 243 controls with available preoperative CT were analyzed retrospectively. The radiological parameters were appendix diameter, length, and wall thickness as concurrent appendicitis signs. CT numbers of periappendiceal fat, mesenteric fat, subcutaneous fat in the anterior and posterior abdominal wall, retroperitoneal fat, gluteal subcutaneous fat and psoas major muscle were measured, as well as the relative CT numbers of periappendiceal fat compared with other locations.

Results: There were 287 suppurative acute appendicitis (SAA) and 21 gangrenous or perforated acute appendicitis (GPAA) cases confirmed by pathology. The CT number of periappendiceal fat was significantly higher in patients than in controls ($P < 0.01$) although there was a wide overlap ($-72.33$ HU–$117.43$ HU). Significant differences in relative CT numbers were observed between the groups in gluteal subcutaneous fat ($\text{RCT}_{gl}$) and psoas major muscle ($\text{RCT}_{ps}$) ($P < 0.01$). The AUCs of $\text{RCT}_{gl}$ and $\text{RCT}_{ps}$ showed high accuracy to discriminate acute appendicitis from controls (AUC = 0.803, 0.761; 0.854, 0.847) and GPAA from SAA (AUC = 0.905, 0.851).

Conclusions: Attenuation of periappendiceal fat on CT is related to the severity of appendicitis, and relative CT numbers ($\text{RCT}_{gl}$ and $\text{RCT}_{ps}$) could be an applicable index for severity determination.

Advances in knowledge: Periappendiceal fat infiltration is related to the severity of acute appendicitis (especially relative CT number). Other clinical and CT features also need to be considered in the evaluation of inflammation.

INTRODUCTION

Acute appendicitis, one of the most common acute abdominal conditions, is divided into uncomplicated (suppurative acute appendicitis, SAA) and complicated appendicitis (gangrenous or perforated appendicitis, GPAA) based on histopathology. Although antibiotics are effective for uncomplicated appendicitis, approximately 30% of patients require surgery because of treatment failure or recurrent appendicitis, and in approximately 17.6% of patients, surgical treatment is delayed because the disease is misdiagnosed as uncomplicated appendicitis. Delayed diagnosis and treatment can lead to various complications, and surgery remains the gold standard for the treatment of acute appendicitis. Approximately 20% of patients present with atypical symptoms that mimic gastrointestinal, urinary, and female reproductive system diseases. Therefore, imaging examinations are necessary for differential diagnosis before clinical intervention. CT is the most common and reliable imaging modality for appendicitis, showing diagnostic sensitivity and specificity >90%. CT examination reduces the negative appendectomy rate from 20% to 2.5–5%. Short- and long-term follow-up results support the feasibility of antibiotic treatment alone as an alternative to surgery for uncomplicated acute appendicitis confirmed by CT, and approximately 20% of appendicitis cases are cured without surgical treatment. Therefore, less severe patients may delay or refuse surgery for a variety of reasons. Typical CT signs can facilitate the diagnosis of acute appendicitis, the detection of perforation, and other clinical and CT features also need to be considered in the evaluation of inflammation.
and excluding the presence of gangrenous appendicitis with high sensitivity and specificity. However, the technique is controversial and there are no unified diagnostic imaging criteria to distinguish uncomplicated from complicated appendicitis or for lesion severity estimation. In most cases, appendicitis is associated with peritonitis, which leads to changes in attenuation of periappendiceal fat stranding on CT (CT number, Hounsefield Unit, HU). Periappendiceal fat infiltration is a common pathological manifestation of acute appendicitis, which is manifested by increased fat density around the appendix. Identifying periappendiceal fat infiltration in patients suspected of acute appendicitis is clinically significant and warrants further clinical research. CT number of periappendiceal fat may be related to the severity of appendicitis, and the CT number or a related parameter (such as relative CT number) may be an applicable index to determine the severity of acute appendicitis. In this study, we examined the accuracy and feasibility of CT number of periappendiceal fat for the preoperative assessment of the severity of appendicitis to help decision-making regarding the need for surgical intervention.

**METHODS**

This retrospective study was reviewed and approved by the Institutional Review Board of our hospital. All procedures involving human participants were performed in accordance with the ethical standards of the institutional and/or national research committee and conformed to the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent was not required.

