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Diagnostic value of abdominal ultrasound in patients with acute appendicitis and analysis of the expression of related inflammatory factors.

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Keywords: acute appendicitis; abdominal ultrasound; inflammatory factors; fuzzy appendiceal border; ultrasound signs.

Abstract. Appendicitis is an inflammation of the appendix that, if left untreated, can be life-threatening. Abdominal ultrasound helps diagnose it and differentiate it from other causes of abdominal pain. This study aimed to evaluate the diagnostic value of abdominal ultrasound in acute appendicitis (AA) and assess inflammatory factor levels in different types of appendicitis. One hundred patients with AA were selected as the observation group, and 30 patients with simple abdominal pain as the control group. Among the 100 AA patients, 37 (37%) cases had blurred appendiceal boundaries, 24 (24%) cases had fecal calculus in the appendix cavity, 13 (13%) cases had enhanced echo intensity of surrounding fat, 15 (15%) cases presented enlarged outer diameter of the appendix (> 6mm), one (1%) case had peripheral lymphadenopathy, and one (1%) case had peripheral effusion. None of the cases (0%) presented a peripheral mass. The levels of white blood cells (WBC) and inflammatory factors: C-reactive protein (CRP), interleukin-6 (IL-6), and tumor necrosis factor α (TNF-α)) patients with uncomplicated appendicitis were lower than those with suppurative appendicitis, gangrenous appendicitis, or peri-appendiceal abscess (p <0.05). The blurred boundary of the appendix, fecal stones in the appendix cavity, an enlarged outer diameter of the appendix (> 6mm), and an enhanced echogenicity of the surrounding fat are the most common ultrasonic signs of AA. Abdominal ultrasound has an excellent diagnostic value on pathological types of AA. The increase in the level of inflammatory factors can indicate the severity of the disease to a certain extent.

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Valor diagnóstico de la ecografía abdominal en pacientes con apendicitis aguda y análisis de la expresión de factores inflamatorios relacionados.

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Palabras clave: apendicitis aguda; ultrasonido abdominal; factores inflamatorios; limites apendiculares borrosos; signos de ultrasonido.

Resumen. La apendicitis es la inflamación del apéndice, que si no es tratada puede poner en peligro la vida. La ecografía abdominal ayuda a diagnosticarla y diferenciarla de otras causas de dolor abdominal. Este estudio tuvo como objetivo evaluar el valor diagnóstico de la ecografía abdominal en la apendicitis aguda (AA) y evaluar los niveles de factores inflamatorios en diferentes tipos de apendicitis. Se seleccionaron 100 pacientes con AA como grupo de observación y 30 pacientes con dolor abdominal simple como grupo control. Entre los 100 pacientes con AA, 37 (37%) casos tenían límites apendiculares borrosos, 24 (24%) casos tenían cálculos fecales en la cavidad del apéndice, 13 (13%) casos tenían aumento de la ecogenicidad de la grasa circundante, 15 (15%) casos presentaron agrandamiento del diámetro exterior del apéndice (> 6 mm), 1 (1%) caso tenía adenopatías periféricas y 1 (1%) caso tenía derrame periférico. Ninguno de los casos (0%) presentó una masa periférica. Los niveles de glóbulos blancos (WBC) y factores inflamatorios como proteína C reactiva (CRP), interleucina-6 (IL-6) y factor de necrosis tumoral α (TNF-α)) en pacientes con apendicitis no complicada, fueron más bajos en comparación con pacientes con apendicitis supurativa, apendicitis gangrenosa o absceso peri apendicular ($p < 0,05$). El límite borroso del apéndice, los cálculos fecales en la cavidad del apéndice, un diámetro externo agrandado del apéndice (> 6 mm) y un aumento de la ecogenicidad de la grasa circundante son los signos ultrasónicos más comunes de AA. La ecografía abdominal tiene un buen valor diagnóstico en los tipos patológicos de AA. El aumento en el nivel de factores inflamatorios puede indicar la gravedad de la enfermedad hasta cierto punto.

