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Original Article

Diagnostic value of ultrasound compared to CT in patients with suspected acute appendicitis

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Abstract: Objective: The aim of this study was to evaluate the diagnostic efficacy of ultrasound compared to CT in patients with suspected acute appendicitis, thereby reducing unnecessary CT examinations and associated radiation exposure. Methods: A total of 108 patients who underwent ultrasound and/or CT examinations for suspected acute appendicitis were enrolled in this study from February 2014 to August 2015 at our hospital. The ultrasound, CT and pathological records were retrospectively analyzed to evaluate the diagnostic efficacy of the two imaging modalities on acute appendicitis. Results: The sensitivity, specificity, positive predictive value, negative predictive value and accuracy on the diagnosis of acute appendicitis was 85.5%, 66.7%, 98.5%, 15.4% and 84.8% with ultrasound and 87.8%, 75.0%, 97.7%, 33.3% and 86.8% with CT, respectively. Among these patients, there were 24 cases imaged with both modalities, the analysis showed that AUC of ultrasound was larger than that of CT, while the difference was not statistically significant. For thickened appendix, the display rate of ultrasound was 63.5%, which was significantly higher than that of CT (31.9%) (P=0.001). For enlarged appendix, the display rates of ultrasound and CT were similar (82.4% and 93.6%, respectively). Additionally, for different pathological types of appendicitis, the detective rates for ultrasound and CT were as follows: 81.8% and 60.0% for acute simple appendicitis, 86.0% and 92.6% for acute purulent appendicitis, 90.9% and 100% for acute gangrenous appendicitis, while no significant difference was found between the two imaging modalities. Conclusion: Ultrasound should be used as the first-line imaging modality for diagnosing acute appendicitis, and complementary CT may be performed if inconclusive acute appendicitis is indicated.

Keywords: Acute appendicitis, ultrasound, CT, diagnostic efficacy

Introduction

Acute appendicitis (AA) is the most common acute abdominal condition worldwide [1]. On most occasions, a surgery is needed, especially for AA with perforation, because it is associated with significant morbidity and an increase in mortality. Thus far, the clinical diagnosis of AA remains a challenge to emergency physicians and surgeons both in the pediatric and adult populations, as the symptoms are often atypical and overlapped with various other diseases [2, 3]. In recent years, improvements in clinical and laboratory diagnosis have been achieved. What's more, several scoring systems have been developed to guide clinical decision-making, however, the fundamental decision of whether to operate or not remains difficult [4].

The accurate diagnosis of AA depends on both clinical presentations and imaging techniques. Since the first report on ultrasound (US) in 1986, imaging methods have been rapidly and now widely applied in the diagnostic armamentarium for AA [5]. To date, US and computed tomography (CT) remain the most common used diagnostic imaging, and CT is considered the gold standard technique to evaluate patients with suspected AA, because of its high sensitivity and specificity [2, 3]. While the associated radiation exposure remains a concern, especially, among children, the elderly and pregnant women, as radiation protection is of major importance [2, 3, 6, 7]. Over recent years, research on various aspects of US imaging in the diagnosis of AA has gained major importance due to its radiation protection, broad

availability and cost-effectiveness [7]. Therefore, US may be valuable as an initial imaging choice for patients with suspected AA or with equivocal clinical presentations [8-10]. Several previous studies have evaluated the diagnostic value of US compared to CT in patients with suspected AA, while the results remain inconclusive [11-14]. What's more, the diagnostic efficacy of the two modalities on different pathological types of AA has not been well elucidated.

In the current report, a total of 108 patients who underwent US or/and CT examinations for suspected AA were enrolled from February 2014 to August 2015 at our hospital. The US, CT and pathological records were respectively reviewed and analyzed to evaluate the diagnostic efficacy of the two imaging modalities. Our findings will provide important information for suitable imaging choice, which will not only improve the diagnostic accuracy of AA, but also reduce unnecessary CT examinations and associated radiation exposure.