**Patient characteristics**

The 308 patients with acute appendicitis enrolled in this study were selected among 423 patients who met the inclusion and exclusion criteria (124 patients were excluded, including 19 who were under 18-years-old, 72 who received preoperative antibiotic treatment, 25 who had a history of abdominal or pelvic diseases, and eight clinically undiagnosed appendicitis patients who actively applied for appendectomy with pathology diagnosed as mucosal or intraluminal inflammation; all patients were diagnosed and treated at our hospital between January 1, 2016 and March 31, 2018. All patients had complete clinical and imaging data and underwent appendectomy with confirmation by histopathology. There were 150 females and 158 males, and the average age was 47.94 ± 16.14 years (18–91 years). The clinical data of the patients were collected and recorded, including age, sex, clinical manifestations and signs, laboratory examinations, and intervals between CT examination and surgery. The patients were divided into SAA and gangrenous or perforated acute appendicitis (GPAA) groups according to the pathology.

The inclusion criteria were as follows: (a) first time admission to the hospital with no previous treatments and suspected of acute appendicitis before CT examination; (b) underwent whole abdomen CT examination before surgery; (c) underwent appendectomy and pathology confirmation.

The exclusion criteria were as follows: (a) patients who were under 18-years-old; (b) lactating and pregnant females; (c) history of abdominal surgery or trauma, bleeding, or blood...
transfusions; (d) history of abdominal cancer, inflammatory, intestinal, or pelvic inflammatory diseases; (e) history of heart, liver, or renal insufficiencies; (f) with a history of immunodeficiency disorders; (g) lack of peritoneal fat; and (h) other surgical contraindications.

Control group
A total of 243 patients were randomly selected as the control group (CON) among 274 patients who met the inclusion and exclusion criteria (seven patients under 18-years-old and 24 patients who had incomplete clinical information were excluded).

Table 1. CT findings of the appendix and the concurrent signs

|                          | SAA (n = 287) | GPAA (n = 21) | χ²   | P   |
|--------------------------|--------------|--------------|------|-----|
| Diameter >6 mm           | 252          | 21           | 2.89 | 0.09|
| Thickness >2 mm          | 140          | 15           | 4.02 | 0.045|
| Appendicolith            | 124          | 9            | 0.001| 0.98|
| Periappendiceal fluid    | 38           | 9            | 4.74 | 0.03|
| Surrounding intestinal swelling | 26       | 5           | 1.46 | 0.23|
| Pelvic effusion          | 21           | 3            | 0.17 | 0.68|

GPA, gangrenous or perforated acute appendicitis; SAA, suppurative acute appendicitis.

Table 2. CT HU of different ROIs in patients and controls

|               | N   | Maximum HU | Minimum HU | Mean ± SD (HU)            | t    | P    |
|---------------|-----|------------|------------|---------------------------|------|------|
| CTa           | 551 | −72.33     | −130.13    | −83.12 ± 27.67            | 489.14 | <0.01|
| controls      | 243 | −72.33     | −130.13    | −104.54 ± 9.97            |      |      |
| patients      | 308 | −8.27      | −117.43    | −66.29 ± 25.41            |      |      |
| CTm           | 551 | −68.23     | −126.23    | −103.39 ± 11.32           | 20.49 | <0.01|
| controls      | 243 | −68.23     | −126.23    | −105.81 ± 8.59            |      |      |
| patients      | 308 | −47.97     | −128.33    | −101.48 ± 12.76           |      |      |
| CTaw          | 551 | −74.47     | −144.23    | −106.43 ± 9.40            | 9.10  | <0.01|
| controls      | 243 | −74.47     | −144.23    | −107.78 ± 9.03            |      |      |
| patients      | 308 | −35.63     | −132.03    | −105.37 ± 9.56            |      |      |
| CTpw          | 551 | −70.83     | −133.67    | −106.63 ± 9.75            | 18.93 | <0.01|
| controls      | 243 | −70.83     | −133.67    | −108.64 ± 9.37            |      |      |
| patients      | 308 | −55.20     | −125.57    | −105.06 ± 9.78            |      |      |
| CTgl          | 551 | −91.80     | −144.20    | −110.98 ± 8.08            | 15.24 | <0.01|
| controls      | 243 | −91.80     | −144.20    | −112.48 ± 8.07            |      |      |
| patients      | 308 | −88.47     | −133.06    | −109.81 ± 7.95            |      |      |
| CTps          | 551 | −75.97     | −125.27    | −102.47 ± 8.45            | 0.92  | 0.34 |
| controls      | 243 | −75.97     | −125.27    | −102.86 ± 8.54            |      |      |
| patients      | 308 | −69.30     | −100.23    | −102.16 ± 8.38            |      |      |
| CTrp          | 551 | −71.73     | −33.53     | −50.35 ± 6.45             | 1.14  | 0.29 |
| controls      | 243 | −71.73     | −33.53     | −50.61 ± 6.51             |      |      |
| patients      | 308 | 86.20      | 30.53      | 50.02 ± 6.37              |      |      |

