Diagnostic role of multislice spiral computed tomography combined with clinical manifestations and laboratory tests in acute appendicitis subtypes

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ABSTRACT

The study aimed to investigate the diagnostic role of multislice spiral CT (MSCT) combined with clinical manifestations and laboratory tests in acute appendicitis subtypes. Patients diagnosed with acute appendicitis were included for retrospective analysis and their clinical manifestations and MSCT signs were analyzed. The clinical manifestations of different subtypes of acute appendicitis, including simple appendicitis, suppurative appendicitis and gangrenous appendicitis, were compared. The clinical manifestations were anorexia in 51.1% of patients, nausea and vomiting in 62.0%, shifting right lower abdominal pain in 51.1%, elevated body temperature in 31.2%, right lower quadrant abdominal tenderness in 91.4%, rebound tenderness in 91.4%, increased white cell count in 89.1%, high neutrophil count in 88.2%, increased appendiceal diameter enlargement in 100%, surrounding exudate in 95.0%, fecal stones in 51.6%, appendiceal wall thickening in 94.6%, lymph node in 82.8% and intestinal stasis in 18.6%. There were statistically significant differences in body temperature and neutrophil percentage among the subtypes of appendicitis and they were lowest in simple appendicitis and highest in gangrenous appendicitis. There were statistically significant differences in appendix diameter and the surrounding exudate among the subtypes of appendicitis and they were lowest in simple appendicitis and highest in gangrenous appendicitis. Clinical manifestations and MSCT signs, especially body temperature, percentage of neutrophils and the surrounding exudate, might have significant diagnostic value in acute appendicitis.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Multislice spiral CT (MSCT) has been increasingly used in the diagnosis of acute appendicitis as first-line imaging modality due to its wide availability and ability to rapidly identify lesion severity.

WHAT THIS STUDY ADDS

⇒ Body temperature, percentage of neutrophils, appendix diameter and exudation might be used to distinguish the subtypes of acute appendicitis.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Clinical manifestations, laboratory tests and MSCT signs, especially body temperature, percentage of neutrophils and the surrounding exudate, are of great significance in the diagnosis of acute appendicitis.

INTRODUCTION

Acute appendicitis is one of the most common abdominal diseases and usually requires surgical treatment. The histological/microscopy subtype of acute appendicitis determines whether emergency surgery is required, the type of surgical procedure to choose and the most appropriate perioperative treatment. Most of simple appendicitis and appendix abscesses can be cured by conservative treatment or elective surgery. However, regardless of the etiology of acute appendicitis, clinical severity stratification and surgical management decisions rely on preoperative assessment rather than postoperative histology. An effective preoperative assessment and risk stratification plan is essential during perioperative planning for both the surgeons and the patients. However, many patients can only be classified with ambiguous diagnostic criteria, resulting in acute appendicitis remaining one of the most challenging conundrums in acute abdomen management.

As we all know, in clinical practice, preoperative imaging assessment is very important to accurately identify the histological/microscopy subtype of acute appendicitis.[1–3] Multislice spiral CT (MSCT), as a simple, fast and accurate diagnostic approach, has been increasingly used in the diagnosis of acute appendicitis. For clinically referred patients with suspected appendicitis, MSCT is the first-line imaging modality due to its wide availability and ability to rapidly

identify lesion severity. The American College of Radiology recommends MSCT as the primary diagnostic method for adults with suspected appendicitis.[4] A study evaluating the relationship between negative appendectomy and MSCT showed that 86% of patients with acute appendicitis used MSCT for preoperative evaluation, which had a diagnostic sensitivity of 92.3%.[5] Another study[6] showed that MSCT had high sensitivity (91%, 95% CI 84% to 95%) and specificity (90%, 95% CI 85% to 94%) in the diagnosis of acute appendicitis and had higher diagnostic accuracy than ultrasound (sensitivity: 78%, 95% CI 67% to 86%; specificity: 83%, 95% CI 76% to 88%).