Materials and methods

Subjects

A total of 108 patients who underwent US and/or CT examinations for suspected AA were enrolled in this study during the period from February 2014 to August 2015 at our hospital. The medical and imaging records were retrospectively reviewed. Abdominal pain was the primary presenting complaint, and the pain often initiated around the center of abdomen, and then migrated to the right lower abdomen. Other classical presentations included the leukocytosis and fever, etc. US was performed in 79 patients, CT in 53 patients, and both in 24 patients prior to surgery. All the patients enrolled in this study underwent an operation for treatment and recovered without a second surgery. Among all 108 patients, there were 101 (male: 54 cases, female: 47 cases, mean age 42.7 years with range from 6 to 81 years) with pathology-proven AA, and other 7 patients (male: 4 cases, female: 3 cases, mean age 48.7 years with range from 13 to 79 years) were pathologically diagnosed with chronic appendicitis (5 cases), distal ileitis (1 case) and appendix benign tumor (1 case).

This study was approved by the institutional review board. Patient data collection and storage were HIPAA compliant. Written informed consent was waived because it was a retrospective study.

Imaging techniques

US was performed on a ultrasound equipment (LOGIQ E9, GE Healthcare, Cambridge, UK) with a low frequency convex array probe (2-5 MHz) and a high frequency linear array probe (6-15 MHz). Patients were placed in a supine position, and the scan was performed at multiple views, and usually started from the lower right abdomen with the iliac blood vessels of lower right abdomen and psoas major muscle as the center (upside to the lower edge of the liver, and downside to the pelvis). An abdominal probe was firstly used for scanning, especially in the ileocecus and obvious tenderness point. Then, the scan was focused on the suspicious part by using a high frequency probe. For obese patients or patients with extra intestinal gas, appropriate pressure should be added to the probe to better visualize the lesion. Ultrasound imaging was performed and read by experienced residents or attending physicians, and suspected findings were further confirmed by the superior physicians.

CT was performed on a 16 slice spiral CT scanner (Light Speed, GE Healthcare, Cambridge, UK) at 120-KV tube voltage and 350-mA tube current. Plain CT scan was performed in the whole abdomen or lower abdomen with 5-mm layer thickness and 5-mm layer distance. After scanning, multi planar reconstruction (MPR) and curve planar reconstruction (CPR) was conducted at a layer thickness of 1.25 mm. All images were analyzed using soft tissue window (window width 300-380 HU, window level 50 HU). When abnormal enlarged appendix or suspicious lesion was observed on plain CT scan, enhanced CT scan was performed with a range from the top of the diaphragm to the pubic bone, Oral contrast was administrated (iodixanol, Visipaque 320, GE Healthcare, Cambridge, UK) at a dose of 300 mg/ml (60-80 ml), flow rate 4-4.5 ml/s. The images were read and analyzed by two experienced radiologists to evaluate the lesion of the appendix.

Imaging evaluation

The criteria for a positive ultrasound result were as follows, direct US signs: appendix larger than 6 mm in diameter and larger than 2 mm

Figure 1. Ultrasound image of acute appendicitis (low-frequency probe) enlarged appendix, thickened appendix wall, rough edge of each layer of the appendix, hyperecho around the appendix, and no obvious fluid sonolucent area was detected.

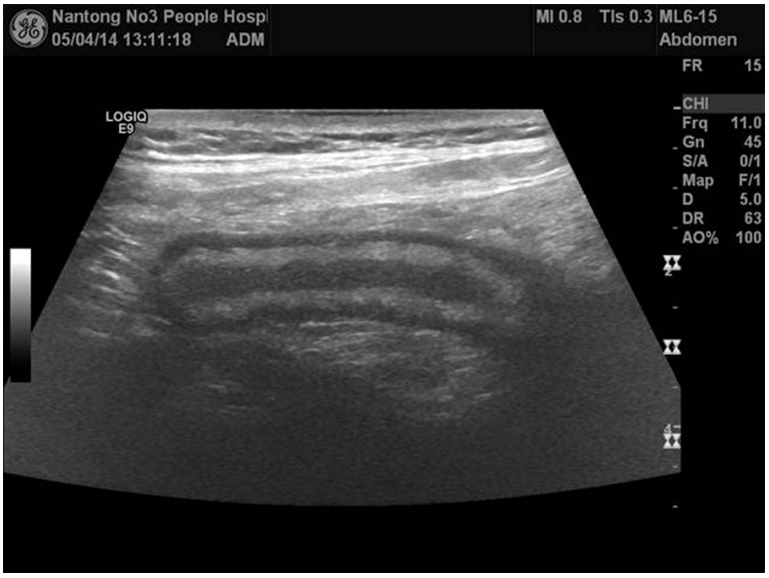

Figure 2. Ultrasound image of acute appendicitis (high frequency probe) enlarged appendix, thickened appendix wall, rough edge of each layer of the appendix, hyperecho around the appendix, and no obvious fluid sonolucent area was detected.