CTa, CT number of the periappendiceal fat; CTgl, CT number of gluteal subcutaneous fat; CTm, CT number of mesenteric fat gap; CTps, CT number of psoas major muscle; CTpw, CT number of abdominal posterior wall subcutaneous fat; CTrp, CT number of retroperitoneal fat; CTaw, CT number of abdominal anterior wall subcutaneous fat.
Patients had no abdominal pain (especially no appendix symptoms and signs), and whole-abdominal CT examinations showed no abnormalities in the appendix and surrounding areas. The control group included 130 females and 113 males, and the average age was 53.43 ± 15.58 years (18–92 years).

The inclusion criteria for the control group were as follows: (a) examined in the same study period as the patient group; (b) no signs or symptoms in the appendix area; (c) underwent whole abdomen CT examination and the appendix appeared clear and normal; and (d) final diagnosis was not appendicitis.

The exclusion criteria for the control group were the same as those for the appendicitis group.

CT imaging data acquisition
All patients underwent whole-abdomen plain CT examinations within 2 h after the onset of the emergency with a MDCT (SOMATOM definition flash CT, Siemens, Germany). No bowel cleansing, oral contrast administration, or antispasmodic agents were permitted in any patient before CT scanning to shorten patient preparation time and avoid possible interference. After breathhold training, the CT examination was performed in a supine position from the diaphragmatic dome to the symphysis pubis. The CT scan protocol was tube voltage of 120 kV and CARE Dose 4D automatic tube current modulation, reference mAs was 400, pitch was 0.6, and the original data were reconstructed with the filter backprojection algorithm with a convolution kernel of "B30f medium smooth" in 1 mm slice thickness and slice space. For postprocessing, multiple planar reconstruction (MPR) and curved multiplanar reformation (CPR) were used to display the appendix and surrounding areas accurately on Syngo via a workstation.

Imaging observation and analysis
The CT findings from the patient and control groups were analyzed by two experts with 5 and 8 years of abdominal imaging experience. If there was disagreement regarding the concurrent appendicitis signs, agreement was reached based on discussion and a third expert. The main CT indicators were assessed as follows: (1) located the appendix and measured the largest diameter, longest length, and maximum appendiceal wall thickness; (2) collected the concurrent appendicitis signs, such as appendicolith, periappendiceal fluid collection, pelvic effusion, extraluminal air, and surrounding intestinal swelling; (3) Measured the CT number of the periappendiceal fat (CTa), mesenteric fat gap (CTm), abdominal anterior wall subcutaneous fat (CTaw), abdominal posterior wall subcutaneous fat (CTpw), retroperitoneal fat (CTrp), gluteal subcutaneous fat (CTgl), and psoas major muscle (CTps) (Figure 1). CT number was measured in a circle of area 10 mm$^2$–20 mm$^2$. CT number was measured three times at each location and the mean was used as the CT number of the site. CTa was measured within 5 mm from the appendix wall; measurements were obtained from multiple locations in