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INTRODUCTION

Appendicitis is usually caused by a bacterial infection in the lumen of the appendix, especially when the appendix is blocked; bacteria can multiply inside the appendix, causing inflammation and infection [1-4]. If left untreated, the inflammation may spread to tissues and organs around the appendix, leading to peritonitis and other infections [5]. In addition, infection in the appendix may accumulate pus, forming an appendiceal abscess. The exact etiology of appendicitis is not fully understood, but it is generally thought to result from obstruction and infection [6,7]. Obstruction in the lumen of the appendix is one of the most common causes, and solid feces, tumors, lymphoid tissue hypertrophy, foreign bodies, or parasites may cause this obstruction [8]. Appendicitis can

affect people of any age, and there is no significant difference in the incidence between men and women. Therefore, AA should be diagnosed and treated as early as possible, and once suspected symptoms appear (such as right lower abdominal pain, fever, nausea, vomiting, and loss of appetite), people should seek medical attention to avoid potential complications and harm [9,10].

There are many methods for the clinical diagnosis of appendicitis, including symptom assessment and physical examination (including light palpation, tenderness, and rebound pain; in the early stages of appendicitis, where the tender point is in the right lower quadrant of the abdomen, muscle tension and tender reactions may occur). The medical history and symptoms help the doctor initially to judge the possibility of appendicitis [11–14]. Blood cell count (WBC) is usually elevated, and the C-reactive protein (CRP) levels, an abdominal CT scan can be performed in complex or ambiguous cases with suspected appendicitis, and imaging examination [15, 16].

Abdominal ultrasound is a non-invasive and non-radiation medical examination method used to evaluate the structure and function of internal organs in the abdomen, which has the advantages of safety and non-invasive nature [17]. In the diagnosis of appendicitis, abdominal ultrasound is often used to check the status of the appendix, which can help identify other possible causes of abdominal pain and check the location and size of the appendix.

This research highlights the ultrasonic indicators and inflammatory markers linked to appendicitis. Therefore, it was necessary to conduct this study to investigate the ultrasonic signs and inflammatory markers related to acute appendicitis.

MATERIALS AND METHODS

Study subjects

One hundred AA patients who underwent surgical treatment in the Fujian Provincial Hospital from September 1, 2019, to February 28, 2023, were enrolled, including 47 males and 53 females, aged 3-73 years old, and were set as the observation group. Thirty patients with simple abdominal pain admitted during the same period were enrolled as the control group.

All subjects agreed to sign an informed consent form with the approval of their family members. Authorization for the trial's conduct was obtained from the Hospital Ethics Society.

Inclusion criteria: (1) clinical diagnosis of AA; (2) patients with different degrees of abdominal pain; (3) under indication of appendicitis surgery; (4) patients had complete clinical data.

Exclusion criteria consisted of patients with (1) acute parenchymal organ rupture, (2) mental diseases, (3) severe coagulopathy, (4) acquired immunodeficiency syndrome, (5) pregnant or lactating women, and (6) patients who did not cooperate with the trial.

Abdominal ultrasound examination methods

Abdominal ultrasound examinations were performed using a Philips iU22 ultrasound system with a 5-2 MHz curved array transducer. With the patient in the supine position, an ultrasound scanner using a convex array probe was used to scan from the ascending colon to the cecum, focusing on the site of pain. The direct and indirect signs of appendicitis were recorded. The gallbladder, bile duct, right kidney, and right ureter were routinely examined before exploring the appendix. The right pelvic cavity was examined in women.

Direct ultrasound signs included a hypoechoic mass with a finger shape, a target ring sign, dilatation and effusion of the appendiceal lumen, hyperechoic with acoustic shadow in the lumen, and irregular hypoechoic mass. Indirect ultrasonographic signs mainly included effusion around the appendix.

Blood collection and examination

Peripheral venous blood (5mL) was collected from all patients within three hours of admission. A routine blood examination was performed using a Siemens ADVIA® 2120i hematology analyzer. CRP was measured by rate nephelometry. WBC with blood routine examination The serum levels of interleukin-6 (IL-6) and tumor necrosis factor (TNF-α) were detected by enzyme-linked immunosorbent assays.

Observation indicators

The examination results calculated the incidence of symptoms, positive signs, and ultrasound signs in patients with appendicitis. The occurrence rates of blurred appendiceal boundaries, fecal calculus in the appendiceal cavity, enhanced peripheral omentum echo, peripheral mass formation, peripheral lymph node enlargement, and peripheral effusion in ultrasound signs were counted. The types of appendicitis were recorded as uncomplicated, suppurative, gangrenous, peri-appendiceal abscess.