However, there is still a lack of research on the diagnostic value of MSCT in different types of acute appendicitis.[7–11] Weyant *et al*[9] reviewed a prospective large hospital database of 625 patients who underwent surgery for appendicitis and multivariate analysis of variance showed that none of the single variables used by radiologists to determine a positive CT scan was associated with the outcome of pathology testing. In addition to this, the correspondence and the degree of agreement between MSCT and the different types of acute appendicitis are not well explained. Selection and identification of patients through more precise clinical criteria may improve clinical outcomes. Therefore, this study intends to analyze the relationship between the pathological and clinical manifestations of acute appendicitis and MSCT signs through retrospective research so as to better guide clinical decision-making in acute appendicitis.

MATERIALS AND METHODS

Written informed consent was obtained from the participants or their guardians.

Patients

This retrospective analysis included a total of 221 patients with acute appendicitis based on surgical pathological findings. The patients' CT and surgical records were checked. They were admitted to our hospital from January 2013 to June 2015. During physical examination, parameters such as body temperature, anorexia, nausea, vomiting, metastatic right lower abdominal pain, abdominal tenderness, rebound tenderness, white cell count (WCC) and neutrophil percentage were recorded. Emergency physicians, including attending physicians and associate chief or chief physicians, performed the physical examination. All patients finished their MSCT examination within 6 hours before surgery and underwent exactly the same CT protocol.

The inclusion criteria were patients who underwent surgery and had complete clinical and surgical data. The exclusion criteria were patients who were treated non-operatively or did not have complete clinical data.

Classification of acute appendicitis based on surgical pathological results

Acute appendicitis was classified into simple appendicitis, suppurative appendicitis and gangrenous appendicitis based on the following postoperative pathological results:

- Simple appendicitis: a type of early appendicitis with the lesion mostly confined to the appendix mucosa or submucosa. The appendix is slightly swollen, the serosal surface has some bleeding spots and the normal luster is lost. One or more defects can be seen in the mucosal epithelium, with neutrophil infiltration and cellulose exudation. There is inflammatory edema in every layer of the submucosa.
- Suppurative appendicitis: often develops from simple appendicitis. This appendix is obviously swollen, the serosal surface is highly hyperemic and the surface is covered by fibrinous exudate. Inflammatory lesions can be seen under the microscope as fan-shaped, extending from the superficial layer to the deep layer, reaching the muscle layer and the serosal layer. Each layer of the appendix wall is diffusely infiltrated by a large number of neutrophils, with inflammatory edema and fibrin exudation. The serous membrane surface of the appendix is covered by a thin film composed of exuded cellulose and neutrophils, which is manifested as periappendicitis and localized peritonitis.
- Gangrenous appendicitis: a serious appendicitis where there is partial or complete necrosis of the wall of the appendix due to blood supply disorders. The necrotic part is dark red or purple black. Perforation is easy to occur and diffuse peritonitis is formed.

Imaging technique

CT examinations were carried out using a GE LightSpeed 16-slice spiral scanner. The following were the scanning parameters: tube current, 280 mA; tube voltage, 120 kV; thickness, 7.5 mm; layer, from 7.5 mm; collimation, 1.25 mm; matrix, 512×512; scan range, routine pelvic scan. Whether to expand the scanning range depended on the location of the ileocecal valve. CT plain scans were performed in all cases and images were reconstructed using AW4.3 workstation. First, the image was reconstructed as 1.25 mm thin-layer image, and then multiplanar reconstruction was performed to observe coronal and sagittal images. At the center of the ileocecum, conventional coronal or oblique coronal reconstruction showed the best coronal cross section of the appendix, with reconstruction thickness of 2 mm and distance of 2 mm.