Figure 3. A 61-year-old female with GPAA at 5 h after onset. The appendix was 12.4 mm in diameter, 3.8 mm in wall thickness and 77.4 mm in length (3a, white arrow); the mesangial wall was rough and irregular, and periappendiceal fluid could be seen in the upper region (3b, white arrow). $CTa = -46.35 \text{ HU}, CTgl = -90.37 \text{ HU and CTPs} = 57.49 \text{ HU, and } R_{CTgl} = 0.513, R_{CTps} = 0.806.$
the highest density area avoiding mesangial vessels. In heterogeneous fat stranding, the measured area was determined by MPR imaging. If the exudate from appendicitis affected CTrp and CTps measurements, the measurement sites were placed symmetrically at the same CT section. CTgl was measured in the subcutaneous fat of the buttocks at the level of the acetabulum. The relative numbers were considered statistically relevant CT numbers. The ratio of CTa to the other six CT numbers was calculated and defined as the relative CT number (RCT). The RCT formulas in this study were as follows: RCTm = CTa/CTm, RCTaw = CTa/CTaw, RCTwp = CTa/CTwp, RCTrp = CTa/CTrp, and RCTgl = CTa/CTgl. For the RCTps, the absolute CT number was calculated using the formula RCTps = |CTa/CTps|, which can better display the receiver operating characteristic (ROC) curves.

Pathology
All 243 appendectomy specimens were diagnosed in the pathology department of our hospital. Acute appendicitis cases were classified into SAA and GPAA according to the study by Carr et al. Acute intraluminal inflammation, acute mucosal inflammation, and acute mucosal and submucosal inflammation were not considered true appendicitis.

Statistical analysis
The clinical and imaging information of the patient and control groups was analyzed by independent sample t-tests and chi-square tests, and Fisher exact test was applied as appropriate. The measurement data were expressed as the mean ± SD. One-way ANOVA was used to analyze the differences in CT numbers between the seven measurement sites. The meaningful relative CT numbers of each group were analyzed using ROC curves, and area under the curve (AUC) and 95% confidence interval (95% CI) were obtained. The cutoff of each RCT was determined, and the diagnostic accuracy, sensitivity, and specificity of RCT in the contrast, SAA, and GPAA groups were calculated. All statistical analyses were performed using SPSS 21 for Windows (SPSS Inc., Chicago, IL, USA). Two-sided p values < 0.05 were considered statistically significant, and a p value < 0.10 was considered marginally significant.

RESULTS
Clinical characteristics of the patient group
In the patient group, there were 287 SAA and 21 GPAA cases. All patients received timely surgical treatment after CT

| Table 3. Relative CT HU analysis of the patients and controls |
|---------------------------------------------------------------|
| **Group** | **CON (n = 304)** | **SAA (n = 287)** | **GPAA (n = 21)** | **F** | **P** |
| RCTgl | 1.02 ± 0.11 | 0.63 ± 0.26* | 0.51 ± 0.24† | 70.725 * | <0.01 |
| RCTps | 2.13 ± 0.34 | 1.33 ± 0.56* | 1.13 ± 0.53† | 65.223 * | <0.01 |

CON, control group; GPAA, gangrenous or perforated acute appendicitis; SAA, suppurative acute appendicitis.

| Table 4. ROC of relative CT HU analysis for patients and controls |
|---------------------------------------------------------------|
| **CON** | **SAA** | **GPAA** | **GPAA/SAA** |
| AUC (95% CI)RCTgl | 0.803 (0.719–0.886) | 0.854 (0.821–0.888) | 0.905 (0.718–0.931) |
| RCTps | 0.761 (0.668–0.853) | 0.847 (0.814–0.880) | 0.891 (0.864–0.918) |
| Std. ErroraRCTgl | 0.042 | 0.017 | 0.013 |
| RCTps | 0.047 | 0.017 | 0.014 |
| Asymptotic Sig. bRCTgl | 0.000 | 0.000 | 0.000 |
| RCTps | 0.000 | 0.000 | 0.000 |
| Cutoff RCTgl | 0.655 | 0.905 | 0.898 |
| RCTps | 1.455 | 1.655 | 1.654 |
| Sensitivity RCTgl | 0.744 | 0.802 | 0.821 |
| RCTps | 0.667 | 0.863 | 0.734 |
| Specificity RCTgl | 0.810 | 0.819 | 0.880 |
| RCTps | 0.857 | 0.725 | 0.926 |

CON, control group; GPAA, gangrenous or perforated acute appendicitis; RCTgl, relative CT number of CTgl; RCTps, relative CT number of CTps; SAA, suppurative acute appendicitis.
examination and were confirmed by postoperative pathology. Regarding the clinical characteristics, there were significant differences in fever, nausea, and emesis (\( P < 0.05 \)) between the SAA and GPAA groups, with no significant differences in other characteristics (\( P > 0.05 \)).