in wall thickness. Indirect US signs: (1) expansion of appendix lumen, non-uniform internal echo, with or without hyperechoic appendicolith, (2) hyperecho around appendix, (3) lower right abdominal effusion, (4) lymphadenectasis in the lower right abdomen, (5) lump in the lower right abdomen, (6) ileocecal wall thickening and edema, (7) bowel dilatation, pneumatosis with weakened peristalsis in the lower right abdomen.

The criteria for a positive CT result were as follows, direct CT signs: appendix larger than 6 mm in diameter with thickened wall. Indirect CT signs: (1) effusion in the appendix lumen with or without appendicolith, (2) periappendiceal effusion or pneumatosis, (3) blurred fatty space with exudation around appendix, (4) adjacent bowel wall thickening, bowel dilatation and effusion, (5) lymphadenectasis around the ileocecus, (6) periappendiceal abscess.

Statistical analysis

Analysis was performed with SPSS (version 19.0, IBM Company, Chicago, IL). Chi-square test used for categorical data. The sensitivity, specificity, positive and negative predictive value (PPV, NPV) and accuracy of US and CT was calculated. Receiver operating characteristic (ROC) curve was conducted, and area under ROC curve (AUC) was calculated and compared to evaluate the diagnostic efficacy of two imaging modalities. A $P<0.05$ was considered significant.

Results

Image features of US compared to CT on acute appendicitis

US image features of AA included enlarged appendix (7-18 mm) (61 cases), thickened appendix (2.3-10 mm) (47 cases), effusion in appendiceal lumen (32 cases), appendicolith (17 cases), periappendicealhyperecho (9 cases), hyperecho around ileocecus and the base of appendix (1 case), inter-intestinal effusion (16 cases), ileocecus edema (6 cases), ileocecus expansion (1 case), appendiceal abscess (3 cases), and invisible appendix (11 cases) (**Figure 1**, **2**).

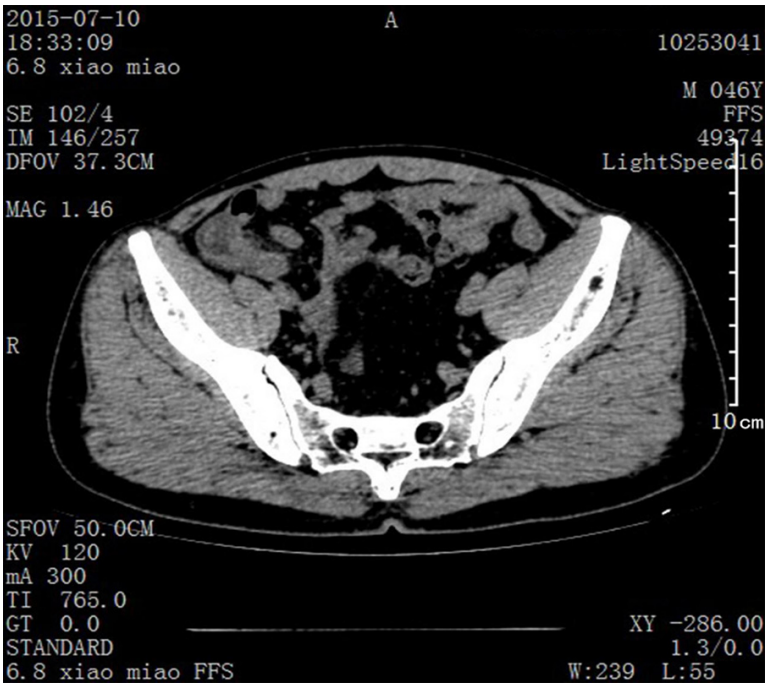

Figure 3. Cross-section CT image of acute appendicitis enlarged appendix, thickened appendix wall, around the see leakage, effusion and blurred fatty space around appendix and ileocecus, shown as the high density strip.