Image analysis

Two associate chief or chief physicians both reviewed and discussed the CT images and a diagnosis was finally given. Patients were admitted to our hospital from January 2013 to June 2015. CT of the appendix was used to evaluate the appendix diameter, presence of extraluminal fluid collection around the appendix, cecal wall thickening, presence of appendicolith, presence of ileocecal lymph nodes and assessment of intestinal stasis (partial intestinal paralysis, and partial intestinal expansion and fluid accumulation). Intraluminal air and appendiceal fecalith were not used as observation indicators to diagnose appendicitis and the reason for which was that intraluminal air also exists in most normal appendixes and appendiceal fecalith also exists in some normal appendixes. Based on the pathological results, the classification of acute appendicitis of all patients was analyzed by an experienced pathologist.

Statistical analysis

Statistical analysis was performed using SPSS V.16.0. Variance analysis was used to explain differences in body

Figure 1 A man in his 60s with acute simple appendicitis. Axial located appendix (arrow) to lower the cecum. There is appendix thickening.

temperature, WCC, neutrophil count and appendix diameter among the different subtypes of acute appendicitis. χ^2 test was used to explain differences in anorexia, nausea, vomiting, abdominal tenderness, antimetastatic right lower abdominal pain and tenderness, vomiting, cecal wall thickening, exudation, ileocecal lymph nodes and intestinal stasis among the different subtypes of acute appendicitis. The sensitivity and specificity of these indicators were analyzed, and a receiver operating characteristic (ROC) curve was drawn to evaluate the accuracy of these indicators in distinguishing the subtypes of acute appendicitis. $P<0.05$ was considered statistically significant.

RESULTS

Of 221 cases, 132 were male and 89 were female, with an average age of 34.73±17.77 years (range 3–88 years old).

Pathological findings

A total of 221 patients with acute appendicitis were pathologically classified into 9 cases with simple appendicitis, 192 cases with suppurative appendicitis and 20 cases with gangrenous appendicitis. Of the patients, 14 experienced perforation of appendicitis, including 7 cases of suppurative appendicitis and 7 cases of gangrenous appendicitis (figures 1–3).

Clinical and laboratory results

All 221 patients had different degrees of abdominal pain; 113 (51.1%) cases had metastatic right lower abdominal pain, 113 (51.1%) had anorexia, and 137 (62.0%) had nausea and vomiting. Body temperature ranged from 36.0°C to 39.6°C, with an average of 37.09°C±0.82°C, with 69 (31.22%) cases above 37.3°C. There were 220 (99.5%) cases with right lower quadrant tenderness and 202 (91.4%) cases with rebound tenderness. WCC was $3–31\times10^9$/L, with an average of $15.03\pm4.67\times10^9$/L, and more than 10.0×10^9/L in 197 cases (89.1%). Neutrophil count ranged from 42.6% to 96.3%, with an average of 84.15%±54.04%, and more than 75% in 195 cases (88.2%) (tables 1 and 2).

Figure 2 A man in his 70s with acute suppurative appendicitis. Coronal reconstruction shows the appendix (arrow) with roots bezoar, diameter thickening, luminal hydrops, exudation and ileocecal wall thickening.

Identification of CT signs

Appendicolith was present in 114 (51.6%) patients. Appendix diameter was greater than 6.00 mm in all patients, ranging from 6.00 mm to 22.00 mm, with an average diameter of 12.30±2.76 mm. The appendix diameters in the different subtypes were 10.0±1.66 mm in simple appendicitis, 12.33±2.81 mm in suppurative appendicitis and 13.10±2.13 mm in gangrenous appendicitis (table 1). Cecal wall thickening was observed in 209 (94.6%) patients, appendix effusion in 210 (95.0%), ileocecal lymph node enlargement in 183 (82.8%) and intestinal stasis in 41 (18.6%) (table 3). Comparison of MSCT signs between pathological subtypes in table 3 suggests that only the surrounding exudate might imply severity of appendicitis. When the surrounding exudate was used