CT findings of the patient and control groups
On the CT images, the appendix diameter (12.43 ± 3.99 mm), length (69.01 ± 18.50 mm) and wall thickness (2.01 ± 0.84 mm) were greater in the patient group than in the control group (6.76 ± 1.55 mm, 56.11 ± 13.79 mm, 0.92 ± 0.23 mm, respectively), and the differences between the three groups were significant (\( p < 0.01 \)). In the patient group, the appendix diameter and wall thickness increased in correlation with the severity of appendicitis, and significant differences were found between the SAA and GPAA groups (\( p < 0.05 \)) (Table 1).

Assessment of the concurrent appendicitis signs (Table 1) showed that periappendiceal fluid, surrounding intestinal swelling, and pelvic effusion were more common in GPAA than in SAA, whereas extraluminal air was only observed in patients with GPAA (7/21). The differences in periappendiceal fluid and extraluminal air between the two groups were statistically significant (\( p < 0.05 \)).

CT number differences between the patient and control groups
Regarding changes in fat density, the CTa of appendicitis (−66.29 ± 25.41 HU) increased greatly compared with that of controls (−104.54 ± 9.97 HU) (\( p < 0.01 \)), although there was a wide overlap range (−72.33–−117.43 HU). One-way ANOVA showed no significant differences in CTgl and CTps between patients and controls (Table 2). These two CT numbers could be selected as a reference for further relative CT number evaluations of appendicitis (Figures 2 and 3).

Correlation between relative CT number (\( R_{CT} \)) and appendicitis severity
The relative CT numbers based on \( R_{CTgl} \) and \( R_{CTps} \) and the corresponding ROC curves were further analyzed. The \( R_{CTgl} \) and \( R_{CTps} \) were higher in the CON group than in the SAA and GPAA groups, and significant differences were observed between the three groups (\( P < 0.01 \), Table 3). The AUCs (95% CIs) of \( R_{CTgl} \) and \( R_{CTps} \) could both distinguish appendicitis from the normal appendix with high sensitivity and specificity, and the diagnostic efficacy of \( R_{CTgl} \) was better than that of \( R_{CTps} \) (Table 4, Figure 4), especially in the comparison between GPAA and SAA (Table 4, Figure 4). The differences in AUCs (95% CIs) of relative CT numbers between the CON, SAA, and GPAA groups indicated that periappendiceal fat infiltration was aggravated in correlation with lesion severity, and the relative CT number was an accurate indicator of the severity of appendicitis.

DISCUSSION
Acute appendicitis is one of the most common acute abdominal disorders. Typical clinical manifestations include migrated abdominal pain, tenderness over McBurney’s point, rebound pain, muscle tension, and an elevated leukocyte count in laboratory tests.20,21 The selection of treatment between antibiotics and appendectomy remains controversial,22–24 especially in cases of uncomplicated appendicitis.22 However, delayed surgery in cases of complicated appendicitis may lead to severe complications such as diffuse peritonitis, systemic infection, and even multiple organ failure or death.9,25,26 The incidence of gangrene and perforation is higher in cases of appendicitis with antibiotic treatment failure.27 Therefore, a precise diagnosis and evaluation of the severity of appendicitis are crucial for the timely implementation of effective treatments. Certain characteristic clinical manifestations such as age \( \geq 52 \) years, body temperature \( \geq 37.5°C \), duration of symptoms \( \geq 48 \) h,20 and C-reactive protein \( \geq 4.7 \) mg dl \(^{-1} \)21 could be used as predictive factors for complicated appendicitis, although their diagnostic accuracy is low.
results of the analysis of clinical factors in this study supported this hypothesis.

Preoperative MDCT can accurately show appendix lesions and the accompanying changes, and MDCT has been the clinically preferred technique for the prognostic evaluation of appendicitis, which can lower the negative appendectomy rate. In addition to establishing diagnostic standards for appendicitis such as appendix diameter and wall thickness, MDCT studies focus on assessing the severity of appendicitis.

Avanesov reported that the appendicitis severity index (APSI) determined by CT showed a positive predictive value of 92% and a negative predictive value of 83% in cases of complicated appendicitis. Indicators of perforated appendix include defects in the appendiceal wall, or periappendiceal phlegmon combined with periappendiceal abscess, extraluminal air, and an extraluminal appendicolith. In this study, the signs detected in cases of suppurative and gangrenous appendicitis supported the results of previous studies.