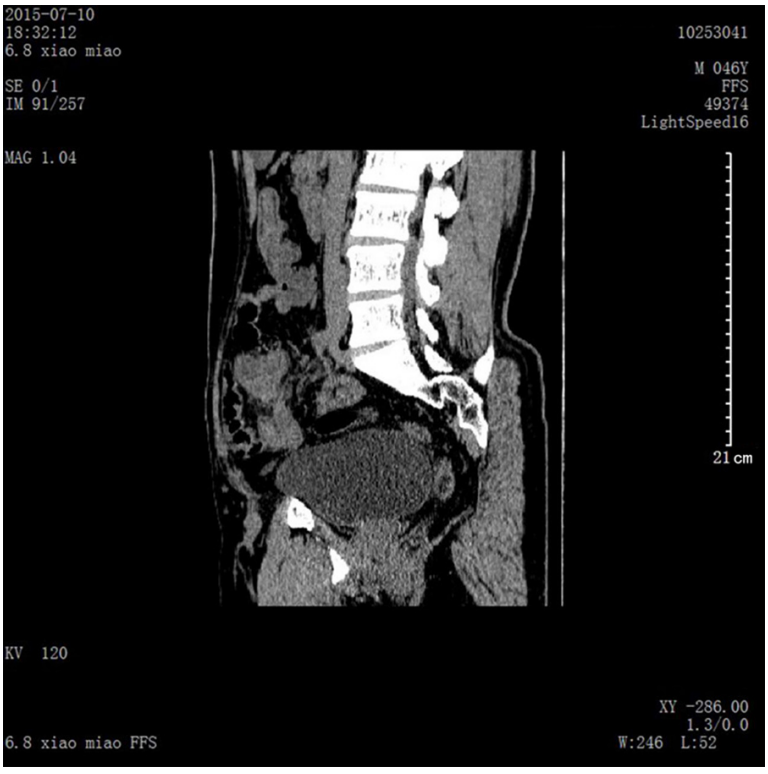

Figure 4. Sagittal reconstruction CT image of acute appendicitis thickened appendix wall, peripheral effusion, shown as the high density strip.

CT image features of AA included enlarged appendix (44 cases), thickened appendix (15 cases), gas in appendiceal lumen (2 cases), appendicolith (15 cases), peripheral exudation or blurred fatty space (40 cases), adjacent peritoneal thickening (2 cases), lymphadenectasis around ileocecus (13 cases), ileocecus edema and thickening (3 cases), exudation around ileocecus (2 cases), appendiceal perforation (1 case), appendiceal abscess (1 case). Enhanced CT scan was performed in 4 cases, and the images features included mucosal enhancement in Ileum and appendix (2 cases), appendix wall reinforcement (1 case), appendiceal abscess (1 case) (**Figure 3**, **4**).

Diagnostic results of US compared to CT

Among 101 pathology-proven AA patients (including 4 patients diagnosed with appendiceal abscess). As shown in **Table 1**, 65 cases were diagnosed with AA using US imaging, including 3 cases with appendiceal abscess, and other 11 cases of AA were missed, because the appendix was invisible due to the interference of intestinal gas. Additionally, 43 were diagnosed with AA using CT imaging, including 1 with appendiceal abscess, and other 6 cases of AA were missed, because the appendix was normal or slightly enlarged. Of 7 non AA patients, 1 case was diagnosed with distal ileitis under US imaging, and other 2 cases of chronic appendicitis were missed. 1 case was diagnosed with appendix benign tumor under

Table 1. Diagnostic results of US compared to CT on acute appendicitis (n)

		Pathological results	
		Acute appendicitis	Non acute appendicitis
US	+	65	1
	-	11	2
CT	+	43	1
	-	6	3

Table 2. Diagnostic efficacy of US compared to CT on acute appendicitis (%)

	US (95% CI)	CT (95% CI)
Sensitivity	85.5 (75.6-92.5)	87.8 (75.2-95.4)
Specificity	66.7 (9.4-99.2)	75.0 (19.4-99.4)
Positive predictive value	98.5 (91.8-100.0)	97.7 (88.0-99.9)
Negative predictive value	15.4 (1.9-45.4)	33.3 (7.5-70.1)
Accuracy	84.8 (75.0-91.9)	86.8 (74.7-94.5)

enhanced CT scan, and other 3 cases of chronic appendicitis were missed.