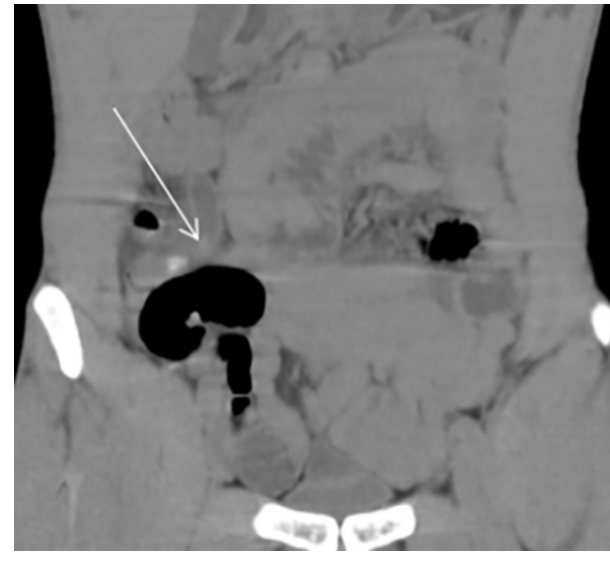

Figure 3 A man in his 30s with acute gangrenous appendicitis and perforation. Coronal reconstruction displays the appendix with roots bezoar, appendix thickening (arrow), increased density and surrounding inflammatory infiltration.

Table 1 Comparison of body temperature, percentage of neutrophils, appendix diameter and white cell count between pathological subtypes of appendicitis

Outcome measures			*F* value	P value
Body temperature	Simple	36.98±0.39	5.47	0.005
	Suppurative	37.03±0.79		
	Gangrenous	37.66±1.08		
N%	Simple	77.86±14.74	10.28	0.048
	Suppurative	88.31±57.83		
	Gangrenous	86.65±7.17		
WCC	Simple	12.35±4.48	1.928	0.148
	Suppurative	15.06±4.50		
	Gangrenous	15.99±5.98		
Appendix diameter	Simple	10.00±1.66	4.08	0.018
	Suppurative	12.33±2.81		
	Gangrenous	13.10±2.13		

With variance analysis between groups, p<0.05 was statistically significant.
N%, percentage of neutrophil; WCC, white cell count.

to distinguish non-simple appendicitis (suppurative and gangrenous appendicitis) from simple appendicitis in our study, the sensitivity and specificity were 0.972 and 0.556, respectively, which implied the surrounding exudate indeed had certain value in diagnosing non-simple appendicitis. When the surrounding exudate was used to distinguish gangrenous appendicitis from suppurative appendicitis in our study, the sensitivity and specificity were 0.95 and 0.026, respectively, which implied the surrounding exudate had very high rate of misdiagnosis between gangrenous appendicitis and suppurative appendicitis and could not be used to distinguish gangrenous appendicitis from suppurative appendicitis.

ROC curve analysis of some indicators

Except for binary variables, we had drawn the ROC curves for body temperature, percentage of neutrophils (N%), appendix diameter and WCC to evaluate their accuracy in distinguishing simple appendicitis from non-simple appendicitis (including suppurative and gangrenous) (online supplemental figure 1). They showed that body temperature had a cut-off value of 37.65°C, with a sensitivity of 0.231 and a specificity of 1, WCC had a cut-off value of 11.925×10^9/L, with a sensitivity of 0.774 and a specificity of 0.667, N% had a cut-off value of 77.95%, with a sensitivity of 0.844 and a specificity of 0.444, and appendix diameter had a cut-off value of 11.5 mm, with a sensitivity of 0.637 and a specificity of 0.889. We had also drawn the ROC curves for body temperature, N%, appendix diameter and WCC to evaluate their accuracy in distinguishing suppurative appendicitis from gangrenous appendicitis (online supplemental figure 2). They showed that body temperature had a cut-off value of 37.45°C, with a sensitivity of 0.6 and a specificity of 0.766, WCC had a cut-off value of 18.33×10^9/L, with a sensitivity of 0.45 and a specificity of 0.797, N% had a cut-off value of 85.45%, with a sensitivity of 0.7 and a specificity of 0.562, and appendix diameter had a cut-off value of 10.5 mm, with a sensitivity of 0.9 and a specificity of 0.271. These results suggest that in distinguishing simple appendicitis from non-simple appendicitis (including suppurative and gangrenous), WCC of 11.925×10^9/L, appendix diameter of 11.5 mm and body temperature of 37.45°C might have some clinical values, while they might not have any clinical value in distinguishing suppurative appendicitis from gangrenous appendicitis.