Statistical methods

The IBM® SPSS19.0 statistical software was employed for data analysis. Measurement data were expressed as means ± standard deviations ($\bar{x}\pm SD$), and count data were expressed as percentages (%). Repeated measurement analysis of variance was adopted for inter-group comparison, and two-way analysis of variance was adopted for intra-group comparison. $p < 0.05$ was considered statistically significant for two-sided tests.

RESULTS

Comparison of patient's primary data

As illustrated in Fig. 1, there were 47 males and 53 females with a mean age of 32.52±17.5 years in the observation group and 18 males and 12 females with a mean age of 35.64±11.33 years in the control group. There was no significant difference in the number of males and females and the mean age between the two groups ($p > 0.05$).

Ultrasound signs

As displayed in Fig. 2, among the 100 AA patients, ultrasound images showed 37 (37%) cases with blurred appendiceal boundaries, 24 (24%) cases with fecal stones in the appendiceal cavity, 15 (15%) cases with enlarged outer diameter of the appendix (> 6mm), 13 (13%) cases with an enhanced echo of surrounding fat, 1 (1%) case with peripheral lymphadenopathy, 1 (1%) case with peripheral effusion and 9 (9%) cases with no signs.

Fig. 3 shows the ultrasound data of a female patient in the right lower abdominal cavity (appendix area). A cord-like hypoechoic wall was detected in the right lower abdominal cavity; the widest diameter was about 7.9 mm, the boundary was still clear, the shape was tortuous, and the transverse section was a "target ring sign".

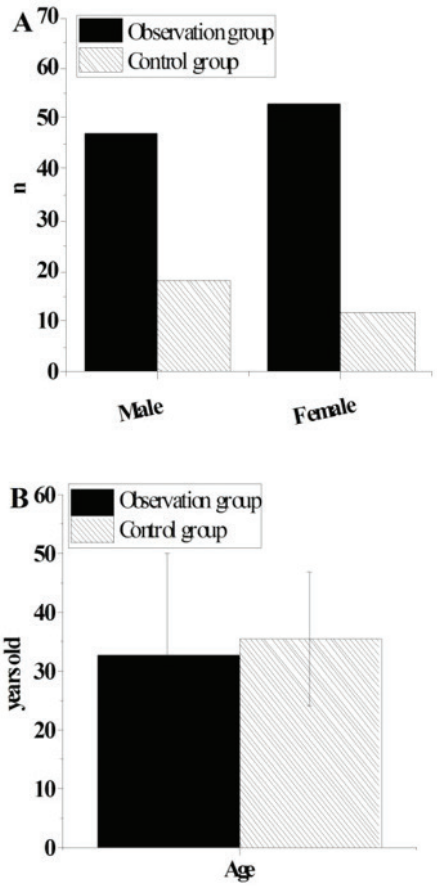

Fig. 1. Comparison of patients' primary data. (A: number of males and females; B: age).

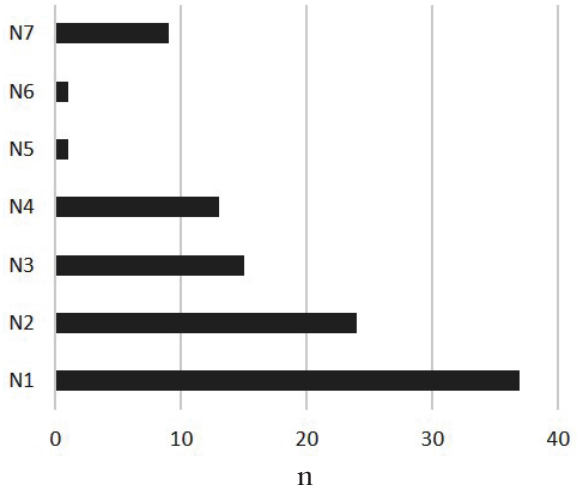

Fig. 2. Ultrasound of AA patients. N1-N6: blurred appendiceal boundaries (N1), fecal stone in the appendiceal cavity (N2), enlarged outer diameter of the appendix (N3), enhanced echo of surrounding fat (N4), peripheral lymphadenopathy (N5), peripheral effusion (N6), no signs (N7).