The sensitivity, specificity, positive and negative predictive value and accuracy of US compared to CT on the diagnosis of AA was 85.5% vs. 87.8%, 66.7% vs. 75.0%, 98.5% vs. 97.7%, 15.4% vs. 33.3%, and 84.8% vs. 86.8%, respectively (**Table 2**). Then a subgroup of 24 patients who received both US and CT examinations prior to surgery were enrolled for ROC analysis to examine the diagnostic efficacy of the two imaging methods. The results showed that the area under ROC (AUC) of US was 0.84, which was larger than that of CT (0.66), while the difference was not significantly statistical (**Figure 5**, **Table 3**).

For thickened appendix, the display rate of ultrasound was 63.5%, which was significantly higher than that of CT (31.9%) (P=0.001). For enlarged appendix, the display rates of ultrasound and CT were 82.4% and 93.6%, respectively, while the difference was not significantly statistical (P=0.077), see **Table 4**.

The detective rates of US compared to CT on different pathological types of acute appendicitis

Then, we further compared the detective rates of US and CT on different pathological types of acute appendicitis, including simple appendicitis, purulent appendicitis and gangrenous appendicitis. As shown in **Table 5**, the detective rates of these three types of acute appendicitis were 81.8%, 86.0% and 90.9%, respectively under US, and 60.0%, 92.6% and 100% under CT, while no significant difference was found between the two imaging modalities.

Discussion

The appendix is a blind-ended tube connected to the cecum and located at the junction of the small and the large intestines. Its shape and size often differs from person to person, what's more, the tip of the appendix is variably located--in the pelvis, outside the peritoneum or behind the cecum, even though the base of the appendix is at a fairly constant location. Usually, the identification of the appendix on the US image is somewhat difficult because of the interference of intestinal gas. While the appendix can be easily identified on the CT image with mesenteric fat surrounded. In recent years, with the development of ultrasonic technology, especially the application of digital ultrasound, high frequency probe and natural tissue harmonic imaging technology, the resolution of ultrasound images is getting higher and higher. It was reported the display rate of the appendix on the US can be up to 97.7%, which was similar with the spiral CT [15, 16].

When acute appendicitis occurs, the appendix wall becomes mucosal inflammatory edema and thickening, and the enlarged appendix in diameter and thickened appendix wall is displayed on image examination. In our study, the display rate of abnormal appendix in patients was high either with ultrasound or with CT, especially, for thickened appendix, the display rate was significantly higher with ultrasound than that with CT (P=0.001). Our results indicated that US presented a high display rate of the appendix, which was consistent with previous report [15, 16]. Additionally, for the first time, our study indicated that US showed a better performance in the display of thickened appendix than CT imaging, which has not been reported in the previous study. It may be because that US can clearly display the structure of the appendix wall and the internal echo. While, CT cannot clearly display the structure of

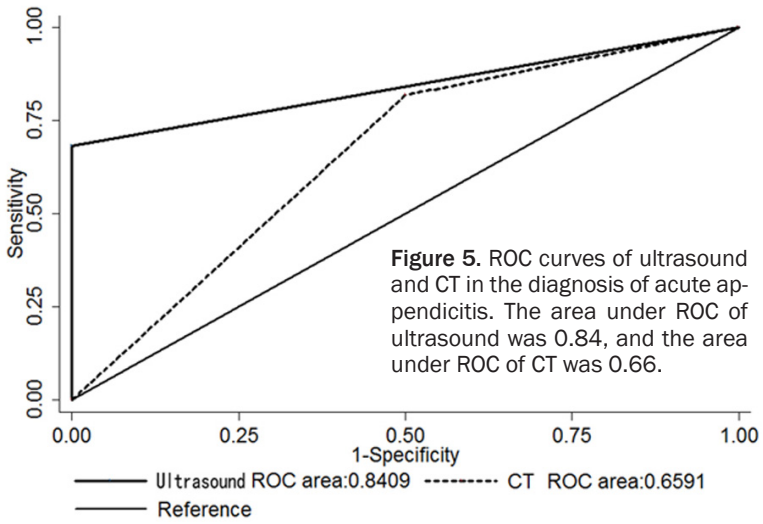

Figure 5. ROC curves of ultrasound and CT in the diagnosis of acute appendicitis. The area under ROC of ultrasound was 0.84, and the area under ROC of CT was 0.66.