DISCUSSION

Clinical significance of MSCT in identifying different pathological subtypes of acute appendicitis

The incidence of acute appendicitis is 8% worldwide and emergency surgery is commonly required.[12] Over the past decade, with the widespread use of MSCT in preoperative examinations for suspected acute appendicitis, the accuracy in the diagnosis of acute appendicitis has continued to increase. More than 90% of cases of acute appendicitis are confirmed by MSCT, with an accuracy rate of 98%.[12 13] Progressive appendicitis is more likely to develop into perforated appendicitis or appendiceal abscess and so emergency surgery is required. There are differences in treatment strategies of the different subtypes of acute appendicitis.[11 14 15] Acute simple appendicitis can usually be treated conservatively, but some patients require surgical treatment.[2 16] Therefore, use of MSCT in effectively discriminating the different subtypes of acute appendicitis has important clinical significance.

Clinical value of CT findings in distinguishing different subtypes of acute appendicitis

Increased appendix diameter, exudation, cecal wall thickening, bezoar appendix, ileocecal lymph node enlargement and intestinal stasis are very specific signs of acute appendicitis. The incidence of increased appendix diameter, peripheral exudation and cecal wall thickening is

Table 2 Comparison of anorexia, vomiting, abdominal tenderness, metastatic right lower abdominal pain and rebound between pathological subtypes of appendicitis

Group	Cases	Anorexia		Vomiting		Abdominal tenderness		Metastatic right lower abdominal pain		Rebound	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Simple	9	3 (2.7)	6 (5.6)	3 (2.2)	6 (7.1)	9 (4.1)	0 (0)	4 (3.5)	5 (4.6)	8 (4.0)	3 (2.7)
Suppurative	192	101 (89.4)	91 (84.3)	120 (87.6)	72 (85.7)	192 (87.3)	0 (0)	99 (87.6)	93 (86.1)	177 (87.6)	101 (89.4)
Gangrenous	20	9 (8.0)	11 (10.2)	14 (10.2)	6 (7.1)	19 (8.6)	1 (100.0)	10 (9.0)	10 (9.3)	17 (8.4)	9 (8.0)
χ^2			1.589		3.521		6.882		0.256		
P value			>0.05		>0.05		>0.05		>0.05		

Using χ^2 test, p<0.05 was statistically significant.

Table 3 Comparison of bezoar appendix, cecal wall thickening, surrounding exudate and ileocecal lymph node between pathological subtypes of appendicitis

Outcome measures	Bezoar appendix		Cecal wall thickening		Surrounding exudate		Ileocecal lymph node	
	Yes	No	Yes	No	Yes	No	Yes	No
Simple, n (%)	5 (4.4)	4 (3.7)	9 (4.3)	0 (0.00)	4 (1.9)	5 (45.5)	9 (4.9)	0 (0.0)
Suppurative, n (%)	95 (83.3)	97 (90.7)	181 (86.6)	11 (91.7)	187 (89.0)	5 (45.5)	157 (85.8)	35 (92.1)
Gangrenous, n (%)	14 (12.3)	6 (5.6)	19 (9.1)	1 (8.3)	19 (9.0)	1 (9.1)	17 (9.3)	3 (7.9)
χ^2		3.12		0.12		22.07		1.42
P value		0.21		1.00		0.00		0.53

Using χ^2 test, $p<0.05$ was statistically significant.