The CT manifestations of periappendiceal fat infiltration include increased fat density around the appendix or ileocecal region in strips or plaques, and an increase in the amount of exudate in correlation with the severity of inflammation. This finding needs to be distinguished from periappendicitis caused by pelvic inflammatory disease, ovarian neoplasia, or chronic inflammatory bowel disease. CT is the most accurate imaging method in inflammatory disease, ovarian neoplasia, or chronic inflammatory bowel disease. CT is the most accurate imaging method for measuring abdominal fat, which can be evaluated by direct measurement or with the pixel method. In this study, direct measurement was used to evaluate periappendiceal fat density changes. Previous studies demonstrated that positive fatty infiltration around the appendix is a possible indicator of appendicitis with a high sensitivity for perforating appendicitis, and similar results were obtained in this study. However, quantitative evaluation of the severity of appendicitis is difficult because of the overlap in periappendiceal fat CT numbers between the controls and the patients. This may be the reason for the lack of studies on CT number in the literature. Referring to the relative CT numbers of previous reports, the correlation between the relative CT number of periappendiceal fat and the severity of appendicitis was quantitatively analyzed in this study. According to the anatomical distribution, six reference measurement sites were selected, which contained the psoas major muscle and five fat-rich areas that are easily measured and are not affected by appendicitis. The results of the relative CT number analysis demonstrated the feasibility of applying C'Tgl and C'Tps as indicators, and the difference in R_CTg and R_CTp suggested that periappendiceal fat infiltration became worse in correlation with the severity of appendicitis, which confirmed the hypothesis that the CT number of periappendiceal fat is related to the severity of appendicitis. The AUCs (95% CIs) of R_CTg and R_CTp confirmed that R_CTg and R_CTp could be used to distinguish complicated appendicitis from uncomplicated appendicitis. The ROC curves of the relative CT numbers suggested that R_CTg and R_CTp can be used to determine the severity of appendicitis with high diagnostic accuracy, which may helpful for clinical decisions regarding surgery. In clinical practice, determination of the severity of appendicitis must be based on other direct CT findings and clinical factors, rather than on AUCs (95% CIs) alone. For example, gangrenous appendicitis can be diagnosed based on factors such as age (≥60 years), temperature (>39.0°C), high CPR, APSI score, and the presence of extramural gas, extramural appendicolith, and focal defects in the appendix wall.

This study had several limitations related to its retrospective nature such as the lack of independent readings and determination of interobserver variability. In addition, the effect of intra-abdominal fat quantity (and/or BMI) on periappendiceal fat CT attenuation was not evaluated. The sample size of GPAA was small, and additional studies are necessary.

In conclusion, periappendiceal fat stranding is a sign of appendicitis but it is not a specific indicator. When combined with other severity indexes, relative CT numbers may be useful for the differential diagnosis of uncomplicated and complicated appendicitis and may improve the accuracy of the assessment of appendicitis severity, which is important to direct the clinical treatment.

ACKNOWLEDGMENT
We thank Mr. Zhaoju Dong of Public Health and Management College of Binzhou Medical University, Yantai, China, for his help in statistical analysis.

CONFLICTS OF INTEREST
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

FUNDING
This work was supported by the Shandong Provincial Natural Science Foundation, China (grant number ZR2018MH034) of Peiyuan Wang. This article is the authors’ original work, hasn’t received prior publication and isn’t under consideration for publication elsewhere.
REFERENCES

1. Vons C, Barry C, Maître S, Pautrat K, Leconte M, Costaglioli B, et al. Amoxicillin plus clavulanic acid versus appendectomy for treatment of acute uncomplicated appendicitis: an open-label, non-inferiority, randomised controlled trial. *Lancet* 2011; 377: 1573–9. doi: https://doi.org/10.1016/S0140-6736(11)60410-8

2. Poddar M, Gerardi C, Cillara N, Fearnhead N, Gomes CA, Birindelli A, et al. Antibiotic treatment and appendectomy for uncomplicated acute appendicitis in adults and children: a systematic review and meta-analysis. *Ann Surg* 2019; 270: 1028–40. doi: https://doi.org/10.1097/SLA.0000000000003225