Table 3. AUC of US compared to CT on the diagnosis of acute appendicitis

	AUC	95% CI	X^2	P
US	0.8409	(0.74130-0.94051)	0.49	0.4829
CT	0.6591	(0.16221-1.00000)		

Table 4. Display rate of direct signs of acute appendicitis on US compared to CT

	Enlarged appendix (% (n/n))	Thickened appendix (% (n/n))
US	82.4 (61/74)	63.5 (47/74)
CT	93.6 (44/47)	31.9 (15/47)
P value	0.077	0.001

the appendix wall although it can clearly display the range of lesions and peripheral tissue.

It was reported that CT scan had a sensitivity of 94%, specificity of 95%, while, US had an overall sensitivity of 86%, a specificity of 81% in the detection of acute appendicitis [17]. What's more, CT scan has been shown to be more accurate than ultrasound on the diagnosis of acute appendicitis, indicating CT presented better performance than the US on the diagnosis of acute appendicitis [3, 14, 18]. Additionally, the study of Jang KM's team suggested that US can be used as an assisted examination to improve the diagnostic accuracy on condition that CT cannot make a conclusive decision [19]. In the current report, the sensitivity of US and CT on the diagnosis of acute appendicitis were both at a high level (85.5% and 87.8%), and the specificity was 66.7% and 75%, respectively. The positive predictive value of the two modalities were both above 95%, and accuracy was 84.8% and 86.8%, respectively, indicating the similar diagnostic value of the two imaging modalities on acute appendicitis.

In our study, a combined examination with US and CT was conducted in 24 patients. The diagnostic accuracy of the 24 patients was as high as 95.8%. Among those patients, 5 cases with invisible appendix on US imaging were further examined by CT imaging, and 4 cases were diagnosed with acute appendicitis, among whom, 1 case with slightly enlarged appendix. In addition, there were 2 cases with normal appendix on CT imaging, then had an assisted US imaging. The US indicated the diagnosis of acute appendicitis with thickened appendix wall (3 mm). Then we enrolled the 24 patients for ROC curve analysis, the results showed that the AUC of US was 0.84, which was larger than that of CT (0.66), while the difference was not statistically significant. Here, we suggest a combined imaging examination to improve the diagnostic accuracy, when a single imaging method failed to make a conclusive decision, especially on patients who presented classical signs.

Acute appendicitis is a pathological process characterized by inflammation, and different pathological types correspond to the different progressive stages, leading to the distinct imaging manifestations. Simple appendicitis is considered as the initial stage, and the inflammation is limited to the mucosa and submucosa without obvious wall thickening, and with or without lumen expansion. At this stage, the image features can be atypical, thus leading to misdiagnosis. In this study, US and CT imaging both missed 4 cases of simple appendicitis, indicating CT imaging had no obvious advantage over the US imaging on the diagnosis of simple appendicitis, which was inconsistent with previous findings, which showed the diagnostic value of CT was higher than that of US [16]. It may be because that all the missed cases on CT imaging were at the early stage of

Table 5. The detective rates of ultrasound compared to CT on different types of acute appendicitis

	Imaging		*P* value
	US (% (n/n))	CT (% (n/n))	
Simple appendicitis	81.8 (18/22)	60.0 (6/10)	0.378
Purulent appendicitis	86.0 (37/43)	92.6 (25/27)	0.472
Gangrenous appendicitis	90.9 (10/11)	100 (12/12)	0.478