over 95%, followed by ileocecal lymph node enlargement, bezoar appendix and intestinal stasis. Our findings suggest that spiral CT signs of acute appendicitis were similar to the results of the study of Wu and Lim,[17] which indicated that increased appendix diameter, appendiceal wall thickening, strengthen of the appendix wall and exudation around the appendix were the four most common signs of acute appendicitis. The results of this study showed that increased appendix diameter and exudation around the appendix were more meaningful than the other signs. Appendix diameter refers to the maximum outer diameter of the appendix, and increased appendix diameter is a direct sign of acute appendicitis. In our study, simple appendicitis has the lowest average appendix diameter and gangrenous appendicitis has the highest, which was similar to the results of Müller *et al*,[7] which suggested that, in these three types of acute appendicitis, the higher the increase in appendix diameter the higher the occurrence of perforated appendix. In addition, enlargement of the appendix was related to the progress of the disease, and the course of the disease was positively correlated with increased diameter, which was consistent with transition from simple appendicitis to suppurative and gangrenous appendicitis. Appendix enlargement, to a certain extent, might increase the risk of perforation of the appendix and thus effective treatment such as surgery is required. Acute exudation around the appendix might suggest appendicitis and inflammatory infiltration to the surrounding tissue.

Clinical value of related clinical manifestations and laboratory tests in distinguishing different subtypes of acute appendicitis

Our data showed that 51.1% of patients had anorexia, 62.0% had nausea and vomiting, 51.1% had metastatic right lower abdominal pain, 31.2% had fever, 91.4% had right lower quadrant tenderness and 91.4% had rebound tenderness. There was an increase in the number of leukocytes in 89.1% of patients and an increase in the percentage of neutrophils in 88.2% of patients. Except for fever, the incidence of the other clinical symptoms was more than 50%, indicating that these clinical manifestations and laboratory findings were common characteristics of acute appendicitis. In the differential diagnosis of acute appendicitis, the percentages of neutrophils in the different subtypes in our study were different ($p<0.05$). Simple appendicitis had the lowest percentage of neutrophils, while gangrenous appendicitis had the highest percentage. There was no significant difference in WCC among the subtypes ($p>0.05$). Zhao and Yin[18] believed that WCC might reflect the degree of appendicitis. Şahbaz *et al*[19] conducted further research on leukocyte classification and suggested that the percentage of lymphocytes had a more important impact on the classification and perforation of reactive acute appendicitis. The difference between these studies and our study might be due to the small number of samples of simple and gangrenous appendicitis in our study. Differences in body temperature ($p<0.05$) among the three subtypes showed that the body temperature of patients with simple appendicitis was close to normal while those with gangrenous appendicitis had a high fever, which might result from the development of gangrene, resulting in a large amount of toxins being released into the blood.

There are some limitations to our study and the details are as follows:

1. our study has a small number of samples and cases of simple and gangrenous subtypes were largely less than those of purulent subtypes;
2. history was collected by residents and therefore subjective bias might exist;
3. all cases were confirmed by surgery and we excluded simple cases and abscess formation undergoing conservative treatment alone and inoperable cases of suppurative or gangrenous appendicitis; and
4. prognostic and follow-up data after surgery were not collected for analysis so it is impossible to discuss whether subtypes of appendicitis are associated with longer hospital stays or higher morbidity and mortality. Therefore, in the future, we will employ a large sample size with almost the same number and proportion of the three types of appendicitis and follow-up data for further analysis, and summarize and analyze the data of conservatively treated group at a certain time in the future to better compare the clinical presentation of these patients and their CT findings with those who underwent surgery.

CONCLUSION

In conclusion, clinical manifestations, laboratory tests and MSCT signs are of great significance in the diagnosis of acute appendicitis. Body temperature, percentage of neutrophils, appendix diameter and exudation might be used to distinguish the subtypes of acute appendicitis. Anorexia, vomiting, abdominal tenderness, metastatic right lower abdominal pain, WCC, bezoar appendix, cecal wall thickening, ileocecal lymph node enlargement and intestinal stasis are helpful in the diagnosis of

acute appendicitis, but of little significance to distinguish different subtypes.

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Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study involves human participants and was conducted in accordance with the Declaration of Helsinki. This study was conducted with approval from the Ethics Committee of the People's Hospital of Qingyuan City (approval no: 20121210). Written informed consent was obtained from the participants or their guardians. Participants gave informed consent to participate in the study before taking part.

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