There was a hypoechoic wall in the periphery, with poor sound transmission in the liquid dark area inside, and no evident hyperechoic area was found in the cavity. On one side of the cavity, there was a blind end, and the other side seemed to extend with the cecum. No obvious peristalsis was observed for several minutes, and the shape and size did not change significantly. After the probe was pressurized, the tenderness was apparent. The Color Doppler flow imaging showed small punctate blood flow signals on the peripheral hypoechoic wall.

Fig. 4 indicates the ultrasound data of a female patient's right lower abdominal cavity (appendix region); the abdominal wall was thick, and abdominal muscles were tense in the patient. A strip of the hypoechoic image extending inward and downward, about 13mm in width, and high echo (about 9mm × 6mm in size) could be observed in the right lower abdominal ileocecal region. The end wall of the strip was not clearly displayed, and a heterogeneous, irregular hypoechoic mass with an area of about 72mm×35mm was observed downward, with a little blood flow signal around it. A slightly hyperechoic wrapping (omental echo) was observed around it. A dark fluid area in the pelvic cavity, about 39mm deep, with acceptable sound transmission was present.

Fig. 5 presents the ultrasound data of a male patient in the right lower abdominal cavity (appendix area). A cord-like hypoechoic area was detected in the right lower abdominal cavity, with the broadest inner diameter of about 8mm, a clear boundary, a tortuous shape, and a "target ring sign"

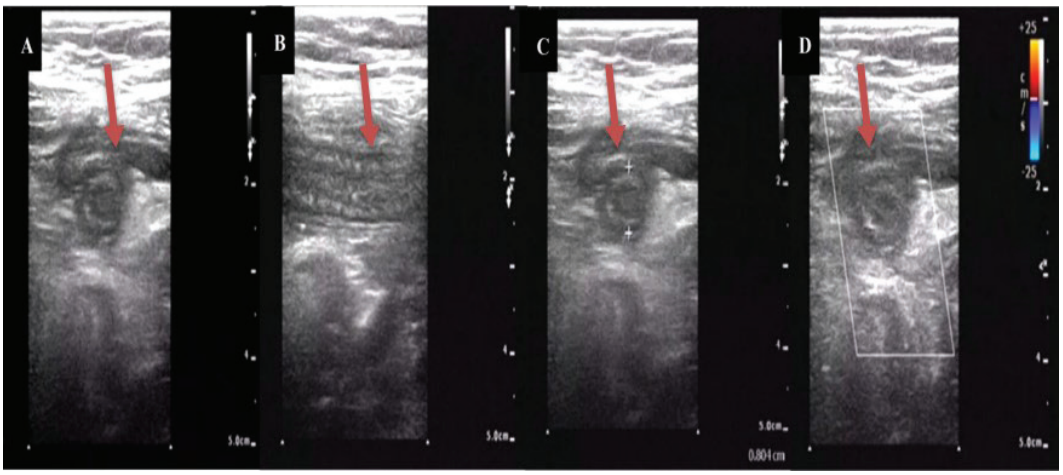

Fig. 3. Ultrasound data of the right lower abdominal cavity (appendiceal region) in a 35 years old female patient. Cord-like hypoechoic wall was (A, B), hypoechoic wall in the periphery (C), side of the cavity (D).
Note: A-C is 2D ultrasound; D is color Doppler flow imaging.