3. Varadhan KK, Humes DJ, Neal KR, Lobo DN. Antibiotic therapy versus appendectomy for acute appendicitis: a meta-analysis. *World J Surg* 2010; 34: 199–209. doi: https://doi.org/10.1007/s00268-009-0343-5

4. van Randen A, Laméris W, Nio Tutein Nolthenius C, et al. Inter-Observable agreement for abdominal CT in unselected patients with acute abdominal pain. *Eur Radiol* 2009; 19: 1394–407. doi: https://doi.org/10.1007/s00330-009-1294-9

5. Laméris W, van Randen A, Dijkgraaf MGW, Bossuyt PPM, Stoker J, Boermeester MA. Optimization of diagnostic imaging use in patients with acute abdominal pain (optima): design and rationale. *BMC Emerg Med* 2007; 7: 9. doi: https://doi.org/10.1186/1471-227X-7-9

6. Foley WD. Ct features for complicated versus uncomplicated appendicitis: what is the evidence? *Radiology* 2018; 287: 116–8. doi: https://doi.org/10.1148/radiol.1810188022

7. Gorter RR, Eker HH, Gorrier-Stam MAW, Abis GA, Acharya A, Ankersmit M, et al. Diagnosis and management of acute appendicitis. EAES consensus development conference 2015. *Surg Endosc* 2016; 30: 4668–90. doi: https://doi.org/10.1007/s00277-016-3524-7

8. Webb EM, Nguyen A, Wang ZI, Stengel JW, Westphalen AC, Coakley FV. The negative appendectomy rate: who benefits from preoperative CT? *AJR Am J Roentgenol* 2011; 197: 861–6. doi: https://doi.org/10.2214/AJR.10.5369

9. Salminen P, Paajanen H, Rautio T, Nordström P, Aarnio M, Rantanen T, et al. Antibiotic therapy vs appendectomy for treatment of uncomplicated acute appendicitis: the APPAC randomized clinical trial. *JAMA* 2015; 313: 2340–8. doi: https://doi.org/10.1001/jama.2015.6154

10. Salminen P, Tuominen R, Paajanen H, Rautio T, Nordström P, Aarnio M, et al. Five-Year follow-up of antibiotic therapy for uncomplicated acute appendicitis in the APPAC randomized clinical trial. *JAMA* 2018; 320: 1259–65. doi: https://doi.org/10.1001/jama.2018.13201

11. Park G, Lee SC, Choi J-B, Kim S-J. Stratified computed tomography findings improve diagnostic accuracy for appendicitis. *World J Gastroenterol* 2014; 20: 13942–9. doi: https://doi.org/10.3748/wjg.v20.i38.13942

12. Kim HY, Park JH, Lee YJ, Lee SS, Jeon J-I, Lee KH. Systematic review and meta-analysis of CT features for differentiating complicated and uncomplicated appendicitis. *Radiology* 2018; 287: 104–15. doi: https://doi.org/10.1148/radiol.2017171260

13. Iacobellis F, Iaveduto I, Romano M, Alfiero M, Bhattacharjee B, Scaglione M. Perforated appendicitis: assessment with multidetector computed tomography. *Semin Ultrasound CT MR* 2016; 37: 31–6. doi: https://doi.org/10.1053/j.sult.2015.10.002

14. Fraser JD, Agyapoo P, Sharp SW, Snyder CL, Rivard DC, Cally BE, et al. Accuracy of computed tomography in predicting appendiceal perforation. *J Pediatr Surg* 2010; 45: 231–5. doi: https://doi.org/10.1016/j.jpedsurg.2009.10.040

15. Elbanna KY, Mohammed MF, Chahal T, Khosa F, Ali IT, Berger FH, et al. Dual-Energy CT in differentiating nonperforated gangrenous appendicitis from uncomplicated appendicitis. *AJR Am J Roentgenol* 2018; 211: 776–82. doi: https://doi.org/10.2214/AJR.17.19274

16. Livingston EH, Woodward WA, Sarosi GA, Haley RW. Disconnect between incidence of perirectal cellulitis and perforation in patients with acute appendicitis. *Ann Diagn Pathol* 2000; 4: 43–50. doi: https://doi.org/10.1053/adpa.2000.1215