the acute appendicitis, the diameter of the appendix was within the normal range (5-6 mm), what's more, there was no obvious exudation around. So it was difficult for CT imaging to identify the abnormality. And, for the 4 cases missed by US imaging, it is because the imaging failed to identify and display the appendix due to the interference of intestinal gas. For purulent appendicitis, the inflammation was progressed to the whole layer. At this stage, the images appear to be typical which present highly hyperemia and edema appendix, and more periappendiceal exudates. So, the diagnostic accuracy of this type of appendicitis was high with either US or CT imaging in our study, which was in accordance with previous report [16]. If the process was left untreated, appendix would continue to swell with increased pressure in the lumen, which can cause blood circulation disorders, then develop to gangrenous appendicitis eventually. In our study, the detective rate of gangrenous appendicitis was high with both the US and CT (90.9% and 100% respectively). When gangrenous appendicitis continues to progress, appendix perforation will eventually occurred, which can lead to increased purulent effusion around the appendix, the greater omentum aggregation, the formation of localized or diffuse peritonitis. In this paper, there was 1 case of gangrenous appendicitis with perforation identified on CT images. While, the appendix of this case was invisible on the US images, only the bowel dilatation in the lower right abdomen was showed due to the formation of a diffuse peritonitis and paralytic ileus, so the US imaging missed this case of gangrenous appendicitis. When the appendix perforation or purulent inflammation occurs, the mesenterium or the greater omentum will be moved to the right abdomen to wrap around the appendix, and then lead to the formation of the abscess around the appendix. At this stage, both US and CT images cannot distinguish the structure of the appendix, only showing the lumps in the lower right abdomen. The tissues surrounding are often not clear with irregular shape, or sometimes fecalith in the lumps. In our study, the detective rate of the periappendiceal abscess by ultrasound and CT were both 100%. As a whole, the diagnostic efficacy of two imaging methods on different pathological types of acute appendicitis was very similar.

Ultrasound has some advantages, including low cost, easy to operate, no trauma, no radiation, strong reproducibility, etc., especially for children, the elderly, pregnant women and other patients with atypical clinical symptoms of appendicitis. Local tenderness by US probe is also an important sign, which can improve the accuracy of diagnosis of acute appendicitis [16]. In addition, under the real-time monitoring of the US, it is possible for the intervention of the appendix abscess, or to be used for preoperative localization of the laparoscopic appendectomy. However, ultrasound also has some disadvantages, it is difficult to display appendix in obese patients, or on the condition of flatulence, retrocecal or extraperitoneal appendicitis [20]. In addition, the variable location of appendix, improper manipulation, lack of experience, subjectivity and other factors can affect the results of the examination. Whatever, it is still feasible to improve the display rate of the appendix on the US imaging by focusing the scan on the relatively-fixed illiecus and tenderness point, then, expand the scan range to the right side of the abdomen as a routine. What's more, the combination of high frequency probe and low frequency probe, along with the pressed scanning method is also an effective strategy to improve the display rate.

The advantages of CT include: the image has a high resolution and is less affected by the intestinal gas. The image is not affected by the patient's pain, and not dependent on the operator. CT can not only clearly show the lesions of the appendix, but also show the depths of the abdomen in the vicinity of the abscess and the organs surrounding. Enhanced CT scan not only helps to identify the enlarged appendix, but also can show the enlarged lymph nodes surrounding [21]. The disadvantages of CT are as follows: it takes a long time, there is a risk of radiation, and the display of appendix depends on the surrounding mesenteric fat. For children with less fat in the abdominal cavity, thinner women and the elderly, it is difficult to display

the appendix with a high resolution, which leads to a difficulty in the judgment of inflammatory changes around the appendix. In this study, there were 6 patients with false negative appendicitis, among whom, there were 3 cases missed on CT imaging due to the less mesenteric fat which influence the display of appendix and its surrounding inflammatory changes. Although conventional CT is inferior to high frequency US on the display of appendiceal wall, enhanced CT scan and reconstruction technology can not only display the location and pathological changes of appendix from the different angles, but also ruled out other organ diseases, such as ileocecal occupation, peritoneal gas effusion caused by digestive tract perforation, peritoneal exudation caused by inflammation around the adjacent organs [22, 23]. Some studies suggest that the low-dose CT can obtain a high diagnostic efficacy with reduced radiation exposure [24].

In summary, ultrasound and CT examination both had high value on the diagnosis of acute appendicitis. Ultrasound examination is safe, economical and convenient, which can be used as the first-line imaging choice for patients with suspected acute appendicitis, especially for children, the elderly, pregnant women and patients with thin body. When US examination failed to make a confirmed conclusion, CT can be used as a supplementary imaging modality to improve the diagnostic accuracy in patients with highly suspected acute appendicitis.

Disclosure of conflict of interest

None.

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