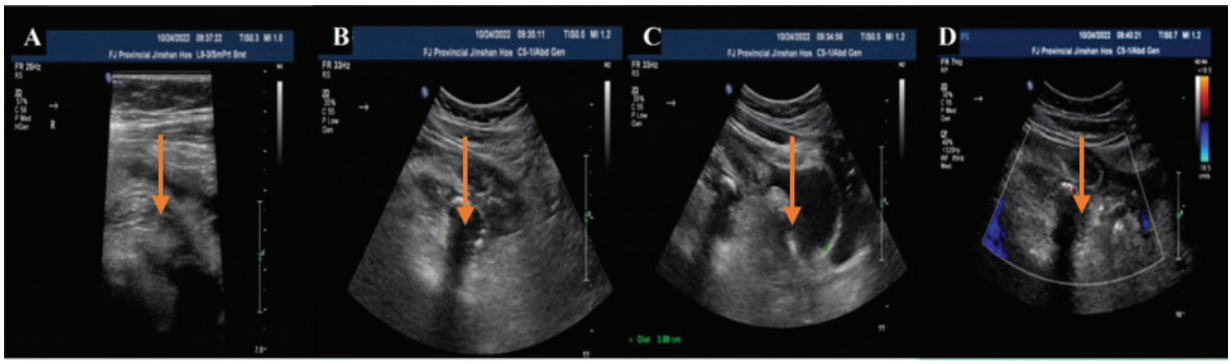

Fig. 4. Ultrasound data of a nine-year-old female patient's right lower abdominal cavity (appendiceal region). Hypoechoic image inward and downward (A), irregular hypoechoic mass (B), wrapping (omental echo) (C), pelvic cavity (D).
Note: A-C is 2D ultrasound; D is color Doppler flow imaging.

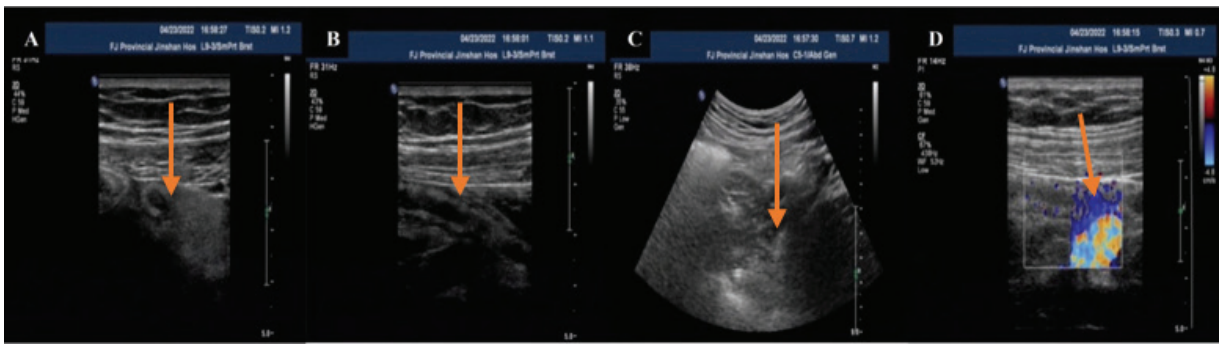

Fig. 5. Ultrasound data of the right lower abdominal cavity (appendiceal region) of a 31-year-old male patient. Cord-like hypoechoic (A, B), target ring sign (C, D).
Note: A-C is 2D ultrasound; D is a color Doppler flow imaging.

in the transverse section. A liquid dark area with poor sound transmission surrounded the hypoechoic wall. One side was the blind end, and the other seemed to continue with the cecum. No obvious peristalsis was observed for several minutes, and the shape and size did not change significantly. After the probe was pressurized, tenderness was evident. Color Doppler flow imaging showed small blood flow signals on the peripheral hypoechoic wall.

Ultrasound diagnosis results

As displayed in Fig. 6, among the 100 AA patients, there were 31 cases of uncomplicated appendicitis, 40 cases of suppurative appendicitis, 21 cases of gangrenous appendicitis, and eight cases of peri-appendiceal abscess.

Comparison of inflammatory factor levels in different types of patients

Fig. 7 indicates the levels of WBC, CRP, IL-6, and TNF-α in patients with uncomplicated appendicitis were lower when compared to those of patients with suppurative appendicitis, gangrenous appendicitis, or peri-appendiceal abscess (p <0.05). The levels of WBC, CRP, IL-6, and TNF-α in patients with peri-appendiceal abscess were higher against patients with suppurative appendicitis, gangrenous appendicitis, or peri-appendiceal abscess (p <0.05).

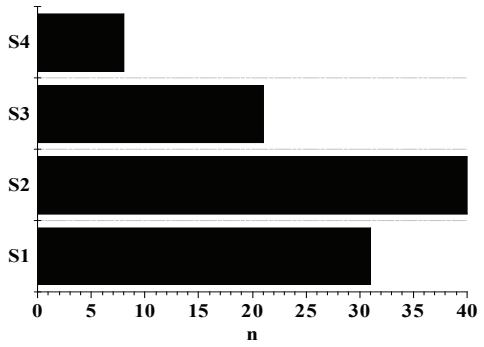

Fig. 6. Ultrasound diagnosis results.
S1: uncomplicated appendicitis, S2: suppurative appendicitis, S3: gangrenous appendicitis, S4: peri-appendiceal abscess.