17. Chaudhary P, Nabi I, Rosenthal D, Krausz MM, et al. Diagnostic and meta-analysis of randomised controlled trials. *BMJ* 2012; 344: e2156–2156. doi: https://doi.org/10.1136/bmj.e2156

18. Liu K, Fogg L. Use of antibiotics alone for treatment of uncomplicated acute appendicitis: a systematic review and meta-analysis. *Surgery* 2011; 150: 673–83. doi: https://doi.org/10.1016/j.surg.2011.08.018

19. Coccolini F, Fugazza P, Sartelli M, Cicutti E, Sibilla MG, Leandro G, et al. Conservative treatment of acute appendicitis. *Acta Biomed* 2018; 89(9-S): 119–34. doi: https://doi.org/10.23750/abm.v89i9-S.7905

20. van Dijk ST, van Dijk AH, Dijkgraaf MG, Boermeester MA. Meta-Analysis of inhospital delay before surgery as a risk factor for complications in patients with acute appendicitis. *Br J Surg* 2018; 105: 933–45. doi: https://doi.org/10.1002/bjs.10873

21. Gaitini D, Beck-Razi N, Mor-Yosef D, Fischer D, Ben Itzhak O, Krausz MM, et al. Diagnosing acute appendicitis in adults: accuracy of color Doppler sonography and MDCT compared with surgery and clinical follow-up. *AJR Am J Roentgenol* 2008; 190: 1300–6. doi: https://doi.org/10.2214/AJR.07.2955

22. Krajeski S, Brown J, Phang PT, Raval M, Brown CJ. Impact of computed tomography of the abdomen on clinical outcomes in patients with acute right lower quadrant pain: a meta-analysis. *Can J Surg* 2011; 54: 43–53. doi: https://doi.org/10.1503/cjs.023509

23. Horroks MM, White DS, Horrocks JC. Differentiation of perforated from nonperforated appendicitis at CT. *Radiology* 2003; 227: 46–51. doi: https://doi.org/10.1148/radiology.227200223
30. De Keulenaer BL, Regli A, Malbrain MLNG. Intra-Abdominal measurement techniques: is there anything new? *Am Surg* 2011; 77(Suppl 1): S17–22.

31. Goodpaster BH, Kelley DE, Thaete FL, He J, Ross R. Skeletal muscle attenuation determined by computed tomography is associated with skeletal muscle lipid content. *J Appl Physiol* 2000; 89: 104–10. doi: https://doi.org/10.1152/jappl.2000.89.1.104

32. Gaskill CE, Simianu VV, Carnell J, Hippe DS, Bhargava P, Flum DR, et al. Use of computed tomography to determine perforation in patients with acute appendicitis. *Curr Probl Diagn Radiol* 2018; 47: 6–9. doi: https://doi.org/10.1067/j.cpradiol.2016.12.002

33. El Hentour K, Millet I, Pages-Bouic E, Curros-Doyon F, Molinari N, Taourel P. How to differentiate acute pelvic inflammatory disease from acute appendicitis? A decision tree based on CT findings. *Eur Radiol* 2018; 28: 673–82. doi: https://doi.org/10.1007/s00330-017-5032-4

34. Kim S, Cho B, Lee H, Choi K, Hwang SS, Kim D, et al. Distribution of abdominal visceral and subcutaneous adipose tissue and metabolic syndrome in a Korean population. *Diabetes Care* 2011; 34: 504–6. doi: https://doi.org/10.2337/dc10-1364

35. Panicek DM, Giess CS, Schwartz LH. Qualitative assessment of liver for fatty infiltration on contrast-enhanced CT: is muscle a better standard of reference than spleen? *J Comput Assist Tomogr* 1997; 21: 699–705. doi: https://doi.org/10.1097/00004728-199709000-00004

36. Rössner S, Bo WJ, Hilibrandt E, Hinson W, Karstaedt N, Santiago P, WJ B, Crouse JR, et al. Adipose tissue determinations in cadavers—a comparison between cross-sectional planimetry and computed tomography. *Int J Obes* 1990; 14: 893–902.

37. Hainaux B, Agneessens E, Bertinotti R, De Maertelaer V, Rubesova E, Capelluto E, et al. Accuracy of MDCT in predicting site of gastrointestinal tract perforation. *AJR Am J Roentgenol* 2006; 187: 1179–83. doi: https://doi.org/10.2214/AJR.05.1179