Comparison of inflammatory factor levels in patients

The inflammatory factor levels in patients are presented in Table 1. The levels of WBC, CRP, IL-6, and TNF-α in the observation group were higher compared to the control group (p <0.05).

DISCUSSION

AA is a common disease in surgery, ranking first in all kinds of acute abdomen causes. AA can occur at any age but is more common in adolescents. Uncomplicated appendicitis often presents with paroxysmal or

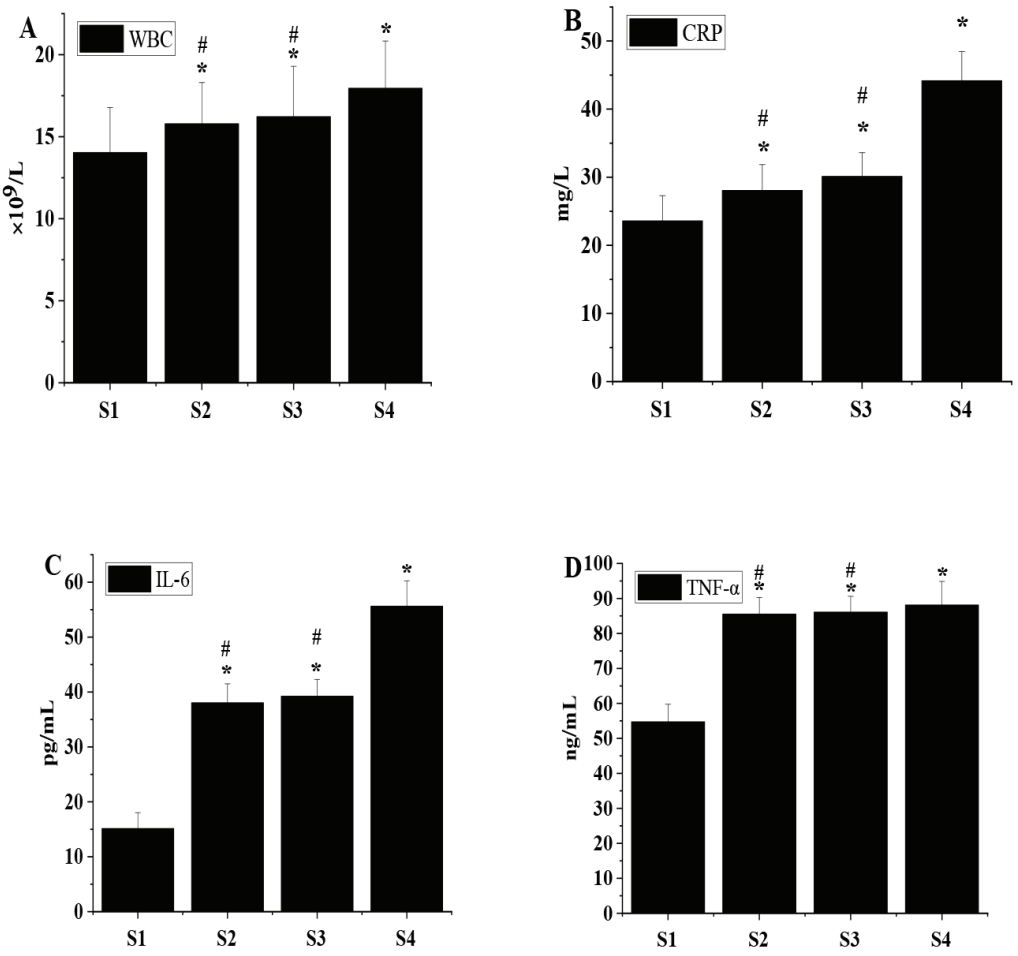

Fig. 7. Comparison of inflammatory factors levels. (S1-S4: uncomplicated appendicitis, suppurative appendicitis, gangrenous appendicitis, peri-appendiceal abscess).
* indicates p <0.05 compared to patients with simple appendicitis; # indicates p <0.05 when compared to patients with periappendiceal abscess.

Table 1
Inflammatory factor levels in patients.

Factor	Observation Group	Control Group	p*
WBC ($\times 10^9$L)	16.81±3.22**	10.57±1.25	<0.05
CRP (mg/L)	30.14±4.55	10.96±3.08	<0.05
IL-6 (pg/mL)	24.71±6.02	5.24±0.92	<0.05
TNF-α (ng/mL)	57.43±5.81	30.71±4.21	<0.05

* t-test, ** (mean ± SD).

persistent dull pain; persistent severe pain often suggests suppurative or gangrenous appendicitis [18–20]. Persistent severe pain involving the middle and lower abdomen or both sides of the lower abdomen is often a sign of gangrenous perforation of the appendix. Sometimes, the abdominal pain diminishes, but this phenomenon of pain relief is temporary, and other accompanying symptoms and signs do not improve or even worsen [21]. Therefore, the early diagnosis of AA is of great clinical significance.

One hundred patients who would undergo elective laparoscopic surgery in the Fujian Provincial Hospital from September 1, 2019, to February 28, 2023, as the observation group, and 30 patients with simple abdominal pain who were admitted during the same period were considered as the control group. First, the primary data of the two groups were compared, and the number of males and females and the average age of the observation group were not statistically significant relative to the control group ($p>0.05$). According to ultrasound signs, among 100 AA patients, there were 37 cases (37%) with blurred appendiceal boundaries, 24 cases (24%) with fecal stones in the appendiceal cavity, 15 cases (15%) with enlarged outer diameter of the appendix (> 6mm), 13 cases (13%) with an enhanced echo of surrounding fat, 1 case (1%) with peripheral lymphadenopathy, 1 case (1%) with peripheral effusion, and 0 cases (0%) with peripheral mass formation. This suggests that most AA patients present direct ultrasound signs, and the most common ultrasound signs are blurred appendiceal boundaries, fecal stones in the appendiceal cavity, and peripheral omental echo enhancement. The results of the ultrasound diagnosis were further analyzed. Among 100 AA patients, there were 31 cases of uncomplicated appendicitis, 40 cases of suppurative appendicitis, 21 cases of gangrenous appendicitis, and eight cases of an appendiceal abscess. These results are similar to those reported by Ravichandran *et al.* [22], indicating that ultrasound represents a particularly useful diagnostic tool for AA pathological types and has an excellent clinical application value [23,24]. In the present article, we also collected the peripheral venous blood of the patients for the detection of inflammatory factors and found that the levels of WBC, CRP, IL-6, and TNF-α in the observation group were higher than those of the control group ($p<0.05$). Inflammatory factors are molecular signaling substances involved in the inflammatory response [25]. These results suggest that the increased levels of inflammatory factors are related to the occurrence of AA. We further compared the levels of inflammatory factors in patients with different types of AA and found that the levels of WBC, CRP, IL-6, and TNF-α in patients with uncomplicated appendicitis were lower in contrast to patients with suppurative appendicitis, gangrenous appendicitis, or peri-appendiceal abscess ($p<0.05$).

One hundred AA patients were enrolled, and 30 patients presenting simple abdominal pain were considered as the control group. The results revealed that the most common ultrasonic signs were the blurred boundary of the appendix, fecal stones in the appendix cavity, an enlarged outer diameter of the appendix (>6mm), and enhanced echogenicity of surrounding fat. The ultrasonic diagnosis of AA pathological types was good and had an excellent clinical application value. With the aggravation of AA, the levels of inflammatory factors also increase, therefore, they can indicate the severity of the patient's condition to a certain extent. However, the sample size of patients included in the present work is rela-

tively small, and all of the patients came from the same source, which may have had some influence on the results. In the process of the ultrasound examination, because the appendix is a blind tube-like structure and the position is not fixed, the congestion and swelling of acute uncomplicated appendicitis are mild, and the typical structure changes may not be apparent. Therefore, in future studies, more AA cases will be selected to explore further the diagnostic value of the ultrasound imaging technology in AA. In conclusion, this result provides a reference for the assessment of AA.

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Conflict of competence

The authors declare no conflict of interest.

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Contributions of authors

SY played a key role in data collection and analysis, MW contributed significantly to the literature review and research design, LY provided expertise in statistical analysis and data interpretation, and NL made substantial contributions to the manuscript's drafting and critical revisions. All authors actively collaborated throughout the research process and reviewed the final manuscript to ensure its accuracy and quality.

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